Efficiency and Fairness of Online Mutual Aid: A New Form of Risk Sharing

Abstract: The online mutual aid (MA) is a decentralized form of risk-sharing that can find its roots in ancient civilizations but has been recently re-discovered and empowered by internet technology. Since its start just over three years ago, the top 10 mutual aid platforms alone have amassed over 350 million users. Despite the significance of this market development, there has been scarce academic literature on its theoretical foundation and current practice. This study first provides a rigorous examination of the underpinning theory and concludes that MA model's low coverage cost is achieved through an effective peer-to-peer cost-sharing mechanism. In addition, as most MA plans differentiate members only by gender and age group of large bandwidths, our empirical analysis shows that the cost allocation in practice often lacks actuarial fairness and confirms the existence of adverse selection.

Keywords: Mutual aid, peer-to-peer insurance, InsurTech, risk sharing

JEL Classification: G14, G22, I13

1. Introduction

The insurance technology industry, often referred to as InsurTech for short, is on the rise worldwide[1]. A variety of innovative business models equipped with advanced

[1] In 2018, the global revenue of the InsurTech industry reached 530 million US dollars (Thakor, 2020; Research and Markets, 2018).

technologies have emerged with the potential to disrupt the traditional insurance industry (International Association of Insurance Supervisors, 2017). Enabling technologies include blockchain, artificial intelligence, Internet of Things (IoT), and big data, etc. (Anish Raj and Prasad Joshi, 2018; Institute of International Finance, 2016; World Bank Group, 2018). The utilization of emerging technology resolves major challenges in the current insurance industry and improves efficiency in underwriting, risk pooling and claims management. For instance, blockchain is a technology that allows transactions and data to be recorded, stored and synchronized across a distributed network of users. The blockchain technology has found many applications in the insurance industry that addresses information asymmetry and the lack of transparency in traditional insurance models. In particular, some applications can be applied to risk sharing and internet-enabled mutualization (Mainelli, M., & von Gunten, C., 2014).

Looking beyond the insurance industry, sharing economy is fast evolving and expanding in a wide range of industries, including transportation, hospitality, financial services, etc. Sharing economy refers to peer-to-peer based activities of acquiring, providing, or sharing access to products and services (Einav, et. al., 2016).[2] In contrast with the traditional server-client model in which a central authority provides services to all, the peer-to-peer model enables the exchange of goods and services among users without the heavy cost of intermediaries. The rise of sharing economy brings a new channel for individuals to share their underutilized assets and receive rewards. For example, Uber and Airbnb are two household names in sharing economic businesses. Uber connects drivers with personal vehicles with customers needing rides and Airbnb allows hosts to offer their properties to travelers for rent. In the recent decade, the rise of peer-to-peer lending is an example of sharing economy reaching the financial sector. As an alternative method of financing, P2P lending enables individuals to obtain loans

[2] Refer to https://www.investopedia.com/terms/s/sharing-economy.asp and https://en.wikipedia.org/wiki/Sharing_economy for definitions of sharing economy.

directly from other individuals without going through a bank.

With risk diversification and sharing at its core, insurance business is a natural ground for the development of sharing economy. Many innovative InsurTech business models brought out new forms of risk sharing based on the sharing economy principle. Online mutual aid (MA) and peer-to-peer (P2P) insurance provide testimonies to the successful merging of concepts from InsurTech and sharing economy (Figure 1). Internet technologies and ecosystems enable online platform users to self-organize and self-service with peer-to-peer financial arrangements. Such new risk sharing models remove or reduce the role of traditional insurers and hence cut down the cost of intermediaries. We provide both theoretical proof and empirical evidence on the cost reduction of MA in comparison with commercial insurance.

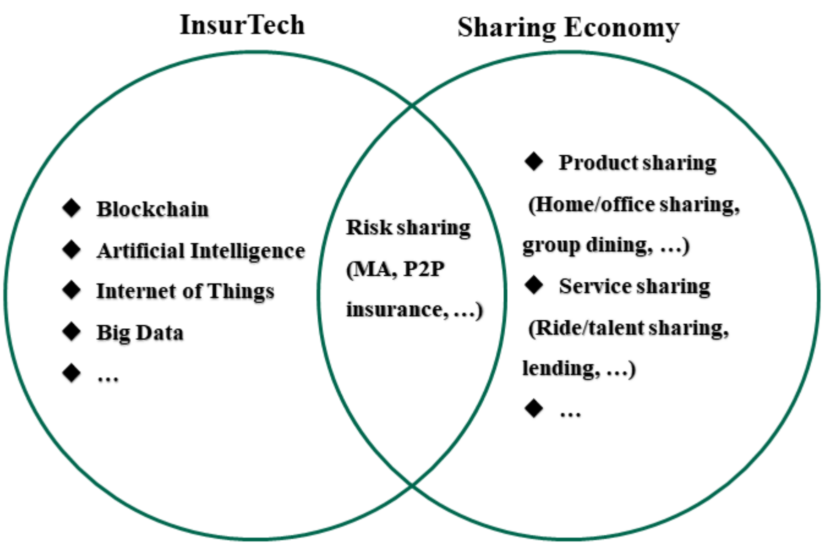

Fig. 1. InsurTech and sharing economy

MA is a network joined by members facing a common risk, typically healthcare risk, that enables them to share financial costs. Every member receives the promise of mutual aid in the case of covered contingencies and commits to carry the cost of losses from other members within the risk pool. For example, if an MA plan has one million members and provides the benefit of 300,000 CNY for the ill member diagnosed with a critical illness, each member is required to pay 0.3 CNY. Early forms of MA existed long before modern insurance, such as the burial society in Ancient Rome to cover the funeral expenses of a deceased member within a local community. In today's internet era, online MA platforms can reach much larger online communities without geographic limitations and enforce a more effective loss sharing mechanism via electronic payments. As of January 2020, the top 10 MA platforms in China have amassed over 300 million users and offered coverages for over 100 critical medical conditions and illnesses.[3]

In contrast with MA, P2P insurance is another internet enabled InsurTech model prevailing in Europe and the United States (Moenninghoff and Wieand, 2013).[4] P2P insurance typically facilitates risk sharing in a small group of family members and friends. All family members and friends contribute to a common fund, a portion of which is used to buy an insurance policy with a high deductible. Claimants' losses are first paid out of the common fund. Any excessive amount beyond the capacity of the common fund would be paid by the insurer. Depending on the actual losses, members may receive a refund of the remaining balance in the common fund. Since the deductible portion of the insurance is covered in a peer-to-peer fashion, this business model also achieves a lower cost than conventional commercial insurance.

There are several main differences among conventional insurance, P2P insurance and mutual aid. First, conventional insurance and P2P insurance require *ex ante* payments, whereas MA cost sharing is typically done *ex post*. It is often the case that members join an MA platform without any initiation fee. The cost of coverage only occurs when there are actually benefit payments to claimants within the community. This ex-post mechanism makes MA fundamentally different from conventional insurance and P2P insurance, as the funding of coverage arises after losses occur and is

[3] As MA platforms are not qualified insurance companies, they are not yet under the supervision of the insurance regulatory authorities. Therefore, the majority of MA platforms name their products MA plans instead of MA insurance.

[4] Friendsurance, an insurance technology company based in Berlin, was the first P2P insurance platform. There are now dozens of P2P insurance platforms worldwide.

guaranteed to be sufficient without any reserve or capital. This explains why no risk pricing in the classic sense is needed for MA and the cost of regulation compliance can be reduced. However, the self-sufficiency of MA funding comes at the expense of members' uncertain payments. In contrast with fixed premium required in conventional insurance, the cost sharing in MA can vary from period to period. The more losses occur, the higher payment is required for each member. Nonetheless, this issue is addressed in practice by most MA platforms imposing limit on mutual aid cost-sharing.

Second, although both MA and P2P provide lower coverage costs than conventional insurance, they achieve the cost reduction by different means. P2P insurance commonly runs a risk pool for property risk, and its members are usually connected through social relations (e.g., relatives and friends). The social interconnectedness of policyholders helps reduce moral hazard as members watch out for each other and share the financial burden of losses with each other. The cost of insurance fraud is also heavier with policyholders' own social network than it is only with an emotionally detached insurer. However, in contrast to MA coverage on the scale of million members, the size of P2P relative-friend community is rather limited. MA plans can take advantage of the economy of scale and the law of large numbers, which are unavailable for P2P insurance model. In this sense, the MA model is similar to conventional insurance, whose quintessence is the pooling of risks through a large number of policyholders.

This paper contributes to the current FinTech and InsurTech literature in three ways, which are summarized as follows.

(1) This study develops a theoretical framework for understanding MA models. As pointed out by Kaffash et al. (2020), research on how InsurTech improves the efficiency of insurance market is scarce. Even less is known about mutual aid, which is a fairly recent InsurTech phenomenon. To the best knowledge of the authors, this is the paper in the literature to systematically exploit MA business models. In this paper, we examine why MA coverage can be provided at a lower cost than conventional insurance and contribute to the existing literatures on risk-sharing schemes (Rothschild and

Stiglitz, 1976; Doherty and Tinic, 1981; Niehaus, 2002; Chen et al., 2021). To analyze this, we build the quantitative framework for comparing the efficiency of MA and conventional insurance models. Our theoretical analysis finds that the low-cost advantage of MA model hinges on the cost-sharing mechanism under which no risk or only the tail risk is undertaken by platform operators.

