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

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Abstract

Unlike insurance transferring risks, mutual risk sharing shares losses among participants. Meaning 'mutual aid' in Chinese, Xiang Hu Bao (*XHB*) was the largest online 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 or low risk sensitive individuals join mutual aid programs while high-risk or highly risk-sensitive 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; Critical illness; sharing economy

JEL codes: G22; G23; I14; I15

1 Introduction

Borch's theorem (Borch, 1962), also known as the *mutuality principle*, applies Arrow (1953)'s general equilibrium framework to characterize optimal risk sharing in the insurance market. It shows that participants mutually insure each other to share diversifiable risks while transferring non-diversifiable risks to the more risk-tolerant parties.[1] While the mutuality principle is regarded 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, instead of having participants pool their risks and mutually insuring each other, insurance companies take on a central role and set insurance premiums with a goal to maximize their own values (Marshall, 1974).[2]

The significant progress in information technologies promotes 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 (Thakor, 2020), 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*, meaning 'protecting each other' or 'shared treasure'), 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 treated 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 number that is comparable to the total number of policyholders holding traditional critical illness insurance policies in China. Nevertheless, owing to substantial pressure to revamp business to comply with insurance and financial regulations, *XHB*

[1] This point is highlighted in Appendix A when we discuss the key aspects of the Borch's theorem.

[2] Notably, Joskow (1973), an influential work on the insurance industry almost half a century ago, characterizes the insurance industry as 'the combination of state regulation, cartel pricing, and other legal peculiarities [that] has resulted in the use of an inefficient sales technique, supply shortage, and overcapitalization.' More recently, Zanjani (2002), Koijen and Yogo (2015, 2016), among others, present evidence on the inefficiency in the insurance market. Data from National Association of Insurance Commissioner (NAIC) between 1990 and 2015 shows that insurers' operating expenses account for one third of insurance premiums charged by U.S. insurance companies.

ceased its operation on January 28, 2022 (Feng and Ng, 2021).

XHB participants equally share aggregate medical claim payments during each claim period plus an 8% margin for operating expenses, which are known as expense loading in practice; in exchange they receive a fixed indemnity - CNY 300,000 for individuals under 40 years old and CNY 100,000 for participants of 40 and older - if they are confirmed to have been treated for one of the covered critical illnesses. *XHB*'s participation cost per member is well below the premium of the corresponding critical illness insurance (*CII*) providing the same level of coverage. In the sample period, *XHB* charged between CNY 3 and CNY 6 for a coverage of over 100 illnesses in a biweekly claim period while the comparable one-year term *CII* for a 30-year old female charged an annual premium between CNY 400 and CNY 600, i.e., between CNY 16 and CNY 25 biweekly. This leads to the central question of this study: what accounts for the substantial difference between *XHB*'s participation cost and the premium of traditional critical illness insurance?

The association with Alipay, an online payment giant in China, offers *XHB* a significant advantage. In particular, the large member base of Alipay allows *XHB* to operate at a low cost and in a large scale. In this sense, *XHB* resembles index funds designed to attract investors for diversification benefits in asset management. Moreover, *XHB* has several technology-driven advantages. First, *XHB*'s enrollment process is conducted online only. To be an eligible *XHB* member, one (or her/his immediate family member) must have an Alipay account while meeting a credit score requirement. Alipay users are younger, thus healthier, than the general public. Second, *XHB* adopts an artificial intelligence (AI) based platform for claim processing, significantly improving its efficiency. In particular, *XHB* announces approved critical illness cases to all participants and communicates with individual participants for rejected claims. *XHB* participate can challenge the unfavorable decisions through the appeal process where the details of appealed claims are posted to *XHB*'s public panel which involves millions of qualified *XHB* members who voluntarily participate in the arbitration process. This offers incentives to the large number of *XHB* members actively participating 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.'

Our data allows us to compare incidence rates of *XHB* and commercial critical illness insurance offering similar coverage. The test result turns out to be highly supportive: across all age groups, the average incidence rate of *XHB* is 1/7 to 1/6 of *CII*'s for the 6 and 25 leading critical illnesses. A glimpse at the incidence rates of the most senior group of *XHB*'s critical illness program (ages 50 to 59) reveals that *XHB*'s average critical illness incidence rate is still far below that of the incidence rates of commercial critical illness insurance. The incidence rates of critical illness insurance are respectively 7.4 and 7.8 times of the incidence rates of *XHB* in terms of the 6 and 25 leading critical illnesses.

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 amount for members who are confirmed with one of the covered critical illnesses is below the typical medical cost to treat such illnesses, 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 show 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. High-risk individuals value the flexibility in choosing coverage amount offered by traditional insurance over the rigid indemnity level under *XHB*. We offer evidence to the separating equilibrium by comparing participation rates of young people and older individuals. The participation rate of an age group is defined as the fraction of the number of *XHB* participants of an age group in the national population of that age group. We find that, out of Chinese national population, 8.5% of those younger than 40 years are members of *XHB* while the participation rate for people who are 40 and above is less than 5%, suggesting a lower participation rate of middle-aged and old individuals – a reduced coverage limits high-risk individuals' incentive to participate in *XHB*.

The existence of the separating equilibrium may alternatively be attributed to heterogeneous motives for *XHB* and *CII* participants. Specifically, the advantageous selection argument (see, e.g., de Meza and Webb, 2001; Cutler, Finkelstein, and McGarry, 2008; Fang, Keane, and Silverman, 2008; Einav, Finkelstein, and Mahoney, 2021) suggests that risk aversion and other individual attributes such as wealth and education also matter to individuals' risk taking incentives. using the data from a mutual aid product survey conducted by Ant Financial, It differs from adverse adverse selection that individuals to differ in their risk levels under adverse selection while advantageous selection conceives individuals to differ in their willingness in risk taking. While a clear separation of these two types of selections is impossible, we find that young wealthy people are more willing to participate in mutual aid platforms, suggesting the advantageous selection not only exists in the insurance market, but also prevails among mutual aid platforms. In addition, we find young individuals, who are healthier and *less risk averse* than old individuals, are more likely to participate in *XHB* and other mutual aid platforms. This is consistent with the conventional understanding of advantageous selection that the protection demand and risk are inversely related, while it extends to individuals of low risk aversion, instead of high risk aversion. Moreover, we find mutual aid products to complement traditional insurance markets. Our tests show that survey respondents that already have a commercial health insurance are less interested in participating in mutual aid programs. More importantly, the survey shows that mutual aid participants become more likely to purchase commercial health insurance afterwards than are non-participants, confirming that mutual aid platforms are able to reach customers typically not covered by conventional medical insurance and critical illness coverage.

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 tightly knot society; given that each household is insured by its neighbors, who have an incentive to monitor the behavior of a given household. In contrast, *XHB* does little to discipline bad behavior/incentives, such as concealing illness history and submitting a fraudulent claim; unlike 'La Crema', members are typically not tightly connected with each other. Instead, the use of Fintech and its connection with Alipay serve as useful devices to deter fraudulent activities, reduce processing costs, and expedite claim payments.

Our paper extends the household risk sharing literature, which highlights the connection among between friends and families is an important channel to cope with idiosyncratic risks such as illness, unemployment, and bad harvest (See, e.g., Cochrane, 1991; Townsend, 1994; Cox and Fafchamps, 2007; Fafchamps and Gubert, 2007; Ambrus, Mobius, and Szeidl, 2014). The literature focuses 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. However, due to transaction costs and information asymmetry, the social-connection based informal insurance mechanism is restrictive – studies show that agents may be able to share their risks within a group, such as a community, but they cannot sufficiently diversify risks across groups (see, e.g., Ambrus et al., 2014). *XHB*'s Fintech system helps to eliminate unqualified claims and efficiently process disputable claim applications, thus lowering transaction costs and incidence rates. Our work suggests that Fintech complements large social networks in mutual risk sharing. To this end, our paper pinpoints the critical role of Fintech in risk management, largely ignored by the existing literature.[3]

The remainder of the paper is structured as follows. Section 2 describes the institutional background of *XHB*; in Sections 3, 4, and 5, we compare incidence rates of *XHB* and critical illness insurance as well as their enrollment rates and offer explanations; Section 6 concludes.

2 Xiang Hu Bao: A Mutual Aid Platform

2.1 An Overview of Xiang Hu Bao

Xiang Hu Bao was the largest online mutual aid platform sponsored by Alibaba's Ant Financial. Started in October 2018, it 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 Appendix B), 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 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. In both plans, members are only eligible

[3]Extant literature focuses on Fintech applications in banking, asset management or general settings related to data processing and artificial intelligence (for example, Chen, Wu, and Yang, 2019; Thakor, 2020; Zhu, 2019; Zetzsche, Arner, and Buckley, 2020).

to receive one indemnity in their lifetime.

Table 1 discusses the evolution of *XHB*'s critical illness coverages. The first version ('V1') 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 ('V2'), *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.[4] Next, in the third version ('V3') 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.[5] The latest version of the program ('V4') 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 1 outlines its enrollment procedure. Individuals apply for *XHB* membership using a smartphone application with their authentic identities. To become a member, applicants need to maintains a clean medical record and be free of any illness listed in Appendix B. Individuals receiving medical treatments for 30+ days or hospitalized for 15+ days in the past two years are not allowed to join *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 *XHB* terminates the membership and refunds dues. Moreover, *XHB* applicants are either Alipay (the Chinese counterpart of PayPal) account holders or their immediate family members. In Figure 2, we show that Alipay participants are much younger and healthier than the national population. In June 2020, nearly 40% of Alipay users are younger than 25 years old which accounts for 27% of the population; merely 9% of Alipay users are 40 years old and above and this age group accounts for nearly 50% of the national population. Alipay users are much younger, thus healthier, than the general public. Moreover, *XHB* requires applicants to have an above-average credit score (a minimum of 600 sesame points

[4]The two types of illnesses originally categorized as malignant tumors in *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.