(2) The concept of relative fairness is proposed and analyzed for MA in this paper. In contrast with absolute fairness in traditional actuarial literature, relative fairness is a mechanism for risk sharing that prevents some risk groups from inadvertently benefiting from other groups' losses. The formulation of the concept enables us to study the fairness of MA model and to test the fairness of existing business models in the market. Our empirical analysis suggests that there exist fairness issues with many current MA plans in the market. This finding is important, as it partly responds to the ongoing debate in China's insurance market regarding whether MA should be overseen by the insurance regulator and whether actuarial services are needed for MA business models.

(3) Economic consequences of MA unfairness are considered with both theoretical analysis and empirical evidence. The problem of adverse selection has long been investigated in the context of conventional insurance, for which differential pricing provides an effective solution (e.g., Rothschild and Stiglitz, 1976; Cutler and Reber, 1998; Dionne et al., 2001; Finkelstein and Poterba, 2004; Cohen and Siegelman, 2010). In this paper, we explore the link between the unfairness of MA rules and the adverse selection. Using data from a leading MA platform, we find evidence that the risk groups treated less fairly by MA plans show a higher tendency to exit the MA plan. This finding is of great significance as it may suggest a path for MA platforms to ensure fairness among different risk groups and make their business models economically viable in the long run.

The remainder of the paper proceeds as follows. Section 2 introduces details of the online MA platforms in China. Section 3 develops the theoretical framework to compare conventional insurance and MA coverage models, as well as their fairness and efficiency. Section 4 is dedicated to the discussion on the efficiency of two models. Section 5 analyzes the fairness of two models and provides an empirical analysis. The paper ends with a summary of main findings in Section 6.

2. Online mutual aid

2.1 Rise of online MA platforms

Since their emergence, as noted earlier, MA platforms have attracted and covered a considerable number of members (Figure 2). By the end of 2019, the total number of members of MA platforms in China had exceeded 300 million.[5] The development of MA industry went through three phases over the last few years (See Appendix A1). Currently, Xianghubao and Shuidi are the two largest MA platforms in China, with more than 100 million and 80 million members, respectively (Table A1 in Appendix).

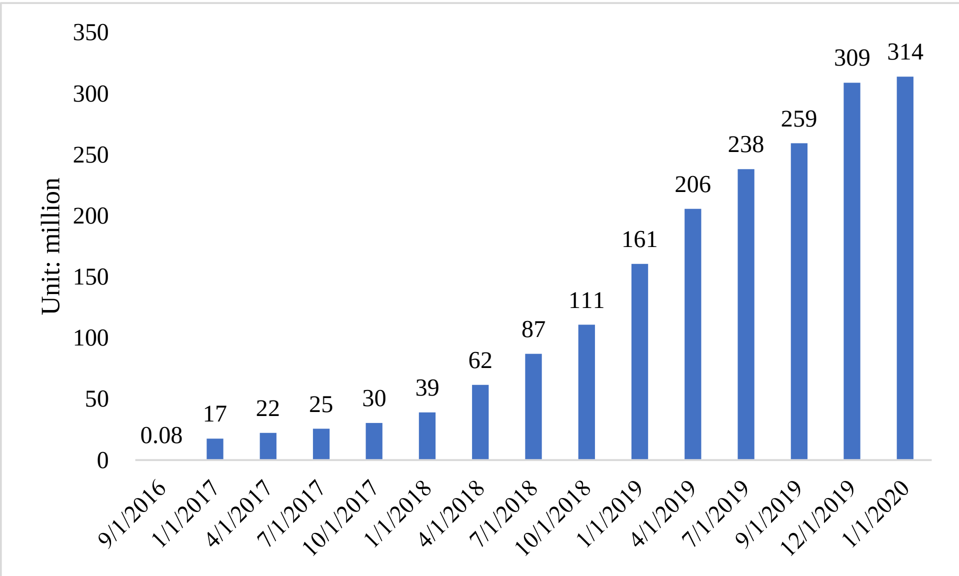

Fig. 2. Memberships of MA platforms in China

The majority of MA plans available in the market provide critical illness (CI)

[5] This figure is the total number of members on the main online MA platforms. However, an individual may participate in multiple platforms.

coverage, especially cancer.[6] Almost all such MA plans cover at least 25 medical conditions identified by the Insurance Association of China and many include dozens of other CIs into their coverage. When a member is diagnosed with a CI, he or she receives a lump-sum payment corresponding to the MA benefit and the remaining members share the costs of this loss event equally. To ensure that members participate in this sharing principle, MA platforms require them to pay a minimum deposit into their personal accounts in advance, usually 10 CNY. In terms of the CI benefits funded from all MA platforms, the MA industry has become an influential role in providing CI coverage in China. By the end of 2019, more than 40,000 members diagnosed with CIs have received MA benefits and the cumulative amount of claimed benefits has reached more than 6 billion CNY. In 2019, the total occurred losses covered by MA industry is 4.7 billion CNY, roughly equivalent to 50% of that of CI insurance providers in China.[7] By rough estimation,[8] CI benefit payment provided by MA industry currently accounts for 5% of that of the commercial CI insurance market. This ratio is projected to double in 2020 and reach 10% of whole commercial CI insurance market.

There are two major reasons for the popularity of MA platforms. First, the online MA coverage fills the vacuum in the market for supplementary healthcare coverage beyond the national public healthcare program, which merely provides coverage to meet basic healthcare needs (See Appendix A2). Second, currently there is no regulation for entering into MA industry in China. The regulator has been hesitating to introduce MA regulation due to the lack of comparable experience in other countries. By contrast, the insurance market is heavily regulated with no new insurance license issued over the past few years. Many technology firms with the aspiration to enter the insurance market found the MA as a shortcut to enter the market.

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[6] Several MA platforms offer MA coverage plans for accidental death, but the member scale is much less than under CI coverage plans.

[7] In 2018, the annual claimed CI benefits of Pingan and Taikang insurance, two commercial CI business giants in China, are 10.6 and 9.1 billion CNY.

[8] Due CIRC only reports the annual *claimed health insurance benefits* of whole insurance market, we estimate the *claimed CI benefits* of whole insurance market using the ratio of Pingan (*claimed CI benefits/ claimed health insurance benefits*). By this estimation, the annual claimed CI benefits of whole insurance market in 2019 is around 80-90 billion CNY.

2.2 Mechanism of MA coverage

We shall break down the mechanism and distinctive features of a typical MA coverage plan, which are summarized in Figure 3. The differences between MA and conventional insurance are further listed in Appendix A3.

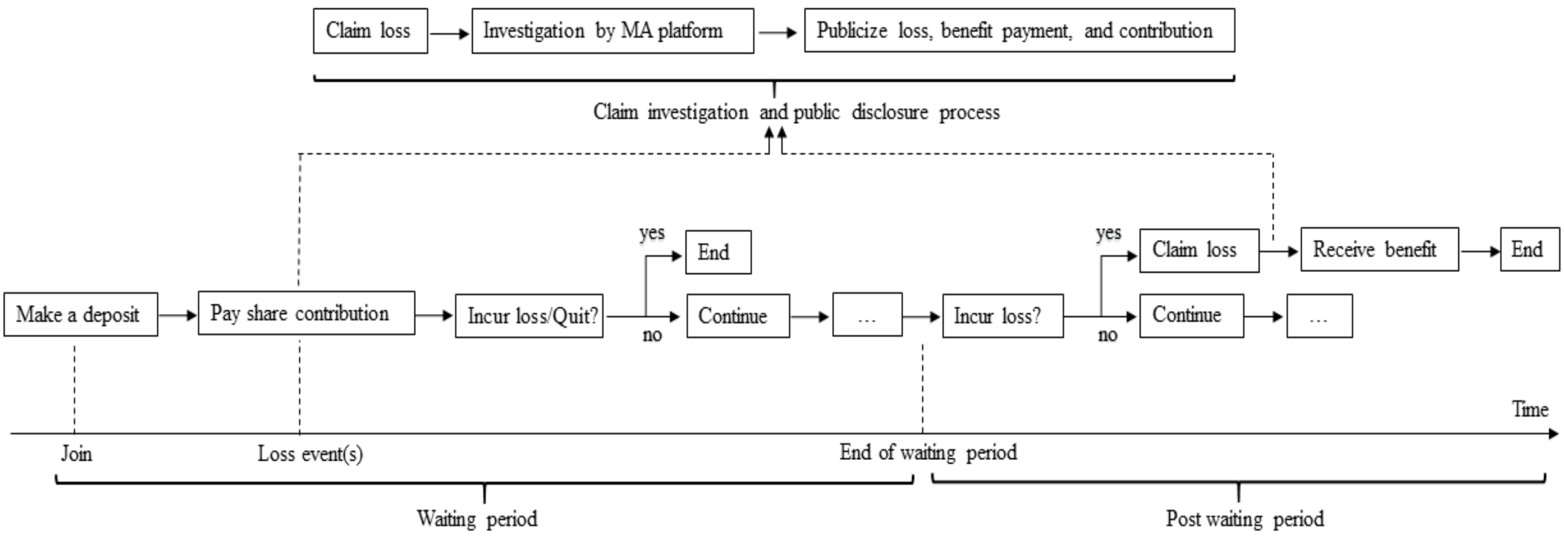


Fig. 3. Mechanism of MA coverage plan

(Membership) Each member is eligible for benefit when diagnosed with critical illness and is obliged to share the cost of coverage at the end of each period within the same group under MA rules. Many MA platforms require members to make a deposit upon entrance, e.g. usually 10 CNY, although it has become increasingly common that no initiation fee is required. After all claims are validated and approved, MA operators announce the total amount of benefit to be paid to claimants and split the cost among all existing members. The shared cost is typically deducted from each member's account. The deposit is used to ensure members' ability to pay for their shares. To maintain valid membership, members are required to honor their commitments for cost sharing and top up their personal account above a minimal level.