[5]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.

out of the maximum of 950 points) to be eligible for *XHB*. Earlier studies (e.g., Ettner, 1996; Lopez, 2004; Deaton, 2008) show that wealthier people are healthier. Thus, *XHB* participants are potentially more healthy.

Panel B of Figure 1 describes *XHB*'s claim procedure. The first step is claim submission and investigations. It begins with online claim submissions that claim documents are required to be submitted through *XHB* mobile phone based online applications. The platform applies textual analysis to process submitted files and generate digital documents and subsequently process and settle claims using an artifical-intelligence based system. The details are provided in Appendix C. As discussed, Fintech applications make *XHB* a standardized platform, offering stringency and flexibility to implement rules and restrictions in its claim procedure. After validation, *XHB* publicly announces information of approved claims to members on scheduled announcement dates, the 7th and 21st in each month. Claims challenged by *XHB* members over the announcement period will not be included from pending payments and these claims will be re-examined by claim specialists while undisputed claims are scheduled for payments on the 14th and 28th of each month, known as payment dates. The aggregated claim payments are equally shared by *XHB* participants. If a member does not plan to share, she or he needs to leave *XHB* before the announcement day. All claim related information is recorded on a temper-proofed blockchain.

XHB members can challenge a decision by requesting a review by a appeal panel consisting *XHB* members who have passed qualification test. Appeals are administered by a third-party and appeal panel members cast their votes within a 24-hour interval. The result is only valid if 1,000 or more valid votes are cast. The appealing claimant is set to be a winner or a loser following the simple majority rule and each case involved more than 1 million panel member votes – the 'wisdom of crowds' is applied. Merely 12 appeals took place from its inception in October 2018 up to its end in January 2022, among which three appeals were successful. This extremely low number of appeals suggests a low likelihood of false negatives in its routine claim process.

2.2 Mutual Aid vs. Insurance

Like *XHB*, commercial critical illness insurance *CII* offers lump-sum indemnities to claimants.[6] The same types of illnesses are covered by *CII* and *XHB*. Yes, they are different in several ways.

[6]This is different from other medical insurance policies which typically reimburse actual medical costs up to a certain limit.

First, different 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. Second, 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. Third, 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* provide a more comprehensive coverage than *XHB*. At the end of 2019, *CII* covered approximately 100 million people, a comparable size to the *XHB* participants.

Besides mutual aid and commercial insurance, the government also provides critical illnesses coverage under the 'social security' program, including 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.[7] In 2012, the government-sponsored critical illness insurance was introduced as an extension to *URRBHI* to cover critical illness patients' medical expenses (Jiang, Chen, Xin, Wang, Zeng, Zhong, and Xiang, 2019). However, different from *XHB* and commercial *CII* offering fixed amount indemnity, this government-sponsored critical illness insurance reimburses medical expenses, typically for less expensive drugs and medical treatments on the permitted drug list. This makes its coverage quite limited. The government-sponsored critical illness insurance has a low reimbursement rate, lower than 60% of medical expenses.[8] For example, in Shanghai, the most economically-developed region in China, the employer-sponsored critical illness insurance covers merely four types critical illnesses.[9]

[7]National Health Security Administration (NHSA); http://www.nhsa.gov.cn/art/2022/3/4/art_7_7927.html.

[8]National Health Security Administration (NHSA); http://www.nhsa.gov.cn/art/2019/5/13/art_78_3554.html.

[9]According to the Mutual Aid Industry White Paper (2020) published by Ant Financial, 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 60% reimbursement of medical insurance coverage for critical illnesses.

3 Comparing *XHB* and *CII*: Incidence Rates and Participation

Using x to denote *XHB*, we express the price, or more precisely the sharing cost, of *XHB*, π_t^x, as:

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

where p_t^x is the incidence rate for *XHB* at time t (which is determined by the proportion of participants from $t-1$ to t;) k^x is the amount of fixed indemnity to a *XHB* participant; λ^x is margin (also known as loading or markup) charged to *XHB* participants proportional to the indemnity cost.

Using i to denote insurance, we express the insurance price, π_t^i, as below:

$$\pi_t^i = p^i k^i (1 + \lambda^i) \tag{2}$$

where p^i and k^i are the expected incidence rate and the amount of indemnity under *CII*; λ^i is the insurance markup.

Considering the special case that *XHB* and *CII* have the identical coverage, k, we can express the price difference between *XHB* and *CII* as below:

$$\begin{aligned}\Pi_t^i &= \pi_t^i - \pi_t^x = p_t^i k[1 + \lambda^i) - p_t^x (1 + \lambda^x] \\ &= \underbrace{[p^i - p^x]k(1 + \lambda^x)}_{\text{IR difference}} + \underbrace{p^x k(\lambda^i - \lambda^x)}_{\text{Loading difference}}\end{aligned} \tag{3}$$

In other words, the price difference between *CII* and *XHB* is the sum of i) the difference in their incidence rates (*IR*s) and ii) the difference in their expense loadings. As noticed earlier, the expense loading of *XHB* is 8% of its claim payment while the expense loading of *CII* is much higher, resulting in a positive loading difference between conventional insurance and *XHB*. In the next subsection, we explore the price differences coming from the incidence rates of two products.

3.1 Data

Our *XHB* data include i) participation cost in each period (i.e., *XHB* price), ii) claim payment, and iii) enrollment. The data begins from the inception of *XHB*, October 2018, to December 2020. As we discussed earlier, *XHB* has a 90-day probation period for new members. As a result, the first claim payment made by *XHB* was in January 28 2019, i.e., 201901P2 (the second payment period of January 2019). For this consideration, our sample begins from 201901P2 and it ends in 202012P2, involving 47 payment periods.

Our *XHB* participation information includes the aggregate number of participants in each payment period and the numbers of *XHB* participants of six age groups provided by Ant Financial's Financial Research Institute including 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 hand-collect *XHB* claim data published on its bulletin board, which includes the following key items: payment time, payee's names, names of illnesses, patient age, gender, province, and indemnity amount.[10]

For comparison, we obtain data 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 B. These incidence rates are estimated based on a majority group of critical illness insurance in China,[11] 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 corresponding 6 and 25 critical illness incidence rates for *XHB*. We elaborate the details about *XHB* incidence rates in Section 3.2.

Two important details about the *CAA* table are worth noting. First, incidence rates published in the *CAA* table are calculated based on the first critical illness claim of a policyholder despite that critical illness insurance permits multiple illness payments. This makes incidence rates reported in the *CAA* table comparable with *XHB*'s incidence rates. Second, like *XHB*, *CII* also has a probation period (90 or 180 days) over which policyholders would not receive claim indemnity if receiving

[10]Specifically, we took screenshots of each claim report posted on the bulletin board of *XHB*'s mobile application, and converted images to the digital data. To ensure data quality, we identify two 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. Altogether we found 149 such cases (out of a total of 68,007 claims of our sample) and correct them. We also verify the quality of 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. This reveals five erroneous observations (removed from the sample) in terms of age/payment amount out of 5,558 observations of the randomly selected samples.

[11]Namely 'pre-paid' critical illness insurance policies, they account for 85% of critical illness insurance policies in China.

critical illness treatments. Nevertheless incidence rates reported in the *CAA* table are not affected by this practice since first-year policies (i.e., *CII* policies newly acquired by policyholders) are excluded when constructing the table.

In Table 2, we report the number of enrollments, aggregate claim payments and per member allocated cost in bi-weekly payment periods from January 2019 to December 2020. The first reported number of enrollment is 23,307,500 on January 28, 2019. The total amount of claim payment is CNY 600,000 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 merely CNY 0.03. *XHB* enrollments grow 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 3, the aggregate number of enrollments stays stable in 2020 and the first negative growth rate appeared in May 2020. The pattern is clearly demonstrated in Figure 3.

XHB has a 90-day probation period that participants are eligible to receive claim payments in their first 90-day membership. The results reported in Table 2 is 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 of 2019), corresponding to a bi-weekly premium of CNY 0.51. It increased to about CNY 4 per payment in August 2020, corresponding to roughly CNY 100 of the annual payment.

Table 2 shows *XHB* claim enrollment and claim payments experienced exponential growth in the first half year of 2019 and later become stabilized. As September 2019 is a clear switching point shown in Figure 3, we consider payment periods from September 2019 to the sample end as stable claim periods. Our analysis on *XHB*'s claims and incidence rates mainly focus on the stable period.

It is noticeable that 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. Nevertheless, *XHB*'s enrollment remained stable during the COVID lockdown period.

3.2 Results

We analyze *XHB*'s critical illness incidence rates of different age groups and run comparisons between *XHB* and *CII*. We first report basic claims information in Table 3. The first column reports the total number of claims that *XHB* paid in each payment period from January 2019 to December 2020. It shows that the first *XHB* claim was paid on on January 28th, 2019. The number of paid claims was 1,953 at the end of 2019 and it rose up to 2,810 at the end of December 2020. In the next two columns, breaking down participants to young participants (below 40 years) and middle-age participants (40+ years), we report the number of cases of each type. There are more claims for the above-40 group than the below-40 group. As reported in the last row, 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).

We report annualized incidence rates of critical illnesses of *XHB* in Column 4. The incidence rate of each payment period of all covered illnesses, IR_t^x, is estimated and annualized as $24 * IR^x$.

$$IR_t^x = \frac{c_t}{e_{t-6}} \tag{4}$$

where IR_t^x represents *XHB* incidence rates at time t of all critical illnesses; c_t represents the numbers of paid claims at time t of all critical illnesses ; e_{t-6} denotes the trailing 90-day (6-period) aggregate enrollment.