(Public disclosure) According to MA plan rules, once there are claimed loss event(s) verified by MA platforms after investigation, the information about the loss event(s) such as claimants' diagnosed diseases, benefits and share contribution per member would be publicized.[9]

(Waiting period) In order to discourage enrollment of members with pre-existing medical conditions, MA platforms impose a waiting period before members are eligible for benefits, e.g.180 days. In other words, any benefit claim occurred within the waiting period is considered to be invalid and not covered.

(Risk pooling) Most MA platforms separate their members into different risk pools with a rough classification by age, such as the youth pool (age 0-39), middle age pool (age 40-59), and old age pool (age 60-70). A risk pool is often considered as an independent MA plan. Members of a same MA plan share occurred losses equally, regardless of their age, sex, or participating time. Thus, a member still in his/her waiting period also needs to pay the share contribution. To maintain fairness among different ages, MA plan rules roughly differentiate the MA benefit, the amount a member receives once he or she makes a legitimate claim. Normally, older members receive lower MA benefits.

(Maximum out-of-pocket cost) To make the plan affordable even in case of severe losses, most plans set limits on members' maximum contribution for each incident or yearly maximum out-of-pocket cost. For example, Shuidi MA platform limits a member's cost per claim to 3 CNY. Xianghubao MA plan requires members to pay no more than 188 CNY per year and any excessive amount to meet funding target will be covered by the platform.[10]

(Management fee) To compensate for overheads and administrative costs, most MA platforms charge management fees as a fixed percentage of benefit amount,

[9] Some MA platforms regularly publicize the collected loss events during the time interval, e.g. per half or one month.
[10] In April 2019, Xianghu Insurance changed its name to Xianghubao Mutual Aid and stated that the maximum share for members would not exceed 188 CNY from January 1 to December 31, 2019. Any excess amount would be paid by Ant Financial.

typically set at 8%. As some platforms limit out-of-pocket pay and are hence responsible for the excess, the cost of tail-risk undertaking is implicitly embedded in the management fee.

2.3 Mutual aid puzzle

The puzzle to many observers of the mutual aid development is why mutual aid coverage is much cheaper than commercial health insurance. For example, a typical one-year critical illness policy provides similar lump-sum cash payment to mutual aid if the policyholder is diagnosed with an illness on an approved list. The annual premium for the benefit of 300,000 CNY ranges between 2,000 and 3,000 CNY (Figure 4, Table A2). By contrast, the annual cost of comparable MA plan is typically less than 150 CNY per person (Figure 4, Figure A2, Table A3). Understanding the reasons for MA aid's low-cost advantage is important, as it would shed light on the discussion of whether the attractiveness and business model of MA platforms is sustainable.

There are many conjectures on the drastic difference in cost between healthcare insurance and mutual aid. First, some argue that the CI morbidity rates adopted by insurance companies are vastly over-estimated. As heavily regulated as China's insurance industry, the ratemaking of CI policies by all insurers is universally based on the regulator's standard morbidity table. The mutual aid is based on ex post payments, which does not require actuarial assumption. The cost of coverage reflects the true morbidity rates. Second, some believe that MA platforms have not yet reached their steady state with regularly occurring claims. Most MA platforms require a waiting period of 180 days before members are eligible for benefit claims. In early months, a large number of new members join the platforms to share costs without any benefit claims over the waiting period. Thus, the shared cost decreases as the platform grows rapidly in the number of customers. However, this "growth dividend" cannot fully explain the low MA coverage cost, since the CI plan coverage costs of MA platforms with low member growth rate, whose members reach a stable level, maintain lower than similar commercial insurance (see Table A3 and Figure 4).

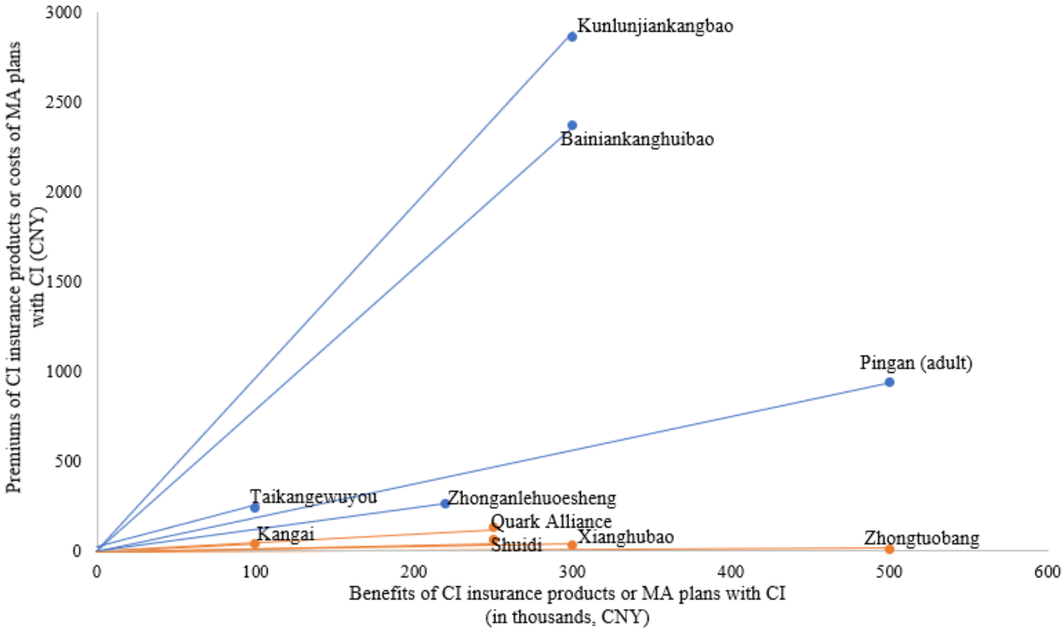


Fig. 4. Comparison of premiums (costs) and benefits between CI insurance products (in blue) and MA plans with CI (in orange)

2.4 Fairness and adverse selection

In the traditional insurance market, differential pricing is a mechanism used to reduce adverse selection. Rothschild and Stigliz (1976) provided theoretical analysis on how insurance companies could provide contracts with varying premiums and coverages to differentiate different risk groups. Further work on differential pricing and adverse selection in various insurance markets can be found in Wilson (1977); Riley, (1979); Cutler and Zeckhauser, (1998); Riphahn et al., (2003); Finkelstein and McGarry, (2006); Hagedorn, et al., (2010) and Hansen et al., (2014).

The ex post mechanism of MA is not in conflict with differential pricing. As we shall see in several specific examples of existing policies, many MA plans offer varying benefits or cost sharing coefficients for different age cohorts. This is a clear indication of efforts to ensure certain extent of fairness as a way to discourage adverse selection and to avoid giving the impression that low-risk members subsidize high-risk ones.

However, there has been no previous literature to analyze the fairness of differential ex post payments. Most existing MA plans use broadly defined age groups and use ad-hoc basis for differential treatments. For instance, most platforms offer policies to three age groups: youth, mid-aged, and old-aged groups. All members share mutual aid costs equally, but the three groups are eligible for benefits in proportion to 3:2:1.[20] As shown later in the empirical study, the morbidity rates of the three age groups are not in proportion to 3:2:1 and hence the setting lacks rigorous theoretical basis. As shown in Tables A4 and A5, the cost difference between conventional insurance and MA plans for the middle-aged is much lower than that of the elderly, which to some extent shows that middle-aged groups subsidize the costs of the elderly group. We find it critically important to address the fairness issue of mutual aid as an innovative risk management mechanism and its long-term impact on adverse selection and the sustainability of this newly emerging market.

3. Theoretical framework

3.1 Risk sharing mechanisms

To ensure fair comparison, we consider traditional insurance and mutual aid models with lump-sum benefits. Specifically, each claimant receives a contractually specified amount of lump sum benefit regardless of actual financial loss. Note that such an assumption is consistent with the market practice and the lump sum benefit is typically set at a competitive level from which a critically ill member is unlikely to make a profit. Owing to its simplicity, the proposed framework considers only a one-period static pool of participants with no additional entrance or exit.

Throughout this paper, we consider a group of n individuals with the same cause of concern for financial losses numbered $1,2,\ldots,n,$ such as CI risk or accidental death risk. The service provider, whether insurer or MA platform, is numbered by 0. We assume that participants' claims are independent of each other. The risk pool is homogeneous if the probability of loss is identical for all peers. Otherwise, the pool is considered heterogeneous.

Consider a one-period setting: the insurance period begins at time 0 and ends at time 1. Individuals' payout cashflows to the provider happen at time 0 or 1, depending on the mechanism (ex ante or ex post payment). The indicator I_i indicates the i -th individual's survivorship at the end of the insurance period. If the individual survives (with a survival probability ofp_i), we consider him/her as a survivor and write $I_i = 1$. Otherwise, the individual is known as a claimant and we set $I_i = 0$ (with a loss rate of $q_i = 1 - p_i$). Figure 5 shows the general risk sharing mechanism. The sample space of all scenarios is denoted by Ω, with each possible outcome state denoted by $w = (I_1, I_2, ..., I_n)$. At time 1, a claimant is entitled to a fixed benefit payment of b_i (cashflow from the provider to the claimant). A survivor might or might not receive cashflows (refunds) from the provider, depending on both the mechanism and outcome state$w$.

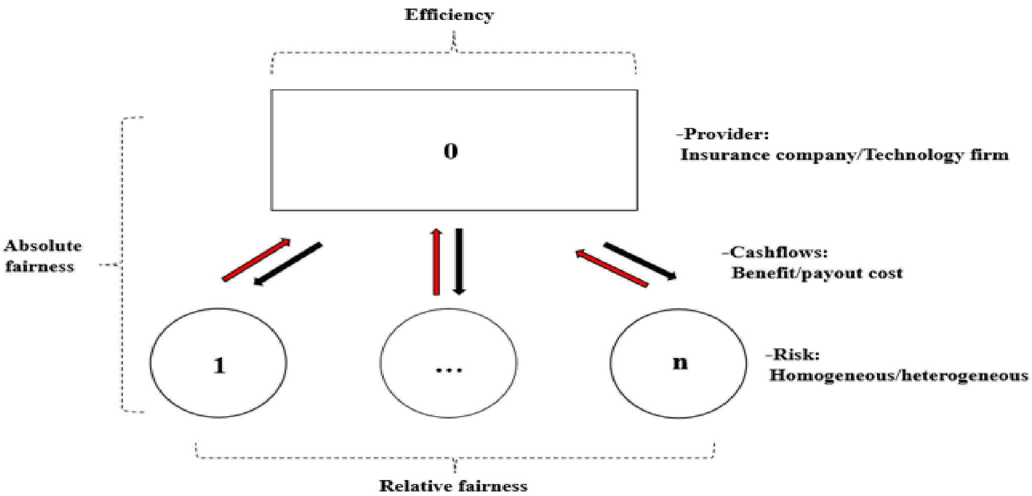


Fig. 5. General risk sharing mechanism

In the following, we introduce the risk sharing mechanism of the conventional insurance and MA coverage.

3.1.1 Conventional insurance

A policyholder pays the premium to the insurance company at time 0 and transfers the risk to the insurer. The premium is determined in advance and includes the insurer's profit margin and regulatory compliance cost. In return, the policyholder receives the benefit amount at time 1 if he or she suffers a loss over the insurance period and otherwise receives no payment.

3.1.2 MA coverage

Members join the MA plan at time 0 and are obliged to share costs evenly at time 1. There is a maximum out-of-pocket limit d for each survivor. Hence, the shared cost for each survivor is given by

$$S = \frac{\sum_{i=1}^{n} b_i(1 - I_i)}{N} \wedge d \quad if N > 0,$$

$$S = d \quad if N = 0,$$

where N is the number of survivors at time 1 and $a \wedge b = min(a, b)$.

The MA platform undertakes tail risk, as it offers to pay if members' contributions are insufficient to pay all benefit claims due to the maximum out-of-pocket limit. In return, it charges each survivor an additional fee of π_0. Thus, at time 1, member i

- pays the amount $S + \pi_0$ (the net payout cashflow $C_i(w) = S + \pi_0$) in the case of survival with a survival probability of p_i;
- or otherwise receives benefit b_i (the net payout cashflow $C_i(w) = -b_i$) with a loss rate of q_i.[11]

The platform receives a total of $\sum_{j=1}^{n} I_j \pi_0$ and faces a possible payout of $(\sum_{j=1}^{n}(1 - I_j)b_j - Nd)_+$, to make up the difference between total claim and members' total contributions.

3.2 Expected net return and absolute fairness

We denote the net financial return of individual i under outcome state $w \in \Omega$ by

$$R_i(w) = b_i(1 - I_i) - C_i(w),$$

where $C_i(w)$ is the net payout cashflow of i. Then, the net financial return of the

[11] Both q_i and p_i here are objective probabilities like the statistics (based on e.g. age and gender) provided by actuary associations.

provider, $R_0(w)$, is

$$R_0(w) = \sum_{i=1}^{n} C_i(w) - \sum_{i=1}^{n} b_i(1 - I_i).$$

In this simplified model, it is straightforward to verify that the ***zero-sum condition*** holds (i.e., the sum of the net return of all individuals and providers is zero):

$$R_0(w) + \sum_{i=1}^{n} R_i(w) = 0, \text{ for any } w \in \Omega.. \tag{1}$$

This means that the coverage model works as a system redistributing cashflows, whether the individuals or provider make profit or suffer loss depends on the specific outcome state $w \in \Omega$. Clearly, they make profits in some outcome states $w \in \Omega$, while it suffers losses in others.

Thus, the concept of financial return of both provider and individuals relies on the expectation of net return under all states $w \in \Omega$. We define the ***expected net return*** **(ENR)** as the expected net returns of all possible outcomes. The ENRs of the provider and individual are denoted by $E[R_0]$ and $E[R_i]$.

Definition 1 A coverage model is said to be absolutely fair to the provider if $E[R_0] = 0$ and it is said to be absolutely fair to any individual i if $E[R_i] = 0$.

In an absolutely fair coverage model, the ENR of any individual and provider is zero. Lemma 1 shows that the expected coverage cost of any absolutely fair coverage model is equivalent.

Lemma 1 In an absolutely fair coverage model, any individual's expected coverage cost equals his or her expected benefit $q_i b_i$.

The proof of Lemma 1 is implied immediately by the individual's absolute fairness condition. Combining the zero-sum condition (1) and absolute fairness conditions leads to its proof.

In practice, because of administrative costs and profit margins, we often have $E[R_0] > 0$. Consequently, the sum of individual's ENR is negative, $\sum_{i=1}^{n} E[R_i] < 0$. Thus, the following Lemma 2 shows that the absolute fairness of a coverage model is systematic.

Lemma 2 Consider a coverage model:

• For a group of homogeneous individuals, the coverage model is absolutely fair to the provider if and only if it is absolutely fair to any individual,

• For a group of heterogeneous individuals, if the coverage model is absolutely fair to any individual, then it is absolutely fair to the provider.

The proof of Lemma 2 is straightforward. In both the homogeneous and heterogeneous scenarios, the absolute fairness condition of the provider can be implied by that of individuals. However, when the provider requires a profit margin, then the coverage model is no longer fair to all individuals. For instance, under conventional insurance the policyholder's ENR is negative.[12]

3.3 Efficiency and relative fairness

To begin with, we introduce a measure to compare the ***efficiency*** of coverage models. Under the premise that two models provide the same coverages, it is intuitive that the model with higher overall individuals' ENR has higher efficiency. Thus, we employ the individuals' ***total ENR***, termed as $\sum_{i=1}^{n} E[R_i]$, to measure the efficiency. Due to the zero-sum condition, we further know that $\sum_{i=1}^{n} E[R_i] = -E[R_0]$. As the model with a higher total ENR value has a higher coverage efficiency, then a more efficient model allows a lower $E[R_0]$.

Definition 2 Considering two different models with same coverages, plan A is said to be more efficient than plan B if and only if

$$E[R_0^A] < E[R_0^B],$$

where $E[R_0^A]$ and $E[R_0^B]$ are the provider's ENR under plans A and B, respectively.

Now, we introduce the meaning of relative fairness for a coverage model with

[12] An insurance market still exists because the policyholder's utility of having insurance coverage is higher than that without insurance.

heterogeneous risks. Given that the provider is profit-driven, the relative fairness means the model allows no group to take advantage of any other.

Definition 3 A coverage model is said to be relatively fair to individuals if it satisfies $E[R_i] = E[R_j]$ for any $i, j = 1,2,\ldots,n$.

Under the relative fairness condition, any individual faces the same amount of expected losses. In a relatively fair MA model, no group profits at other groups' expense. The existence of relatively fair rule is important for MA model dealing with heterogeneous risks to mitigate adverse selection problems.

Keep in mind that the ENR, $E[R^i]$, can be viewed as a measure of the plan's attractiveness to the group i when the relative fairness condition no longer holds. The plan is more (less) favorable to the groups with higher (lower) ENRs. Under the MA model, the ENR of group i is

$$E[R^i] = q^i b^i - p^i(E[S] + \pi_0)$$
$$= p^i(t^i - E[S] - \pi_0),$$

where $t^i = \frac{q^i b^i}{p^i}$. Therefore, for any group i , the t_i value increases with the benefit. The higher the t value, the more favorable the plan is to a group.

Lemma 3 In a relatively fair MA model with a fixed ENR, $E[R^i] = Const,$ for all heterogeneous groups,

(i) t_i decreases with the loss rate q^i if $Const < 0$;

(ii) t_i increases with the loss rate q^i if $Const > 0$;

(iii) t_i is constant for all groups if $Const = 0$.

4. Efficiency of MA model

In this section, we investigate the efficiency of MA model. To understand its low-cost advantage, we adopt conventional insurance as the benchmark. We consider the homogeneous risk case as the actuarial ratemaking of conventional insurance relies on pooling a large number of independent and identically distributed (i.i.d.) individuals.

Any individual's survivorship indicators I_i , $i = 1,2, \dots, n,$ are homogeneous and i.i.d. variables. The probability of loss for each individual is denoted by q. For brevity, hereafter we denote the Bernoulli variable $N \sim Bin(n, p)$ as the number of survivors at time 1. Moreover, the homogeneous individual's benefit is b.

Under the homogeneous risk setting, the total ENR becomes $\sum_{i=1}^{n} E[R_i] = nE[R_i]$, where $E[R_i] = bq - E[C]$. Hereafter, we call $E[C]$ as the ***expected coverage cost*** **(ECC)**, which is the individual's expected payout for obtaining the coverages. Since the provider pursues profit, the $E[C]$ of both conventional insurance and MA models are higher than qb. Thus, individual's ECC can be represented as$E[C] = qb + \frac{P}{n}$, where$P$is the provider's profit.