As shown in Column 4 of Table 3, the incidence rate was low in early periods and rose over time. It had a jump from the first to the second payment period in September 2019 from 226 per million participants to 540 per million participants. The incidence rates became stabilized after that point, ranging between 529 and 670 per million participants each bi-weekly payment period. Apparently, the number of *XHB* claims and incidence rates are much lower during the COVID lockdown period from 202002P2 to 202004P1, consistent with the amount of claim payments reported in Table 2.

Next, we contrast incidence rates between *XHB* and *CII* across different age groups. While we have payment data for individual claims, we only have data of *XHB* enrollment for different age groups (<10; 10∼19; 20∼29; 30∼39; 40∼49; and 50∼60). Further, as noted in the data section, our *XHB* claim data contains the names of illnesses, allowinb us to match incidence rates between *XHB* and critical illness insurance (detailed below). Consistent with *CII* data, we define two incidence rates: one for the 6 leading critical illness ($IR6_{k,t}^x$) and the other for 25 leading critical illness

($IR25^x_{k,t}$).

$$IR6^x_{k,t} = \frac{c6_{k,t}}{e_{k,t-6}} \quad and \quad IR25^x_{k,t} = \frac{c25_{k,t}}{e_{k,t-6}} \tag{5}$$

Incidence rates of *CII* 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. By contrast, while our *XHB* data contains detailed information about individual claim payments, it just has rough enrollment data for six age groups (< 10; 10∼19; 20∼29; 30∼39; 40∼49; and 50∼59). To facilitate an effective comparison, we estimate *CII*'s incidence rates of the six age groups based on the incidence rates from the *CAA* table. For the age group k, *CII*'s incidence rates for the 6 leading critical illnesses ($IR6^i_i$) and the 25 leading critical illness ($IR25^i_k$) are respectively expressed as:

$$IR6^i_k = \sum_{j \in k} w_{jk} * IR6^{CAA}_j \text{ and } IR25^i_k = \sum\nolimits_{j \in k} w_{jk} * IR25^{CAA}_k \tag{6}$$

In Eq. (6), j is a specific age, e.g., 35 years, reported in the *CAA* table. $IR6^{CAA}_j$ and $IR25^{CAA}_j$ 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. This is because we cannot estimate *XHB*'s incidence rates separately by gender. w_{jk} is the proportion of participants at a specific age j within age group k. Note that as we discussed in Section 3.1, the incidence rates reported in *CAA* table are consistent with *XHB*'s.

The comparison results are reported in Table 4, with Panel A covering stable periods from 201909P2 to 202012P2 and Panel B for stable periods but excluding COVID lockdown from 202002P2 to 202004P1. The result shows that for *XHB* the 10∼19 age group has the lowest average incidence rate (Columns 4 and 5), while the lowest incidence rate group for *CII* is the 0∼10 age group (Columns 6 and 7). The 50∼59 age group has the highest incidence rates among all age groups of *XHB* and *CII*. For *XHB*, the incidence rates are 46 and 54 per million participants respectively for CI6 and CI25 in age group of 10∼19, while they are respectively 1,440 and 1,491 per million participants in age group of 50∼59.

The table also reveals that *XHB* participants are much 'healthier' than insurance buyers - with a much lower incidence rate than that reported by *CAA* in each age group. In Columns (8) and (9), we report the ratios of *CII* and *XHB* incidence rates (calculated in each payment period and averaged over time) which shows that when aggregated across all age groups, the incidence rate of *CII* is 7.34 times that of *XHB* for the 6 critical illnesses, and 7.66 times of that of *XHB* for the 25 leading critical illnesses. The result indicates that the average incidence rate is significant lower than that of insurance in every age group and both way we categorize illnesses, i.e., CI6 and CI25. We obtain consistent results when excluding the COVID lockdown period. *XHB*'s incidence rates reported here, e.g., 460 and 478 per million (i.e., 10^{-6}) during stable periods, are far below those of critical illness insurance which are 3,192 and 3,459 per million participants. As displayed in Figure 4, we compare incidence rates of *XHB* in the stable non-COVID periods and *CII* for different age groups. Two panels of the figure respectively depict the contrasts in the incidence rates between two programs for the 6 leading critical illnesses and 25 leading illnesses across different age groups. We can see that insurance incidence rates are higher in every age group than that of *XHB*. The most striking finding is that the incidence rate of insurance exceeds *XHB* most in the 50 to 59 age group.

4 Separating Equilibrium: à la Rothschild-Stiglitz

In this section, we come up with a separating equilibrium, à la Rothschild-Stiglitz (1976), to explain the difference in participation rates between *XHB* and *CII* reported in Section 3.2. The idea is quite simple, through offering a restrictive coverage, X, *XHB* is able to attract individuals of lower risk or lower risk aversion while high risk or high risk-averse individuals select insurance, I which offers a better coverage.

The setup involves two states of wealth with W_1 denoting the state when an individual has no loss and W_2 denoting the state when an individual experiences a critical illness of a loss amount of l. The individual has endowment is w. Without any protection, the individual's wealth in two states is $(w,\, w-l)$. With protection which offers an indemnity of k with a premium π, the individual's wealth is $(w-\pi,\, w-\pi-l+k)$.

We first describe the demand of critical illness coverage. Assume there are two individuals, one with a high risk while the other having a low risk, i.e., $p^h > p^l$. Individuals know their loss probabilities while the market does not. The utility functions of the high risk individual, denoted as h, and the low-risk individual, denoted as l, are:

$$
\begin{aligned}
E[u^l] &= [1 - p^l]u(w - \pi_t) + p^l u(w - \pi_t - l + k) \\
E[u^h] &= [1 - p^h]u(w - \pi_t) + p^h u(w - \pi_t - l + k)
\end{aligned} \tag{7}
$$

Using W_1 to denote $w - \pi$ and W_1 to denote $w - \pi + k$, we express the indifference curves, the combination of an individual's consumption in two states, of the low- and high-risk individuals as follows (the proofs are provided in Appendix D.2):

$$
\frac{\Delta u^j(W_2)}{\Delta u^j(W_1)} = -\frac{1 - p^j}{p^j}, \, where\, j = l, h \tag{8}
$$

The expression state that the ratios of the marginal utilities between the loss ($\Delta u(W_2)$) and no-loss states ($\Delta u(W_1)$) equate the negative of the ratios between the probability of no-loss and having a loss. When the probability of the loss state is higher (i.e., $1 - p$ is lower), a reduction in the utility of the no-loss state leads to a smaller increase of the marginal utility in the loss state. This is displayed in Figure 6, the difference in shapes reflects the fact the high-risk individual is more willing to trade off the utility in the no-loss state for wealth in the loss state since she is more likely to experience losses than the low-risk individual.

Individuals differ from each other in their risk and risk preference in this simplified risk paradigm. In our setup, the former is determined by the loss probability while the later is driven by the utility function. Below, we show the distinction between risk and risk preference leads to different predictions of individual behaviors.

Case 1: When individuals differ only in risk types

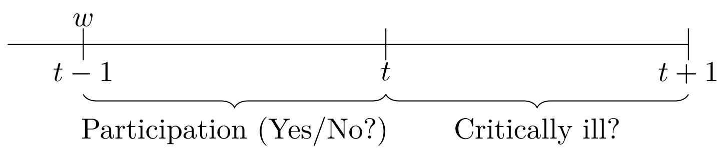
When two individuals share the same utility function, the difference in the tradeoffs in marginal utilities of two individuals would be fully captured by difference in the tradeoff their wealth.

$$
\frac{\Delta W_2^j}{\Delta W_1^j} = -F(\frac{1 - p^j}{p^j}), \, where\, j = l, h \tag{9}
$$

where F is an increasing function of $\frac{1-p^j}{p^j}$.

It states that the substitution rate between W_2 and W_1 is inversely related to the loss probability.

Now we offer some details of critical illness coverages. We illustrate timing of premium and claim payments using the following timeline:



An individual has an endowment of w at $t-1$. She makes the decision about whether to have a coverage, either *XHB* or *CII*, between $t-1$ and t which covers losses between t and $t+1$. For *XHB*, the premium depends on the incidence rate p_t^x which is publicly announced at time t. To be eligible for the claim payment between t and $t+1$, the individual must be a *XHB* member before t. In other words, when an individual makes the decision whether to stay with *XHB* and share the cost of π_t^x, she or he does not know p_t^x. In contrast, the premium of *CII* is known since insurance price is determined ex-ante. Considering *XHB* has a large pool of participants, thus the idiosyncratic component of the incidence rate can largely be diversified. We set side the difference between

As illustrated in Figure 6, E represents individual payoffs in two states without any protection; X represents individual payoffs in two states after joining *XHB*; I represents individual payoffs with insurance. Their specific coordinates are specified as below:

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

E shows the individual payoff when she/he has no protection - the individual's total wealth is w in the no-loss state (W_1) and the total wealth is $w-l$ in the loss state (W_2). After joining *XHB*, the individual's aggregate payoff is $w-\pi^x$ in W_1 while it is $w-\pi^x-l+k^x$) in W_2. With *CII*, the individual's aggregate payoff is $w-\pi^i$ in W_1 while it is $w-\pi^i-l+k^i$) in W_2.

EX and *EI* are the budget curves for *XHB* and *CII*. Their slopes are specified as below:

$$\begin{aligned} \frac{\partial W_2}{\partial W_1}|_X &= \tfrac{\pi_t^x - k^x}{\pi_t^x} = 1 - \tfrac{1}{p_t^x(1+\lambda^x)} \\ \frac{\partial W_2}{\partial W_1}|_I &= \tfrac{\pi_t^i - k^i}{\pi_t^i} = 1 - \tfrac{1}{p^i(1+\lambda^i)} \end{aligned} \tag{10}$$

The derivations of the slopes of both budget curves are provided in Appendix xx.