Therefore, under the homogeneous setting, the coverage model's efficiency is equivalent to be measured by $E[C]$. That is, a higher $E[C]$ indicates a lower model efficiency. In Section 4.1 and 4.2, we investigate the ECCs of conventional insurance and MA models, followed by a numerical comparison in Section 4.3.

4.1 Conventional insurance

At the time of purchase (time 0), an insurer receives a total premium of $n\pi$ from n policyholders, where π is the premium of each policy. At time 1, it pays out the claimed losses, $(n - N)b$. Now, we calculate the premium π .

As the insurance industry is regulated to ensure its financial solvency and protect the interests of policyholders, the cost of solvency capital is implicitly embedded in the premium. We denote the solvency capital required to underwrite the risk payoff $(n - N)b$ as $\rho[(n - N)b]$, where ρ is the risk measure. Therefore, without considering the profit margin, the premium of each policy is

$$\pi = \frac{1}{n}[E[(n - N)b] + r\rho[(n - N)b]],$$

where r is the cost-of-capital rate.[13]

Then, we further take into account the profit margin charged by insurance companies. The total premium is

$$\pi^I = \frac{1+\alpha^I}{n}[E[(n-N)b] + r\rho[(n-N)b]], \tag{2}$$

where α^I is the certain profit margin rate. Clearly, the policyholder's ECC equals

$$E[C^{Ins}] = qb + \alpha^I qb + \frac{1+\alpha^I}{n}[r\rho[(n-N)b]], \tag{3}$$

and thus

$$E[R_i] = -\alpha^I qb - \frac{1+\alpha^I}{n}[r\rho[(n-N)b]] < 0.$$

Moreover, the absolute value of n insureds' total ENR equals the expected gain of the insurance company, that is

$$E[R_0] = n\alpha^I qb + (1+\alpha^I)[r\rho[(n-N)b]].$$

4.2 MA coverage

For an MA plan with a group of homogeneous members, we first consider the net financial return of the MA platform. Its net return can be represented as

$$R_0(N) = N \cdot \pi_0 - (b(n-N) - Nd))_+$$
$$= \begin{cases} N \cdot \pi_0, & N > \dfrac{bn}{b+d} \\ N \cdot \pi_0 - (b(n-N) - Nd), & N \le \dfrac{bn}{b+d} \end{cases},$$

where $N \sim Bin(n,p)$ is the number of survivors. That is, the MA platform's net return depends on the survivorship outcome of members.

The break-even additional fee π_0 can be implied by the MA platform's absolute fairness condition,

$$np\pi_0 - E[(b(n-N) - Nd)_+] = 0,$$

which leads to $\pi_0 = \frac{1}{np}E[(b(n-N) - Nd)_+]$. As π_0 is absolutely fair to the

[13] See Braun et al. (2015) for a similar approach to calculate the insurance company's premiums and returns.

provider and all members are homogeneous, by Lemma 2 it also satisfies $qb - p(E[S] + \pi_0) = 0$, where the survivor's shared cost equals $S = \frac{b(n-N)}{N} \wedge d$ and $b > d$.

Unlike insurance companies, MA platforms are unregulated and thus face no regulatory cost. Consider they still charge a profit margin α^M and hence the total fee $\pi_0^{MA} = (1 + \alpha^M)\pi_0$. The ECC of members i is given by

$$E[C^{MA}] = p(E[S] + \pi_0^{MA})$$

$$= qb + \frac{\alpha^M}{n} E[(b(n-N) - Nd)_+], \tag{4}$$

and $E[R_i] = -\frac{\alpha^M}{n} E[(b(n-N) - Nd)_+]$.

Theorem 1 If $\alpha^M = \alpha^C$, the MA model is more efficient than the conventional insurance.

The proof is in the Appendix A4. Theorem 1 implies that the cost advantage of MA coverage comes from the cost-sharing mechanism. As stated above, both MA platform and commercial insurer make profits from their underwritten liability. By contrast, the profit requirement of MA platform is less than commercial insurer as it only underwrites the tail risk.

4.3 Numerical comparison

In this section, we provide a numerical illustration to analyze the ECC of the commercial insurance and MA models. We investigate and compare $E[C^{Ins}]$ and $E[C^{MA}]$ of CI coverage for 25-year-old men. In particular, we consider a benefit of 300,000 CNY covering the 25 CIs listed by the CIRC. We assume that the morbidity incidence rate of the insured group follows the morbidity rate table (0.067%).

Figure 6 compares the ECCs of the commercial insurance and MA models. In this illustration, we assume that the profit margin rate of the MA is $\alpha^M = 20\%$ as a reward for undertaking tail risk. The MA coverage's share limit is$d = qb$. Moreover, a 40% profit rate is adopted for conventional insurance, as its operations and sale costs are much higher. Here, we adopt the Value-at-Risk measure with a 99.5% percentile and a cost of capital rate $r = 6\%$ as the solvency capital risk measure according to the requirement of Solvency II.

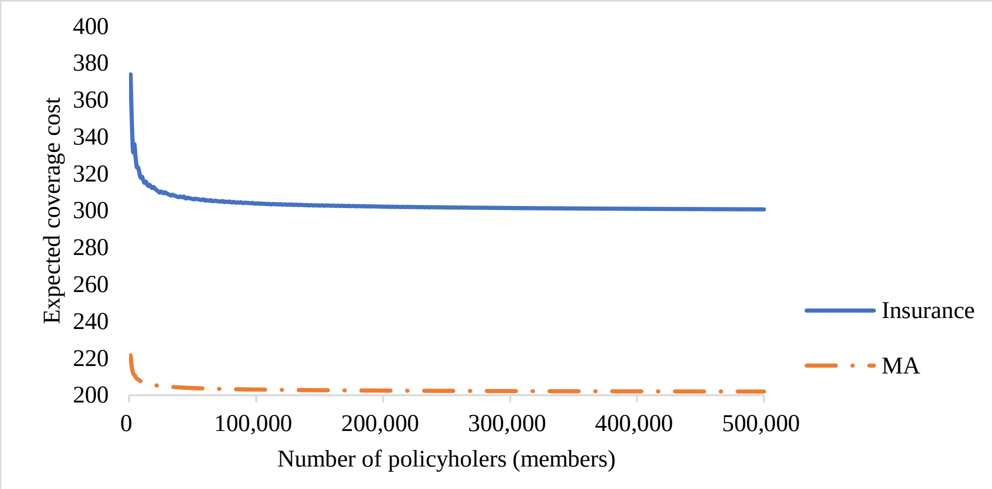


Fig. 6. ECCs of conventional insurance and MA coverage models

Figure 6 shows that ECCs decrease to a steady state with the growth of membership. This is expected as the law of large numbers dictates the average cost for a large pool. The cost of MA coverage is lower as it charges a lower profit requirement.

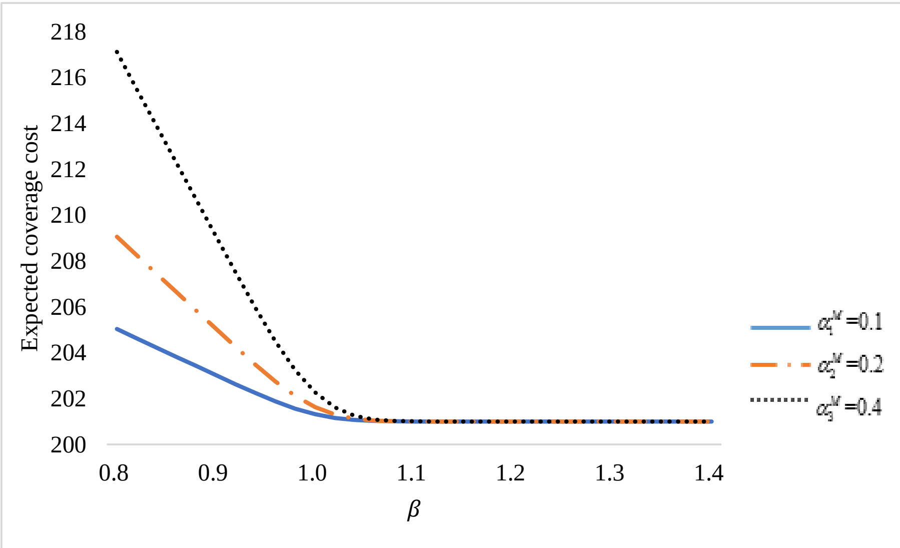


Fig. 7. ECCs of MA coverage with different profit requirements

In addition, we set the number of members as 100,000 and assess the effect of the promised upper limit d on MA coverage cost C^{MA}. As we consider $d = \beta \cdot qb$, the upper limit is measured by and increasing with β. Figure 7 shows the decreasing relationship between the MA's $E[C^{Ins}]$ and the upper limit d. Meanwhile, the larger profit requirement α^M leads to higher costs, however, their differences diminish as d increases. The result suggests that the tail risk underwritten by MA platforms is sufficiently low for larger upper limit (three lines merges), because the MA platform only undertakes the liability when member's payment exceed the upper limit d.

5. Relative fairness of MA model

Gathering a group of completely homogeneous policyholders is unlikely in practice. The MA model is often based a heterogeneous population with different age cohorts (e.g., 20-to-50-year-old groups are in a middle-aged MA plan). This section investigates the relative fairness of MA model involving heterogeneous risks. Assume that there are m homogenous groups, with n_i members in each group, $i = 1,2,\ldots,m$. Members in each group are indistinguishable with identical loss rate q^i and benefit amount b^i, $i = 1,2,\ldots,m$.