Given the loading of *XHB* is lower than *CII* ($\lambda^x < \lambda^i$), *EX* is steeper than *EI* even when the expected incidence rate of *XHB*, p^x, is the same as the expected incidence rate of *XHB*, p^i. A steeper budget line indicates a 1-unit decrease in the no-loss state, W_1, leads to a greater wealth increase in the loss state, W_2, which is aligned with the fact that *XHB* offers a less expensive coverage.

Consider that an economy involves a high-risk (i.e., high incidence rate) individual and a low-risk (low incidence rate) individual. As shown in Figure 6, the low-risk individual has a steeper indifference curve (*IC*) than the high-risk individual does. It reflects the high-risk individual's preference to trade off her/his payoff in the no-loss state (W_1) for the payoff in the loss state (W_2). Also shown in Figure 6, coverage *I*, offering more coverage than *X*, delivers a higher expected utility than *X* to the high-risk individual. Intuitively, the high-risk individual prefers more coverage thus they are willing to pay a higher cost to purchase insurance while low-risk individuals would rationally choose the low-coverage *X*. This results in a separating equilibrium, à la Rothschild and Stiglitz (1976), where high-risk individuals choose *I* while low-risk individuals choose *X*. This results in the first type of advantageous selection in *XHB*'s competition against *CII*.

Proposition 1 *Given a higher level of indemnity offered by* XHB *and* CII*, high-risk individuals choose* I *and low-risk individuals choose* X *under asymmetric information of risk types.*

Case 2: When individuals differ both in risk types and risk preference

When the utility function of two individuals are no longer identical, the ratio between probability of no-loss and having loss would reflect the substitution effects of the marginal utilities. In other words, a lower loss probability leads to a high $\partial(1-p)p$, corresponding to a higher marginal utility of loss state (W_2) relative to marginal utility of loss state (W_1). a lower loss probability does not necessarily mean a more wealth in the having loss state (W_2). It rather measures an agent is less sensitive to losses. This leads to the second type of advantageous selection of *XHB* relative to *CII*.

Proposition 2 *Holding risk type constant, given a high level of indemnity offered by* XHB *and* CII*, investors who are more sensitive to risk choose* I *and those who are less sensitive to risk choose* X *under asymmetric information of risk types and risk preference.*

Intuitively, individuals who are less sensitive to risk prefer a less expensive contract offering lower protection, i.e., *XHB* while individuals highly sensitive to risk prefer better coverage. This idea may be viewed as an extension to the advantageous selection argument proposed in the insurance literature. Earlier empirical works, e.g., de Meza and Webb (2001), show that individuals who are more risk averse, taking more precautions on health risk, are more likely to purchase insurance. Subsequent studies take a broad perspective on advantageous selection arguing various individual characteristics, such as the wealth and education levels, are important insurance decision factors (e.g., Fang et al., 2008). As pointed out in Einav et al. (2021), preference heterogeneity drives an inverse relationship between risk and insurance purchase as long as risk aversion, or other individual characteristics, and risk are negatively correlated. A new argument we bring to the table is that an individual who is not sensitive to risk prefers mutual aid products.

We note that high-risk individuals may be a part of *XHB* under both types of advantageous selection explanations. To be specific, the first considers consumers to be homogeneous in their risk preference. When they are fully informed about their risk types and they cannot buy two products simultaneously, the high-risk individual buys insurance and the low-risk individual joins *XHB*. However, the practice does not take place in this way given the choices of two products are not mutually exclusive and individuals may not be fully informed of their risk types (Doherty and Thistle, 1996; Doherty and Posey, 1998). High risk individuals may join *XHB* because they want to take advantage of *XHB*'s low price and they are uninformed of their risk types. On the other hand, the second proposition allows heterogeneity in individuals' risk preference. Individuals of low risk sensitivity could be both low- and high-risk types. It is likely for high-risk individuals to participate in *XHB* as long as risk and risk sensitivity may be negatively correlated.

The fact that *XHB*'s incidence rate is much lower than that of *CII* depends largely on two factors: i) access restrictions to less healthy individuals, such as aged and people with low credit scores, and ii) the use of Fintech to eliminate payments to claims not meeting criteria. It is difficult to empirically examine the role of Fintech on *XHB* participants and claims. Despite the difficulty, we are able to draw inference about mutual aid participants' preference using a survey about the mutual aid business conducted by Ant Financial. The analysis is presented in the following section.

5 Further Analysis on Individual Choices

5.1 Do Individuals Adversely Select *XHB*?

We first take a look at whether adverse selection presents among *XHB* participants. To do so, we look at age gradients in incidence rates of *XHB*. *XHB* sets different indemnities for individuals below 40 years old (CNY300,000) and those who are 40 and above (CNY100,000). This motivates us to look at the average incidence ratios of individuals below and above 40 years old. If the ratio of incidence rates of these two groups, i.e., age gradients, is close to 1:3, we would conclude *XHB* is fairly priced. Otherwise, we conclude that *XHB* favors one age group against the other.

We implement this idea and estimate the age gradient of incidence rates above and below 40 for *XHB* participants. Like we did in the previous tables, we complete two sets of analysis: one for the "stable" period reported in Panel A of Table 5 and the other excluding the COVID lock-down period in 2020 reported in Panel B of Table 5. Shown in Panel A, We find that the ratios of incidence rates for 6, 25 and 100 illnesses between the middle-aged and young groups are respectively 4.53, 4.47 and 4.24 in the stable period. They are all statistically significantly exceeding the indemnity ratio of 3 based on incidence rates in payment periods. For the comparison purpose, we also report the ratios of *CII* incidence rates between the middle-aged and young groups - they are 5.21 and 5.12 for the 6 and 25 leading illnesses, higher than the ratios for *XHB*. We obtain consistent results when excluding COVID lockdown periods.

The finding shows that *XHB* is not fairly priced - young participants subsidize the elder group even the shared cost of the young group is one-third of the mid-aged group. This indicates that adverse selection is a factor driving individuals' incentive to participate in *XHB*. Nevertheless, we also find that the magnitude of "mispricing" is smaller for *XHB* – the adverse selection problem is less severe among *XHB* participants. This is consistent with the result reported in Section 3.2.

5.2 Evidence on Advantageous Selection

Now we study the drivers of individual choices: whether it is attributed to differences in risk types or individuals' risk sensitivity. We do so by studying an additional source of the data, which is the survey of internet mutual production products conducted by the Financial Research Institute of Ant Financial in 2020. The survey was distributed to Alipay account holders. The key questions of the survey are 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. Other survey data include participants' ages, gender, city tier of the residence, and their income levels. The total number of survey respondents is 58,721, including 24,117 participating in at least one type of mutual aid products, 51,128 enrolled in the social security program, 33,329 purchasing commercial health insurance. The government-sponsored social security has the largest number of participants, followed by commercial medical insurance and mutual aid plans. In the survey, respondents were asked to provide ages, genders, economic status of their residing city, and ranges of their personal annual income. The survey contains multiple questions regarding respondents' participation in mutual aid programs, government-sponsored medical insurance programs (known as 'social security'), current involvement in commercial medical insurance programs and plans for future participation. Relevant survey questions are provided in Appendix E.

We specifically answer the following two questions. First, what are the driving factors for individuals/households to participate in mutual aid programs – advantageous selection or adverse selection? Second, what is the relationship between mutual aid participation and individual insurance purchases? Are they complementary to or substituting each other? Logistic regressions are performed. The dependent variable is an indicator equal to 1 when an Alipay account holder participates in at least one of the major mutual aid programs and 0 otherwise.[12] The independent variables include i) age of a survey participant (*AGE*), ii) an indicator for a female survey participant (*FEMALE*), iii) economic condition of a respondent's residing city (*TIER*) which takes a number from 1 to 6, a higher city tier score suggests a lower economic development status,[13] iv) four 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,[14] v) whether a

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

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

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

respondent participates in a social security health insurance program (*SS*),[15] and finally vi) an indicator for purchasing commercial insurance (*INS*).[16] The results are reported in Panel A of Table 6.

The result is presented below. The first variable reported in Column 1 is *AGE*, a factor most closely associated with individuals' risk types. We find the coefficient is insignificant, potentially indicating risk types are not a key factor driving individual choices. Further, the same column reports a negative coefficient on *TIER* (= -0.02; t-stat = -2.92). As *TIER* is inversely related to the wealthy level of the respondent's city of residence, this result suggests that respondents from rich regions are more likely to join mutual aid programs than those from poor regions. This is consistent with Fang et al. (2008)'s perspective where income is regarded as an important source of advantageous selection. Interestingly, the coefficient on *FEMALE* is negative (= -0.08; t-stat = -4.09), suggesting that females are less likely to participate in mutual aid programs.

In Column 2, we add dummy variables of different income ranges (*INC2*, *INC3*, *INC4* and *INC5*) in the regression (leaving out the income group below CNY 50,000 as the benchmark). We find consistent results for the coefficients on variables reported in Column 1 except that *TIER* now has an insignificant coefficient. The coefficients on the individual income dummy variables are all significantly positive. The coefficients on income indicators are respectively 0.28 (t-stat = 14.4), 0.37 (t-stat = 14.32), 0.43 (t-stat = 9.27), and 0.24 (t-stat = 3.67). The result suggests that the probability of joining a mutual aid program for any of the four higher income groups is greater than the benchmark group.

Next, we separately analyze the determinants of mutual aid participation of the relatively young group and the middle-age/old group. Reported in Columns 3 and 4 of Table 6, the coefficients of the same variable sometimes take opposite signs. Among young participants (Column 3), mutual aid is more attractive when participant ages grow. When risk types are the sole driver of individual choices, we expect to see younger individuals, who are less risky, are more likely to participate in a mutual aid program. Our finding is inconsistent with this expectation. However, in the regression for the middle-aged group (Column 4), the coefficient on *AGE* is negative, suggesting that old respondents have less incentive to participate. This is consistent with the first type of advantageous

[15] 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'.