5.1 Conventional insurance

Under the equivalence principle, the premium of an insurance policy with a benefit b^i for a policyholder with loss rate q^i is

$$\pi^i = (1+\alpha^I)\left[q^i b^i + \frac{r}{n^i}\rho[(n^i - N^i)b^i]\right],$$

for $i = 1,2,\ldots,m$, where $N^i \sim Bin(n^i, p^i)$, $p^i = 1 - q^i$. Thus, the ENR of the policyholders in age group i equals $E[R^i] = q^i b^i - \pi^i < 0$. Given that $b^i = b$ and $n^i = n$ for $i = 1,2,\ldots,m$, ENRs of old-aged groups are lower than that of young groups as $q^i b^i + \frac{r}{n^i}\rho[(n^i - N^i)b^i]$ increases with age. Therefore, to maintain the relative fairness condition $E[R_i] = E[R_j]$ for any $i,j = 1,2,\ldots,n,$ the provider has to adjust b^i according to a policyholder' age.

5.2 MA coverage

Consider an MA plan offered to the same population with *m* homogeneous groups, where $t^i = \frac{q^i b^i}{p^i}$ is the t value of group i. The following theorem investigates the relative fairness condition.

Theorem 2 When the provider does not require a profit margin, the MA plan is relatively fair if and only if

$$t^i = t^j, \text{ for any } i, j = 1, 2, \ldots, m;$$

When the provider requires a profit margin, the relatively fair MA model satisfies

$$t^i > t^j, \text{ if } q^i < q^j \text{ for any } i, j = 1, 2, \ldots, m.$$

The proof of Theorem 2 is on the basis of Lemma 3 (see the Appendix A4). It implies that when the provider requires a profit margin, the t value of higher risk group should be lower than that of the lower one, in order to maintain relative fairness. This result is consistent with the observation in the market that MA plans offer lower benefits to higher risk groups. Specifically, benefit gradually diminishes with age, as the loss rate increases with age. In Section 5.3, we illustrate that the rules of some representative MA plans violate this rule in practice.

5.3 Examination of MA plan's fairness

In this section, we examine the relative fairness of three representative MA plans in the Chinese market based on the analysis introduced above. As the purpose of this paper is to analyze and critique the current market practice, we conceal the names of these platforms to avoid being interpreted as product reviews.

Table 1

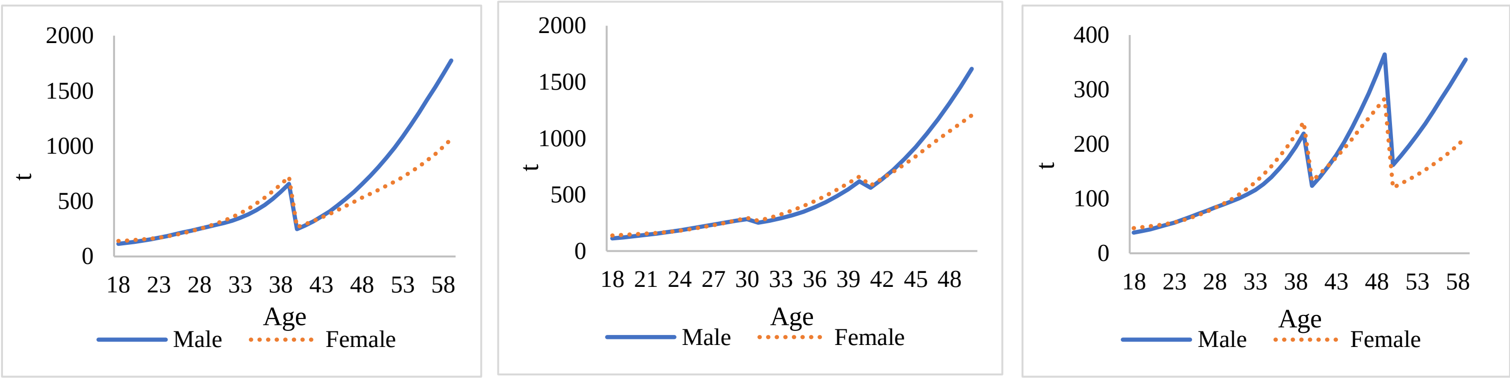
The rules of Plan A, B and C

Age range	Benefit (CNY)	Cost-sharing mechanism
Panel A: Plan A		
Age range	**Benefit (CNY)**	**Cost-sharing mechanism**
0-39 years old	300,000	All members share the costs equally.
40-59 years old	100,000	
Panel B: Plan B		
Age range	**Benefit (CNY)**	**Cost-sharing mechanism**
18-30 years old	300,000	
31-40 years old	250,000	All members share the costs equally.
41-50 years old	200,000	
Panel C: Plan C		
Age range	**Benefit (CNY)**	**Cost-sharing mechanism**
0-39 years old	100,000	
40-49 years old	50,000	All members share the costs equally.
50-59 years old	20,000	

Plans A, B and C are three representative MA plans in the market, which provide similar coverages of CIs. As shown in Table 1, the MA plan rule (called 'rule' for brevity) sets members' benefits according to the age range rather than their specific age. Such rules are clearly not friendly to the youngers of each age group, as they have a relatively low incidence rate of CIs. Moreover, all plans require members to share costs equally regardless of age and gender.

Next, we calculate the t value of Plans A, B and C to analyze their relative fairness for different ages and genders. For any age i, the t_i value measures the rule's degree of favoritism toward this group. In other words, a higher t value for a certain age group indicates that the plan rule is more favorable and vice versa. The calculation of t value is based on the morbidity rate table issued by the CIRC.[14] Figure 8 shows t values of Plans A, B and C.

[14] The morbidity table presents the incidence rates of men and women of all ages. Although MA plans enlarge their covered diseases, the 25 CIs listed in the table are the most important in MA plans.



(a) Plan A **(b)** Plan B **(c)** Plan C

Fig. 8. The t value of Plan A, B and C

Based on the increasing relationship between members' age and the t value of MA plan, we conclude that the rules above are relatively unfair. In general, the rule is relatively unfriendly to lower age groups with a lower morbidity rate, as they receive the same benefits as older members. Thus, unfairness exists among different age ranges. There is a significant jump in the t value near the boundary age of two adjacent intervals, such as age 39 in Plan A and C. Such a jump also causes other relative unfairness. For example, Plan A's t value for the 39-year-old group is higher than that for the 42-year-old group, even though both are lower than the above 49-year-old groups. In addition, all MA rules do not distinguish different gender groups, which causes sex inequality. In general, women are less fairly treated as their incidence rate is lower.

Furthermore, we explain the economic meaning of MA model's t value. According to the definition, the increase of benefit is proportional to that of t value, $\Delta b^i = \frac{p^i}{q^i}\Delta t^i$. Take the 50-year-old in plan A for instance, their t value (around 800) is around 600 higher than that of 18-year-old groups (around 200). For the 50-year-old, a 100 value increase of t value is roughly equivalent to an additional 10,000 CNY benefit, as their ratio $\frac{p^i}{q^i} \approx 100$. Thus, the "extra" benefits of 50-year-old group (around 60,000 CNY) is in fact paid by other age groups. Similar pattern also exits under the

MA plan B and C.

To sum, the fact that members of different ages are not evenly treated by MA plans mainly result from the coarse design of plan rules, e.g., large bandwidths of age group and lack of lacks actuarial technique in tailoring rules. This raises a concern that MA plans may suffer an adverse selection problem.

6. Adverse selection due to MA plan's unfairness

While the lack of actuarial fairness in MA plans can be shown from numerical analysis, it is unclear whether members are conscious about the fairness issue. In this section, we empirically prove the existence of adverse selection in MA industry. More specifically, the more discriminated age groups (with lower t value) have higher tendencies to lapse, suggesting that members are sensitive to the fairness of MA plan rule.

6.1 Data

Our data is from a pioneering MA platform that runs MA plan C, containing a 2-year period observation of lapse behavior among all cohorts. This data includes the observations of 902,614 members aged between 18- to 59-years-old and is in half-month frequency from January 2018 to December 2019. The lapse behavior refers to that valid members exit the MA plan and no longer put deposit into their accounts.

The half-month frequency is due to that this MA plan publicizes the information of occurred loss claims to all members every half month, on the 1st and 16th of each month. We call the half-month period 1st – 15th (16th – end of month) after the public disclosure date 1st (16th) as the current period. The disclosure information in public disclosure of each period includes the claimants' name, joining time, diagnosed disease, brief investigation report, benefit amount to be shared and cost per member.[15]

[15] As introduced earlier, before publicity the MA platform is responsible for investigating the authenticity of reported cases.

Fig.9. Average annual lapse ratio of MA plan C.

Figure 9 presents the average annual lapse ratio of 2018 and 2019 among different ages. The annual lapse ratio is the quotient of the number of quitting members within a year to the number of total valid members at the beginning of the period. We observe that in general lapse ratio decreases with age and that women exhibit a higher propensity to quit. This observation is consistent with the facts that both younger and women groups are relatively more unfairly treated by the MA plan rule.[16] This observation rules out one alternative explanation that the pattern of lapse ratio is shaped by the age-varying risk aversion because generally women are found more risk averse than men.

6.2 Empirical strategy

We use both plan-level and individual-level identification strategies to examine the relationship between members' lapse behavior and MA plan's t values. First, we

[16] Moreover, we observe kinks but no significant jumps of lapse ratios near the age cutoffs of MA plan rules, i.e. 39-age-old and 49-age-old. This insensitivity may be explained by that the generally MA plan members aim for a long-term coverage.

empirically examine the relationship between cohorts' lapse ratios and t values by estimating the following model:

$$lapse\_ratio_{c,t} = \alpha + \beta \cdot t\,\text{value}_c + \gamma \cdot Controls_{c,t} + \phi_t + \varepsilon_{c,t} \qquad (5)$$

where $lapse\_ratio_{c,t}$ represents the lapse ratio of the cohort c in the period t, $t\,\text{value}_c$denotes the MA plan's t value of cohort c. $Controls_{c,t}$ is a vector of cohort-level control variables. ϕ_p represents the time fixed effect.

Moreover, after estimating the cohort-level specification, we estimate the effect of t values on individual's lapse behavior using the following equation:

$$lapse\_dummy_{i,c,p,t} = \alpha + \beta \cdot t\,\text{value}_c + \gamma \cdot Control_{i,c,p,t} + \phi_p + \mu_t + \varepsilon_{i,c,p,t} \qquad (6)$$

where $lapse\_dummy_{i,c,p,t}$ is the dummy variable indicating lapse behavior of individual i of cohort $c$in province$p$in the period t, which equals to 1 for lapse and 0 otherwise. $Control_{i,c,p,t}$ is a vector of control variables, including individual characteristics and provincial insurance market development.ϕ_p and $\mu_t$represent the province and time fixed effects, respectively. We summarize the definitions of the variables in the Appendix Table A6.

6.3 Regression result

Our hypothesis is that MA members' tendency to lapse is negatively influenced by their t values, which roughly measure MA plan's friendliness to each cohort. If our hypothesis is true, we expect that the primary parameter of interest, the coefficient β, will be significantly negative in both specification (5) and (6). In addition, we also expect that the women would be more sensitive because they are less fairly treated than men by the plan rule.

Table 2 reports the regression results. First, Columns (1) - (2) report the results of specification model (5) and show that the coefficients of *age* and *t value* are both significantly negative. This implies that an increase of 100 of t value averagely diminishes cohorts' annual lapse ratio by around 8.17%. Column (3) - (5) illustrate the results of specification model (6) on individual-level's *lapse_dummy*, which also documents the significant negative coefficients of *age* and *t value*. Such effect causes the cohorts with lower t value have a higher tendency to lapse. The dramatically decreased (but still significant) negative effect of *t value* in Column (5) indicates that *t value* carries some marginal impacts, though largely homogeneous with *age*. Second, we also find that the coefficients of *male* are significantly negative in Table 2. Column (2) shows that the lapse ratio of women is averagely 1% higher than men. Overall, these findings confirm our hypothesis that the lapse ratios of the less fairly treated cohorts are higher.

Inspecting the effect of *cost per member* yields a possible explanation for the observed results. Table 2 documents that *cost per member* has a significantly negative impact on both *lapse_ratio* and *lapse_dummy* in all columns. In other words, MA members' tendency to lapse decreases with the scale of claimants' misfortunes. This result implies that the information of claimants publicized by the MA platform carries impacts on members' awareness of risk, like arousing their demand for coverage after each publicity of loss. In the same way, these periodical publications of loss events may make members to have a rough estimation of risk for each age groups after experiencing many periods in the MA plan. Such awareness could contribute to members' perception of plan's unfairness, and hence, explain the larger lapse ratio of less favored groups.

Table 2

Regression results: relative fairness and members' lapse behavior

Dependent variable	**(1)**	**(2)**	**(3)**	**(4)**	**(5)**
	lapse_ratio			*lapse_dummy*	
t value (in thousands)		-0.8172***	-0.0070***		-0.0019***
		(0.0367)	(0.0002)		(0.0003)
Age	-0.0063***			-0.0001***	-0.0001***
	(0.0002)			(0.0000)	(0.0000)
Male	-0.0338***	-0.0133**	-0.0000	-0.0001***	-0.0001***
	(0.0054)	(0.0057)	(0.0000)	(0.0000)	(0.0000)
Cost per member	-0.0427***	-0.0428***	-0.1286***	-0.1286***	-0.1286***
	(0.0058)	(0.0060)	(0.0001)	(0.0001)	(0.0001)
Other controls	Yes	Yes	Yes	Yes	Yes
Time FE	Yes	Yes	Yes	Yes	Yes
Province FE	-	-	Yes	Yes	Yes
Observations	4,032	4,032	35,337,036	35,337,036	35,337,036
R-squared	0.26	0.21	0.07	0.07	0.07

This table presents the regressions that relates members' lapse behavior and MA plan's t value. Columns (1) - (2) report the results of *age* and *t value* on plan-level's *lapse_ratio*, and the control variables include *average_invited_friends,* and *SMS_notification_ratio*. Columns (3) - (5) report the results on individual-level's *Lapse_dummy*, and the control variables include *invited_friends, SMS_notification, GDP,* and *Premium*. The definitions of variables are in the Appendix Table A6. Standard errors are in parentheses. *,**, and *** denote statistical significance at the 10%, 5% and 1% levels, respectively.

In sum, our findings confirm the concern on potential adverse selection of MA plans. Using the observation data of lapse behavior of different age cohorts, we empirically demonstrate that MA plan's unfairness causes a higher lapse ratio of the lower-risk groups. Given the plan C's inequality, the variation of t values, is already the smallest among three illustrated plans, thus it is of great possibility that adverse selection is a widely existing problem in the MA industry. Therefore, our results imply that the current MA plans require actuarial techniques to improve their fairness and tackle the existing adverse selection problem.

7. Conclusion

The burgeoning online MA platforms, which provide a low-cost Internet-based form of insurance coverage for more than 300 million members in China, are groundbreaking in the InsurTech industry. To the best of our knowledge, academic studies of MA models are rare. This paper is the first of its kind to analyze the efficiency and fairness of the MA model from both theoretical and empirical perspectives. This study makes three main contributions.

First, we provide a quantitative basis to explain and to justify MA model's lower coverage cost than commercial insurance. MA's comparative advantage of cost is owing to its ability to distribute uncertainty among a large pool of participants and hence to reduce or remove the role of traditional insurer, which in turn reduces or eliminates administrative cost.

Second, the paper presents a framework to analyze the fairness of ex post risk sharing mechanisms. It is shown that a relatively fair MA mechanism cannot be attained without actuarially designed benefits and sharing rules. For a risk pool consisting of heterogeneous members, we present relative fairness conditions and provide a method to test the fairness of MA plans. Through numerical examination of relative fairness of typical MA plans, we find that most MA plans favor high-risk groups more in general.

Last, the problem of adverse selection is addressed with empirical analysis. Using lapse ratio data, we find that the risk groups less fairly treated by MA plan exhibit a higher lapse ratio. Therefore, to avoid adverse selection and make the business model economically viable over long run, MA platforms should take into account actuarial fairness in the making of allocation rules.

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Appendix

A.1 Development phases of MA industry

This Appendix summarize three development phases of MA industry went through over the last few years. Table A1 summarizes the major MA platforms in China.

- Emergence of New Business Model (2011-2015). The first online MA platform, Kangai, established in 2011, brought online MA into the public eye. In 2014, the two pioneering platforms in the market had about 350,000 members, and the top four platforms accumulated to 850,000 members by 2015.

• Overheated market with fierce competition (2016-2017). The MA industry became to form in 2016 when sizable capital investments start to enter the market and hundreds of MA platforms started to emerge. The former insurance regulator, China Insurance Regulatory Commission (CIRC), [17] issued an advisory note in November 2016 regarding online mutual aid, which marked the first time MA as a business model was acknowledged by the regulator. On a related note, the CIRC announced its Pilot Regulation for Mutual Insurance Organizations in 2015, which was seen by many as a positive gesture of opening up the mutual insurance market. By 2016, the MA industry grew exponentially, amounting to over 200 platforms and about 16 million members. The overheated market started to undergo close scrutiny by the regulator. For instance, many platforms required payments in advance and formed fund pools, blurring the boundary between MA and insurance. In December 2016, the CIRC issued new regulation, prohibiting entities from disguising their insurance business as mutual aid without insurance license. As a result, a large number of small platforms dissolved, and the number of platforms decreased to 50, with less than 40 million members in 2017.

• Market consolidation (2018-present). In 2018, many technology giants like the Ant Financial and DiDi entered the MA industry. The huge capital injections expanded the market rapidly, and enabled MA industry to regain popularity. By 2019, the top 15 platforms have amassed over 300 million users.

[17] In early 2018, China Insurance Regulatory Commission (CIRC) and China Banking Regulatory Commission (CBRC) were merged as China Banking and Insurance Regulatory Commission (CBIRC).

Table A1
Major MA platforms in China[18]

No.	MA platform	Time of establishment	Membership (million)	Mutual aids (million CNY)	Market Valuation[19] (billion CNY)
1	Xianghubao	October 2018	102	2,495	-
2	Shuidi	May 2016	81	1,205	6.73
3	Qingsong	April 2016	81[20]	532	2.1
4	Meituan	July 2019	23	-	-
5	Zhongtuobang	April 2016	10	724	3
6	E-mutual	July 2014	3.4	586	-
7	Aixinchou	August 2016	2.7	16	1
8	Gecko	June 2015	2.4	131	-
9	Kangai	May 2011	1.8	226	-
10	Quark Alliance	March 2015	1.6	180	-
11	Diandi	December 2018	1.4	3.7	-
	Total		310	6,099	

A.2 Public healthcare program and commercial healthcare insurance in China

While the social medical insurance system has covered about 1.35 billion people, or more than 95% of population, average Chinese citizens pay heavy out-of-pocket health expenditure (Wagstaff et al., 2009). According to the National Healthcare Security Administration,[21] out-of-pocket health expenditure in China accounted for nearly 29% of all health expenditure in 2018, although it has decreased significantly in the past decade. China's out-of-pocket health expenditure rate is much higher than that

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[18] Until January 1, 2020.