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

selection and it is also aligned with the pattern revealed in Figure 5 that the participation rate is lower for the 50-59 group than for the 40-49 group, not in favor of the presence of widespread incentive problems among mutual aid participants.

Interestingly, in both columns 3 and 4, the coefficients on individual income dummy variables are mostly positive, suggesting regardless of their age groups, rich individuals are more likely to participate in mutual aid programs. As rich individuals (who are healthier) are less sensitive to critical illness risk, this finding renders supports to the second type of advantageous selection where less risk sensitive individuals are more likely to participate in mutual aid programs.

Further, Table 6 shows a negative coefficient on *INS* (the indicator for purchasing commercial insurance) in each regression listed in Column (1) through (4). It suggests that survey respondents with a commercial medical insurance are less willing to participate in mutual aid programs. Mutual aid programs are able to reach customers typically not covered by conventional health and critical illness insurance. Our finding differs from Tang (2019) showing that P2P lending often occurs among borrowers who have access to bank credit. It suggests that mutual aid programs complement commercial insurance in health risk management.

The mutual aid survey also inquires whether survey participants desire to purchase commercial medical critical illness coverage in the future if their response on participating in a mutual aid program is yes (see Q5 in Appendix E). INS_{t+1} equals 1 if a survey respondent desires to purchase commercial health insurance in the future and 0 otherwise. MA_t equals 1 if a survey respondent participates in a mutual aid program and 0 otherwise. The outcome is shown in the following exhibit:

	$MA_t = 0$	$MA_t = 1$	*Total*
$INS_{t+1} = 0$	5,962	3,346	9,308
$INS_{t+1} = 1$	13,846	11,011	24,857
Total	19,808	14,537	34,165

The total number of survey participants answering this question is 34,165. Among them, there are more participants not participating in any mutual aid programs (19,808) than those participating in a mutual aid program (14,537). The survey outcome also reveals that it is more likely for respondents to express the interest to purchase insurance in the future if they indicate they are a current mutual aid participants than among non-mutual-aid participants. To be Specific,

$$Prob(INS_{t+1} = 1|MA_t = 0) = \frac{13,846}{19,808} = 0.70$$
$$Prob(INS_{t+1} = 1|MA_t = 1) = \frac{11,011}{14,357} = 0.77$$

The probability to purchase insurance at $t+1$ for a non-mutual aid participant at t is 0.70 while the purchase probability for a current mutual aid participant is 0.77. It suggests that participation in mutual aid programs does not reduce survey participants' incentives to buy similar insurance products. Instead, mutual aid participation appears to positively affect household commercial insurance consumption.

We conduct the logistic multivariate regression using an indicator for survey participants' incentive to purchase insurance in the future as the dependent variable. The purpose is to see whether the positive connection between mutual aid participation and future insurance demand preserves after controlling for survey participants' attributes, such as their age and income. The results are reported in the last three columns of Panel B of Table 6. In Column 5, the reported coefficient on *MA* is 0.49 which is significant at the 1% level, reinforcing the earlier analysis about the conditional probability of subsequent medical insurance purchase. A likely explanation is that mutual aid participation makes individuals more aware of critical illness risk thus enhancing their likelihood to purchase medical insurance. This is a clear evidence on the complimentary relationship between commercial insurance and mutual aid products.

In Columns 6 and 7 we report the findings when separating respondents to the below 40 group and the above 40 group. Confirming earlier results, the coefficients on MA from both regressions are significantly positive. Risk pooling (e.g., mutual risk sharing) and risk transfer (e.g., insurance) are two non-mutual exclusive approaches. Mutual aid is more effective in spreading simple and diversifiable risk among participants while commercial insurance has advantages in handling sophisticated risks. Thus they supplement each other.

To conclude, the overall finding of the mutual aid survey supports the existence of advantageous selection among mutual aid participants and the complementary relation between commercial health insurance and mutual aid programs. The survey result also shows that mutual aid participants are more likely to purchase insurance in the subsequent periods than non-mutual aid participants do.

6 Conclusions

Xiang Hu Bao (*XHB*) is a novel online platform designed to mutually share individuals' critical illness exposure. It leverages the tech giant's platform and digital technology to lower the cost and improve the efficiency of enrollment and claim processing. Different from insurance products applying actuarial models in pricing, *XHB* simply lets healthy participants share indemnity payment 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 show 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 mutuality principle, under which mutual risk sharing is individuals' first order choice when they face risk. However, while diversification and the law of large numbers are at the heart of insurance and risk management, the concepts are poorly implemented due to the presence of transaction costs and potential presence of information asymmetry. Fintech development potentially makes a huge difference: if appropriately implemented, the technology could substantially lowers *XHB*'s operational costs, equipping the risk-sharing platform with high operational efficiency. This will provide incentive to individuals of low risk and those not sensitive to risk to stay in the pool. Evidently, *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 offers the first-hand 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. Mutual risk sharing programs empowered by Fintech can reach customers typically not covered by conventional health and critical illness insurance. 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.

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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, and iii) allocated cost per member from January 2019 to December 2020.

Period	Enrollment	Aggregate Claim Payment (in CNY)	Allocated Cost Per Member (in 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: 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. # (Full sample) is the total number of paid claims in a specific claim payment period. # <40 (≥40) is the number 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	# (Full sample) (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/Avg	52,250	21,272	30,978	430

Table 4: Incidence Rates of Age Groups: *XHB* versus *CII*

This table reports the number of claims, incidence rates of *XHB* and critical illness insurance (*CII*) of six 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 a specific age range. The number of paid claims reported in Columns (2) and (3) are the average numbers of claims reported in the current payment period of a specific age range. Columns (4) and (5) report *XHB* incidence rates (IR^x) estimated as the number of paid claims of an age range scaled by the aggregate *XHB* enrollment in the lagged 6-periods of the corresponding age range. 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 period from 201909P2 to 202012P2. Panel B reports the results during the 'stable' period while excluding COVID-19 lockdown months (202002P2-202004P1).

Group	# *XHB* (6-period lag)	# *XHB* Cases		IR^x (per million)		IR^i (per million)		*IR* Ratio *CII*/*XHB*	
		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									
<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)
Total	94,039,375	1,804	1,875	460	478	3,192	3,459	7.34 (15.06)	7.66 (15.12)
Panel B: Non-COVID 'Stable' Periods									
<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)
Total	93,632,114	1,914	1,990	491	510	3,192	3,459	6.53 (64.20)	6.81 (66.74)

Table 5: Incidence rates of Age Groups and Cost Sharing

This table shows the incidence rates of *XHB* and critical illness insurance as well as ratios between these two for people below 40 years old and those of 40 years old and above. Panel A reports the results in the "stable" claim period from 201909#2 to 202012#2. Panel B reports the results in "stable" periods excluding the COVID lockdown period. *IR6* and *IR25* represent incidence rates for 6, 25 leading critical illnesses of *XHB* and *CII* and and *IR100* is for the incidence rate of all illness. The t-statistics of ratios for the relative incidence rates between the 40-59 group and the below 40 group minus 3 are reported in the parentheses.

Panel A: Results Based on "Stable" Periods

	XHB			*CII*	
	IR6	IR25	IR100	IR6	IR25
<39	233	244	283	1,183	1,300
40∼59	1,055	1,091	1,200	6,167	6,656
40∼59/<39	4.53	4.47	4.24	5.21	5.12
(t-stats)	(6.54)	(6.52)	(6.26)		

Panel B: Results Based on Non-COVID "Stable" Periods

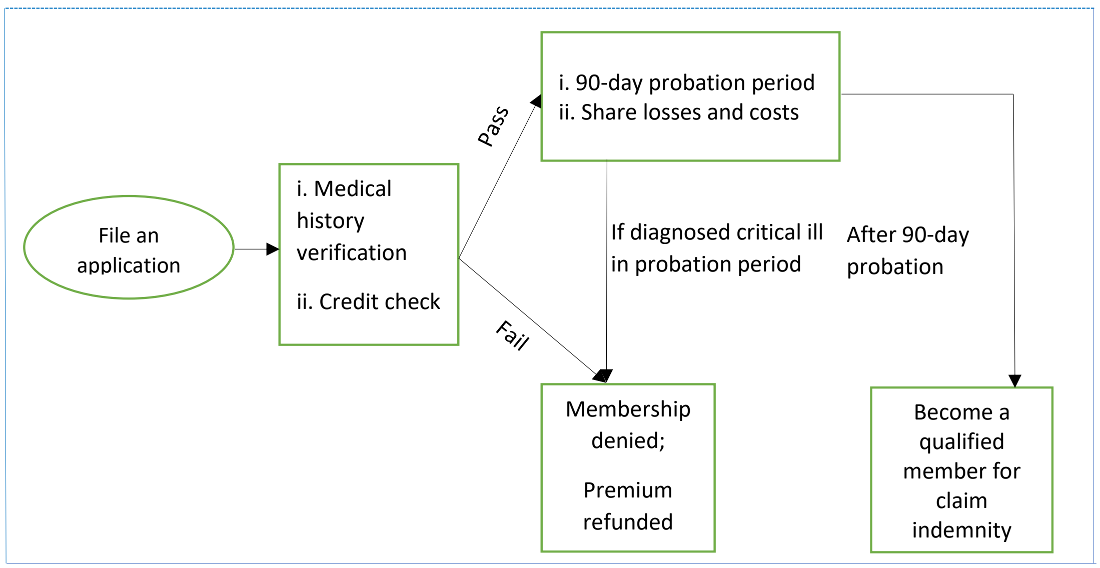
Group	*XHB*			*CII*	
	IR6	IR25	IR100	IR6	IR25
<39	245	258	299	1,183	1,300
40∼59	1,132	1,171	1,288	6,167	6,656
40∼59/<39	4.61	4.54	4.31	5.21	5.12
(t-stats)	(6.56)	(6.48)	(6.20)		

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 in 2020. Panel A reports the logistic regression results when the dependent variable is an indicator of whether a survey participant joined an internet mutual aid program. It reports the regression examining the determinants of mutual aid participation including the following independent variables: i) whether a respondent participates in a social security health insurance program (*SS*), ii) whether a respondent purchases commercial insurance (*INS*), iii) a respondent's age (*AGE*), iv) a respondent's gender (*FEMALE*=1 for a female respondent and 0 otherwise), v) the city tier of a respondent's residence (*TIER* taking a number from 1 to 6, the higher the number is, the worse economic development the city is), vi) four indicative variables for a respondent's annual income range: *INC2* equal to 1 when a respondent's annual income is between CNY 50,000 and 100,000 and 0 otherwise, *INC3* equal to 1 when a respondent's annual income is between CNY 100,000 and 200,000 and 0 otherwise, *INC4* equal to 1 when a respondent's annual income is between CNY 200,000 and 500,000 and 0 otherwise, and *INC5* equal to 1 when a respondent's annual income is more than CNY 500,000. Panel B reports the logistic regression results when 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. It includes whether a respondent joins a mutual aid plan (*MA*). *t*-statistics are reported in the parentheses. The last two rows report the number of observations and the regression R-squared.

	Panel A: MA Participation				Panel B: Insurance Purchase		
	(1) All	(2) All	(3) <40	(4) ≥40	(5) All	(6) <40	(7) ≥40
MA					0.49***	0.50***	0.49***
					(17.16)	(15.37)	(8.17)
AGE	0.00	-0.00	0.01***	-0.01***	-0.04***	-0.04***	-0.04***
	(0.42)	(-0.06)	(6.81)	(-3.50)	(-27.14)	(-13.28)	(-8.56)
FEMALE	-0.08***	0.01	-0.004	0.06	0.37***	0.42***	0.22***
	(-4.09)	(0.39)	(-0.18)	(1.47)	(10.73)	(10.4)	(3.07)
TIER	-0.02***	-0.01	-0.01***	0.03***	-0.01	-0.02*	0.02
	(-2.92)	(-1.52)	(-2.77)	(3.02)	(-1.23)	(-1.93)	(1.04)
INC2		0.28***	0.30***	0.15***	0.34***	0.25***	0.66***
		(14.40)	(13.26)	(3.68)	(10.72)	(6.75)	(9.73)
INC3		0.37***	0.38***	0.21***	0.60***	0.53***	0.85***
		(14.32)	(12.83)	(3.92)	(13.76)	(10.44)	(9.44)
INC4		0.43***	0.46***	0.22**	0.83***	0.75***	1.11***
		(9.27)	(8.47)	(2.38)	(10.14)	(7.70)	(7.09)
INC5		0.24***	0.17	0.42**	0.69***	0.52***	1.33***
		(3.67)	(1.63)	(4.22)	(4.32)	(2.89)	(3.88)
SS	0.60***	0.56***	0.57***	0.49***	0.15***	0.20***	-0.14
	(22.31)	(20.90)	(19.30)	(7.62)	(3.42)	(4.38)	(-1.24)
INS	-0.29***	-0.29***	-0.28***	-0.34***	2.15***	1.99***	2.66***
	(-13.62)	(-16.56)	(-14.07)	(-9.47)	(73.05)	(59.47)	(42.72)
INTERCEPT	-0.69***	-0.88***	-1.00***	-0.65***	-0.19**	-0.10	-0.35
	(-19.48)	(-23.53)	(-22.93)	(-5.05)	(-3.13)	(-1.39)	(-1.64)
N	58,722	58,722	45,031	13,691	34,165	26,103	8,062
R^2	0.01	0.02	0.02	0.02	0.20	0.17	0.28

Panel A: XHB Enrollment



Panel B: Claim Process

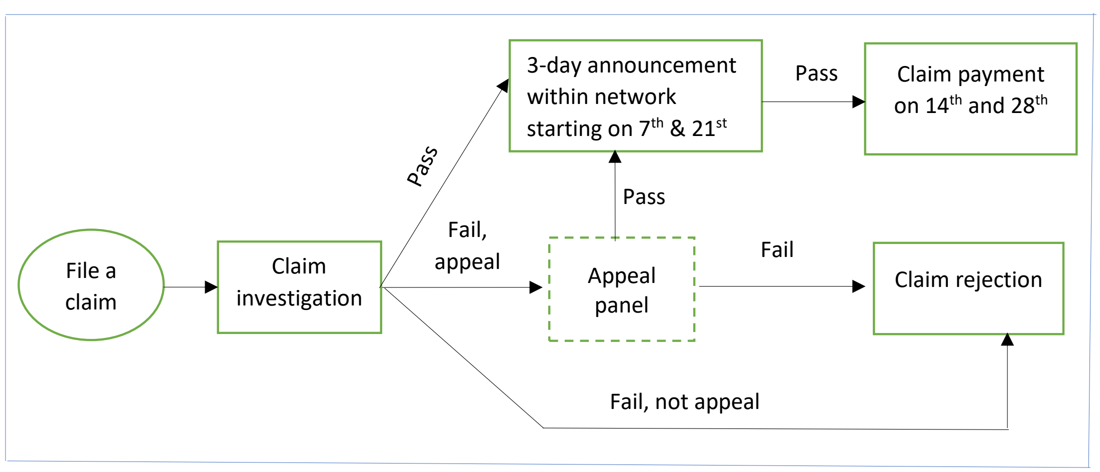


Figure 1: *XHB* Enrollment and Claim Procedures

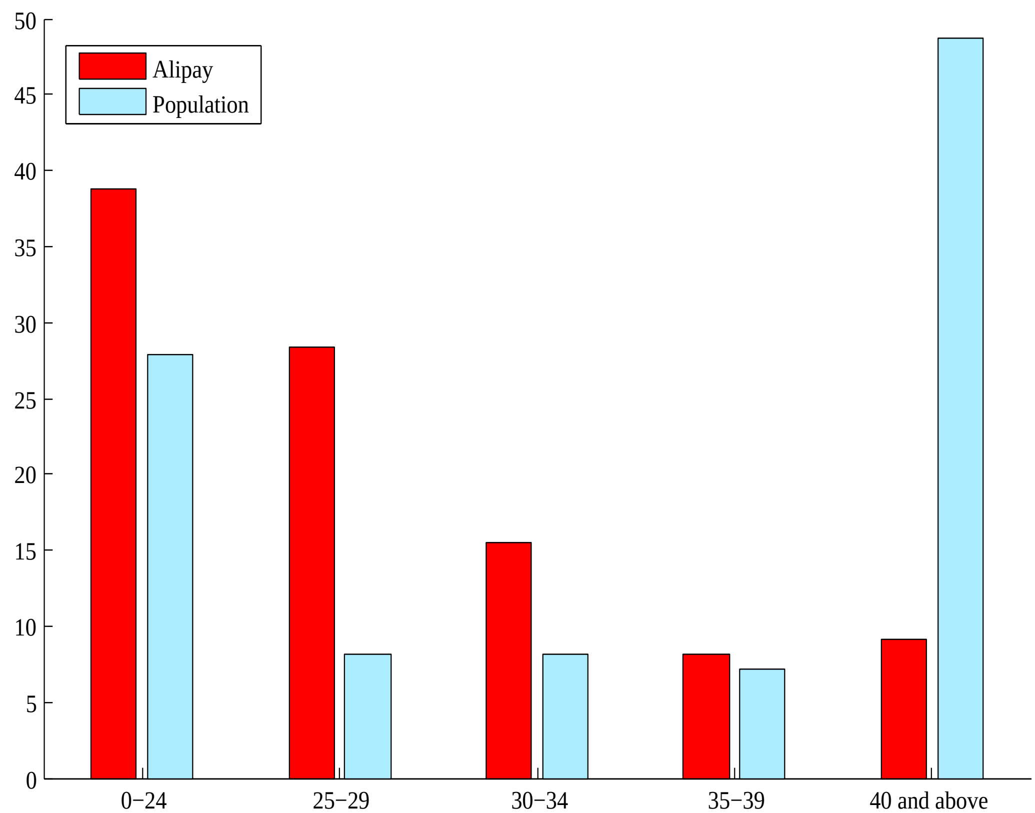


Figure 2: Distributions: Alipay Participants vs. Chinese Population
The figure plots Alipay (the red bar) participants (and the Chinese population (the light blue bar) across different age groups in June of 2020.

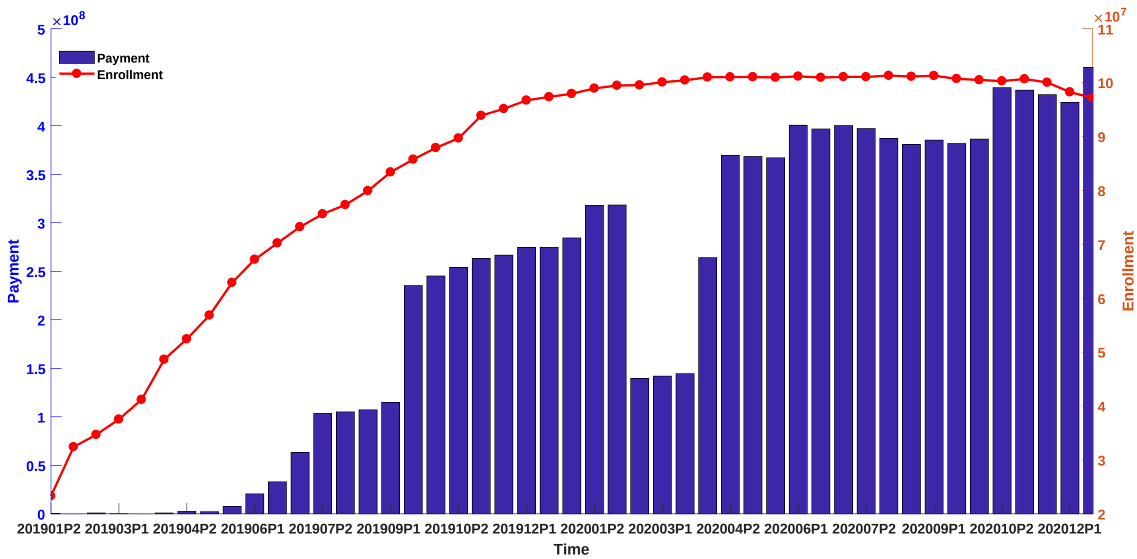


Figure 3: *XHB* Enrollment and Aggregate Claim Payout

This figure shows the number of Xiang Hu Bao enrollments and aggregate claim payouts over time. The curve represents the number of enrollments. Bars represent claim payouts.

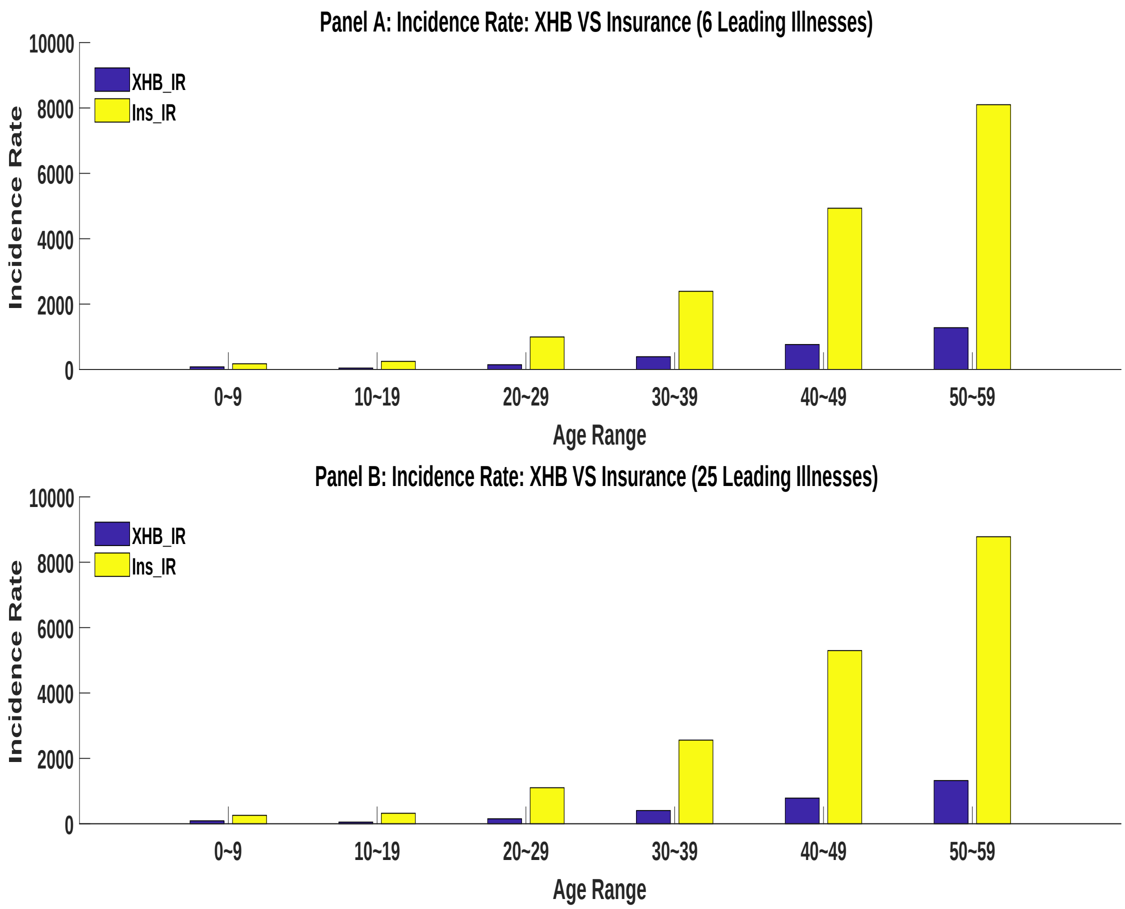


Figure 4: Incidence Rates of *XHB* and Critical Illness Insurance Across Age Groups
This figure shows the incidence rates of age groups for *XHB* and critical illness insurance. The incidence rates for *XHB* are for the stable non-COVID periods.

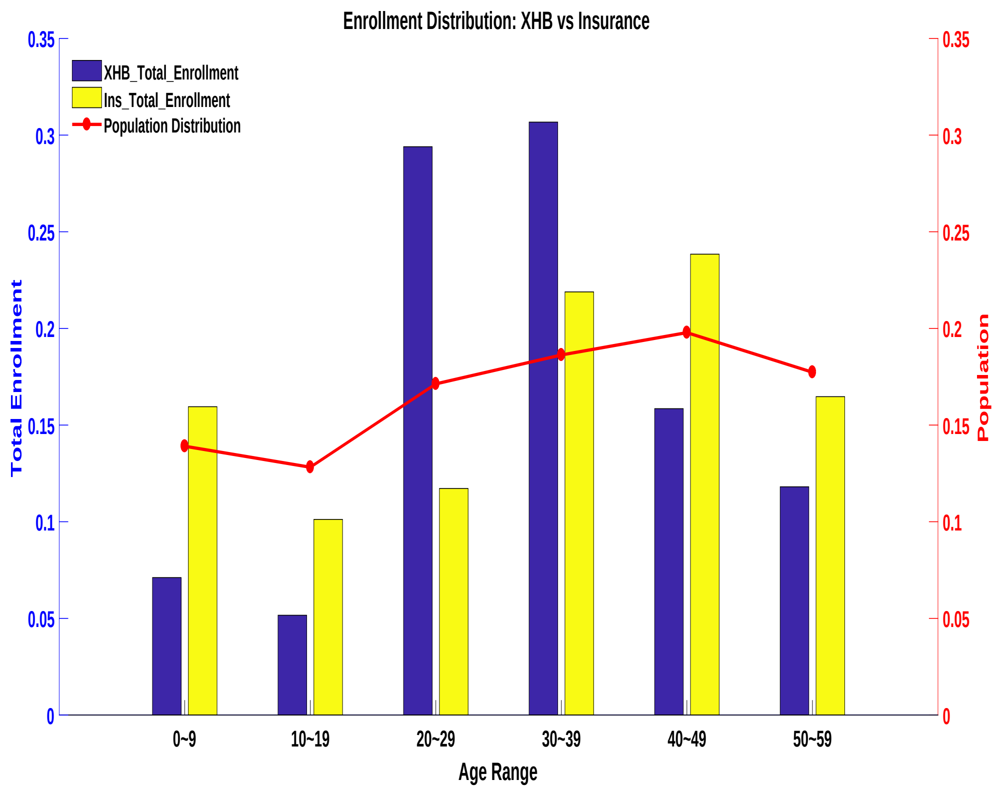


Figure 5: Enrollment Distribution Across Age Groups

This figure shows 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).

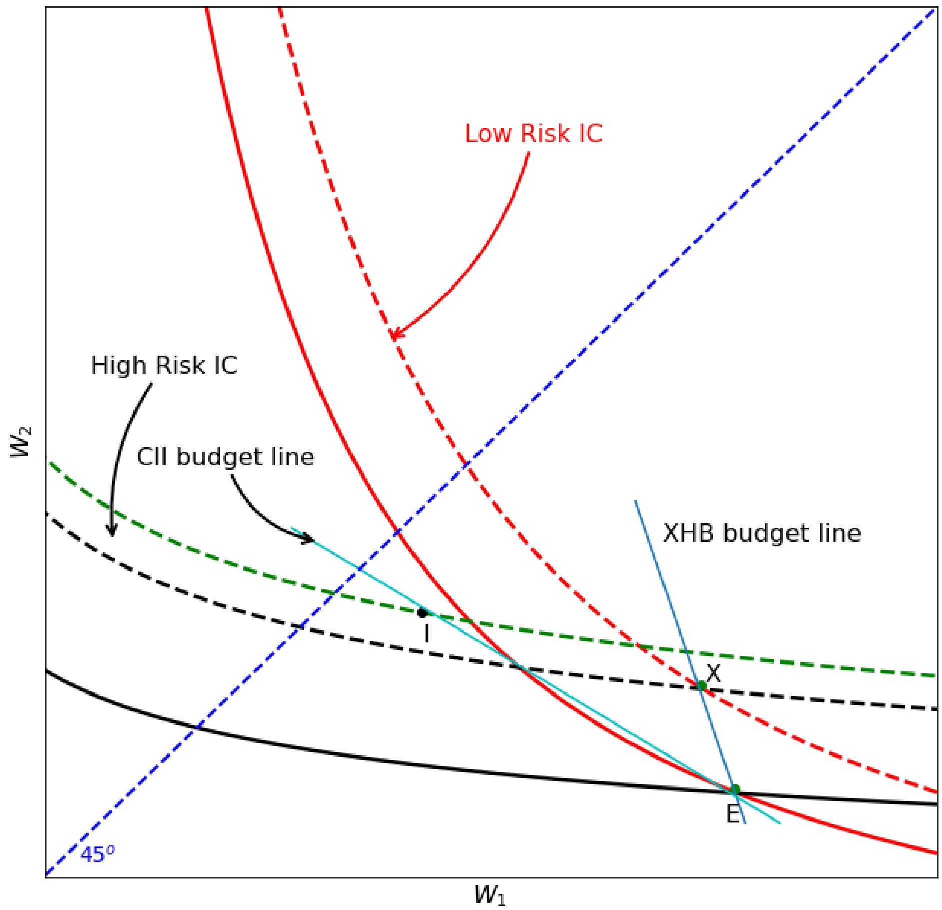


Figure 6: Separating Equilibrium: *XHB* versus Critical Illness Insurance
W_1 represents an individual's aggregate payoff at t and $t+1$ in the no-loss state. W_2 represents the individual's aggregate payoff at t and $t+1$ in the loss state.

Appendix

A Mutuality Principle: A Review

This appendix summarizes Borch (1962)'s theorem which derives conditions for optimal risk sharing under the state contingent framework. Imagine we are in a world with zero transaction costs. There are n risk averse agents and a finite number of possible future states of nature, s = 0, 1, 2, ..., S-1. While which state prevails in the future is unknown, there is a probability p^s attached to the realization of state s. Use w_i^s to denote the uncertain wealth to individual i in state s and use Π_s to denote the price of the Arrow-Debreu asset in state s. Then, agent i chooses a consumption plan in different states, c_i^0, c_i^1, ..., c_i^s,..., c_i^{S-1} to maximize her expected utility:

$$\max_{c_i^0, c_i^1, \ldots, c_i^{S-1}} EU_i[c_i^s] = \max_{c_i^0, c_i^1, \ldots, c_i^{S-1}} \sum_{s=0}^{S-1} p_i u_i[c_i^s] \tag{A1}$$

subject to the wealth constraint for any agent whereas the value of the agent's new portfolio equates the value of her initial endowment:

$$E[\Pi^s(c_i^s - w_i^s)] = 0 \;\; for \; \forall \; i \tag{A2}$$

The first-order conditions for the problem can be expressed as:

$$u_i^{'}[c_i^s] = \pi^s \eta_i \;\; for \; all \; s \tag{A3}$$

where $\pi^s = \frac{\Pi^s}{p^s}$ (the price of state s per unit of state and η_i is the shadow cost of violating the wealth constraint, Eq. (A2).

The above describes the market participant's tradeoff at the equilibrium point. $u_i^{'}[c_i^s]$ is the marginal utility of consumption for agent i in state s; i.e., the gain in the agent's utility given a change in her consumption in state s. $\pi^s \eta_i$ represents the shadow cost for agent i when its consumption deviates from the optimal consumption, $\hat{c}_i^s$.

In equilibrium, an individual agent i's wealth change in state s is $\hat{c}_i^s - w_i^s$, which can be denoted as $\hat{z}_i^s$.

Summing up across individuals in each state s, we have that in each state the aggregate net wealth change is 0 when the market is cleared: $\sum_{i=1}^{n} \hat{z}_i^s = 0$.

$$\sum_{i=1}^{n} \hat{c}_i^s = \sum_{i=1}^{n} w_i^s = w^s \tag{A4}$$

In absence of transaction costs, risk sharing does not alter the aggregate wealth in any state even if it makes changes to individual agents' consumption plan in individual states.

Now let us consider the simple case that the aggregate wealth is constant even though individual wealth varies across states. Since the risk can be diversified away when an individual pools her risk with other participants, she would have the same consumption regardless of the state. In other words, agents hold a risk-free portfolio. It can be easily shown that $\pi^s = \frac{1}{1+r}$ where r is the risk-free rate of return. Accordingly, the state price Π^s is fully determined by p^s:

$$\Pi^s = \frac{p^s}{1+r} \tag{A5}$$

It states that when the aggregate risk can be fully diversified away, the state contingent price does not depend on individual agents' risk tolerance, but fully depends on their probability of having state s. An individual is willing to pay a higher price for state t when she has a greater likelihood to have the state. Take *XHB* as an example. A higher critical illness likelihood results in a more participation cost for *XHB*.

Next we consider the case that the aggregate wealth is not expected to be the same across states. Under the assumption that any individual's optimal consumption, c_i^s is equally sensitive to any individual's initial wealth, the rule for efficient risk sharing can be obtained by Equations A3 and A4 - the sensitivity of agent i's consumption to the aggregate wealth, $c_i^{s'}(w_s)$ (w_s represents the aggregate wealth of state s), is proportional to agent i's risk tolerance to the sum of individual risk tolerance:

$$\frac{d\hat{c}_i^s}{dw_s} = \frac{t_i}{\sum_i^n t_i}. \tag{A6}$$

where $t_i = \frac{u'(c_i^s)}{u''(c_i^s)}$ stands for risk tolerance for agent i.

That is, any increment in an agent's wealth should be shared in proportion to individual risk tolerances. Details of the derivations can be found in Wilson (1968). Under the specific setting of critical illness risk sharing, when the aggregate cost of critical illness is uncertain, we expect less risk-averse agents to take more risks.

A critical condition of the mutuality principle is zero transaction costs under which agents can freely trade their risks. Unfortunately, this condition does not hold and the failure leads to i) the bare existence of mutual risk sharing and ii) high transaction cost of existing insurance operations. Aiming to lower transaction costs and market friction, the development of financial technology potentially makes this fundamental principle in risk management and risk sharing feasible in practice.

B 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

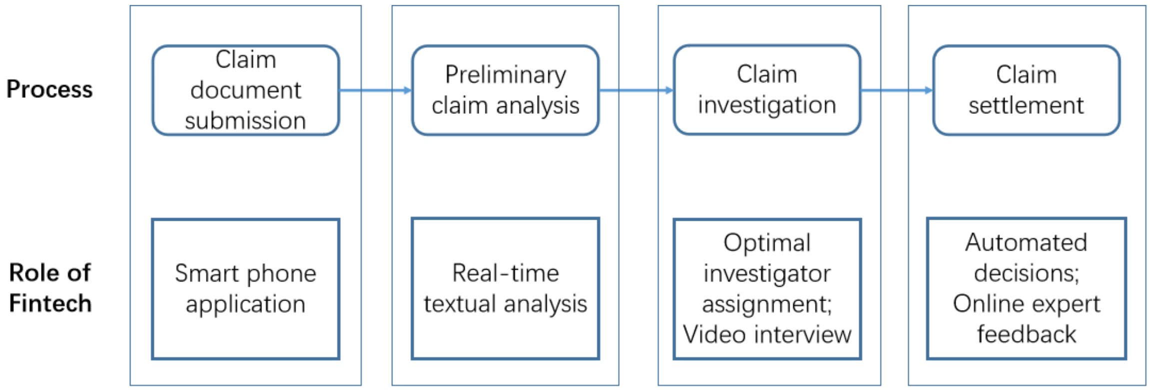
Panel B: Rare Illnesses

#	Name
1	Gaucher disease
2	Fabry disease

3	Mucopolysaccharidosis
4	Pompe disease
5	Langerhans cell histiocytosis

C Fintech Applications in *XHB*

The following figure outlines key steps of *XHB*'s claim process and roles played by Fintech.[1]



In the first step, claimers upload their claim materials to the *XHB* claim system via an Alipay mobile application. The platform converts documents to digital data via an optical character recognition system. When submitted materials are not legible, for example due to a poor image quality or an inappropriate file format, the system automatically sends messages to claim 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.

In the second step, *XHB* performs a preliminary textual analysis on critical illness claims. A claim would be rejected straightly if it does not meet the requirements, such as an illness not on the covered illness list, patient's pre-existing condition, or an illness occurring in the probation period. 50% of submitted claims are rejected in the pre-screening stage - 100,000 out of 200,000 cases submitted claims were declined in this step in 2020. As this step is processed by the artificial intelligence based system involving zero human input, it helps to substantially lower claim adjustment costs.

The third step is claim validation/investigation, a critical element of the practice. 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 sends investigators to the nearest

[1]We had several rounds of interviews with *XHB* key employees and researchers from Ant Financial. The dialogues focused on Fintech use and effects on the claim process.

hospitals. Investigators update documents and their progress to the system. When they encounter problems they also communicate with the system. In sum, the AI system helps *XHB* to minimize human involvement (thus cutting labor costs), and make claim settlement more objective.

The final step is decisions and payments. Claims are settled instantly with three outcomes: i) accepting the claim and making payments, ii) rejecting the claim. Alternatively, iii) labelled as disputable claims which are sent to designated specialists and entering the decision stage again once getting specialists' feedback. This procedure is evidently efficient. In 2020, *XHB* made claim payments to 52,682 individuals, comparable to the total number of critical illness claims processed by traditional critical illness insurance in China.

In summary, Fintech applications make *XHB* a standardized platform, offering the flexibility to implement the specific rules and restrictions in the claim process. With less human inputs than traditional insurance, the platform operates more efficiently and generates lower claim adjustment costs, potentially appealing to individuals seeking low-cost protections.

D Proofs

D.1 Deriving *XHB*'s budget line

The line *EX* is the *XHB*'s breakeven line. As plotted in Figure 6, 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 $\frac{\pi^x_t - k^x}{\pi^x_t}$.

Recall that $\pi^x_t = p^x_t K^x(1+\lambda^x)$ (Eq. (1)) and insert it in the expression for the slope of *EX*. This gives us the following:

$$\frac{\partial W_2}{\partial W_1}|_X = 1 - \frac{1}{p^x_t(1+\lambda^x)}$$

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

Thus, we prove Eq. (10).

D.2 Deriving the Indifference Curve

Assume that the original wealth levels in loss and no-loss states are respectively W^1_1 and W^1_2. It is changed to W^2_1 and W^2_2. The indifference curve can be expressed as:

$$[1-p^j]u(W^1_1) + p^j u(W^1_2) = [1-p^j]u(W^2_1) + p^j u(W^2_2)\, where\, j = l, h \tag{C1}$$

Slightly adjusting the above expression, we have

$$\frac{\Delta u^j(W_2)}{\Delta u^j(W_1)} = -\frac{1-p^j}{p^j},\, where\, j = l, h \tag{C2}$$

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 insurances in the future?
   - Yes
   - No
   - Uncertain