[19] The valuations are obtained via the online media reports. Some referred links (in Chinese) includes https://baijiahao.baidu.com/s?id=1632212997343094963&wfr=spider&for=pc. (April 2019); https://baijiahao.baidu.com/s?id=1654074312956337387&wfr=spider&for=pc. (December 2019); Link in Chinese, https://news.qudong.com/article/532317.shtml., (January 2017); http://www.sohu.com/a/247554347_180284., (2016)

[20] The platform has suspended the disclosure of its membership, the number is estimated by the media.

[21] See http://www.nhsa.gov.cn/art/2019/6/30/art_7_1477.html (link in Chinese).

of developed countries (typically 10–20%) such as Germany (15.4%) and Japan (15.9%).[22] Rural residents have to rely even more on personal savings to pay for health expenditures due to the urban-rural disparity in healthcare system.

There is relatively small competition with commercial healthcare insurance. The commercial insurance market is still in infancy (Fang, H., 2014). During 2011–2018, the annual growth rate of China's commercial health insurance premium was approximately 34.3%, much higher than that of life insurance (15.9%) and property insurance (12.9%). However, China's annual gross premium of commercial health insurance in 2018 was 544.8 billion CNY, around 390 CNY per capita (insurance density) and 0.6% of GDP (insurance penetration). By contrast, the commercial health insurance density of Germany is 610 USD per capita, around 12 times that of China. This has led some media commentators to ask why "in a country where nearly all residents receive medical coverage from the government, 90% of the population doesn't have commercial health insurance."[23] Moreover, China's total health expenditure in 2018 was 5.8 trillion CNY (4,148 CNY per capita). Therefore, commercial health insurance payments account for only 4.5% of total expenditure. Compared with developed countries, China's commercial health insurance has a limited role in the healthcare market (Figure A1).

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[22] Statistics are from OECD and WHO.

[23] See https://www.caixinglobal.com/2018-12-10/chinas-need-for-medical-coverage-is-driving-growth-in-mutual-aid-platforms-101357733.html.

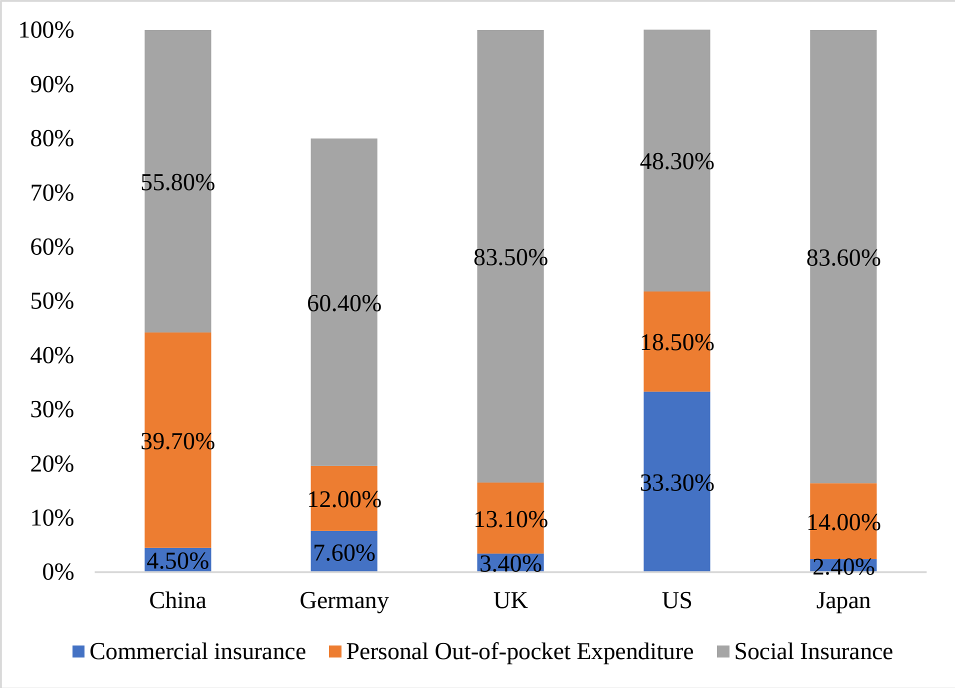

Fig. A1. Health expenditure in 2018.[24]

A.3 Differences between MA and conventional insurance

We summarize some major differences between MA and conventional insurance models.

(Contractual relationship) The contractual relationship in traditional insurance is bilateral between an insurer and a policyholder. In contrast, the contractual relationship among participants on MA platform are in essence peer-to-peer. The platform carries little to no risk and acts merely as a steward of the cash flow system.

(Product and coverage) Though both MA and conventional insurance provide coverages against CI risks, the product of MA platforms is called as MA plans, while that of conventional insurance is insurance policy. So far, the MA plans have not been recognized as insurance products yet. In addition to the CIs and accidental death coverage provided by MA plans, conventional insurers also cover many other life and

[24] See https://www.chyxx.com/industry/201911/803692.html (link in Chinese).

health insurance as well as property and liability insurance.

(Payment) Compared with conventional insurance, the most important distinctive feature of MA platforms' business model is the cost sharing principle. The policyholders of conventional insurance pay premiums in advance, calculated based on actuarial ratemaking, when they purchase coverage. In contrast, members of MA platforms share the observed ex post losses. In other words, the shared cost paid by each member is determined and paid after the occurrence of losses. Thus, the MA model does not require an ex ante sophisticated actuarial ratemaking.

(Mechanism) While conventional insurance is based on an insurer's risk underwriting, the MA model combines crowd sharing (cost sharing among peers) and MA platform's tail-risk undertaking. Under MA model, the loss is first shared among members and the MA platform takes over the tail risk in extreme cases. Thus, if only few members turn out to suffer losses, the cost of MA plans is far less than that of commercial insurance policies. In the less favoring outcomes, the payment is capped as the platform takes over. However, by contrast the "good" or "bad" loss outcomes make no difference to policyholders under the conventional insurance model as they completely transfer their risk and expect no refund.

(Investment) Insurance companies can invest premiums into financial markets, such as bonds or even stocks. By contrast, MA platforms are forbidden from investing participants' assets, as no funding pool is allowed.

(Source of profit) While insurers can benefit from the discrepancies in conservative actuarial assumptions and actual experiences on interest, mortality and expenses, MA platform can only charge management fee as a reward of undertaking tail-risk. The single source of profit is the surplus of management fees and advertising fees for promoting other commercial products.

A.4 Market data on healthcare insurance and mutual aid

Table A2

Representative insurance products with CI cover (age 35)

Insurance Product	Premium (CNY)	Benefit (in thousands, CNY)	Ratio
Zhonganlehuoesheng	264	220	1.20
Pingan (adult)	937	500	1.87
Bainiankanghuibao	2,370	300	7.90
Taikangewuyou	2,748	300	9.16
Kunlunjiankangbao	2,866	300	9.55

Table A3

Representative MA plans with CI cover (age 35)

MA plan	Cost (CNY)	Benefit (in thousands, CNY)	Ratio	Member growth rate in 2019
Zhongtuobang	20.78	400	0.05	2%
Shuidi	59.22	250	0.24	33%
Xianghubao	29.17	100	0.29	445%
Quark Alliance	129.39	250	0.52	10%
Kangai	110	50	2.20	-2%

Table A4

Representative commercial insurance policies with CI cover in China

Product	Coverage	Benefit (CNY)	Premium (CNY)			Notes
			25 years old	35 years old	45 years old	
Pingan (adult)	30 CIs	500,000	461	937	2,988	male, one-year insurance policy
Zhonganlehuoesheng	100 CIs + 50 mild illnesses + 20 special illnesses	220,000	130	264	832	male, one-year insurance policy, basic edition
Kunlunjiankangbao	110 CIs + 25 moderate illnesses + 50 mild illnesses	300,000	2,098	2,866	3,853	male, fixed-payment-term (20 years) insurance policy, with coverage period: to 70 years old
Bainiankanghuibao	100 CIs + 30 mild illnesses	300,000	1,740	2,370	3,120	
Ruitairuiying	100 CIs + 50 mild illnesses	300,000	2,022	2,748	3,630	
Kangleyisheng（2019）	108 CIs + 25 moderate illnesses + 40 mild illnesses	300,000	3,195	4,305	5,763	

Table A5

Annual coverage cost of representative MA platforms in 2019

MA platforms	Coverage	Plan for youth (CNY)		Plan for middle-aged (CNY)		Plan for old-age (CNY)	
		Benefit	Cost	Benefit	Cost	Benefit	Cost
Xianghubao	Cancers + 100 CIs	300,000	29.17	100,000	29.17	100,000	31.87
Shuidi	Cancers	300,000	10.32	250,000	59.22	200,000	74.3
Zhongtuobang	111 CIs + 77 specific illnesses	500,000	10.39	400,000	20.78	200,000	41.56
Quark Alliance	60 CIs	300,000	129.39	250,000	129.39	200,000	129.39
Kangai	115 CIs + cancers	100,000	37.03	50,000	110	20,000	225.38
Weighted average			21.33		42.69		52.43

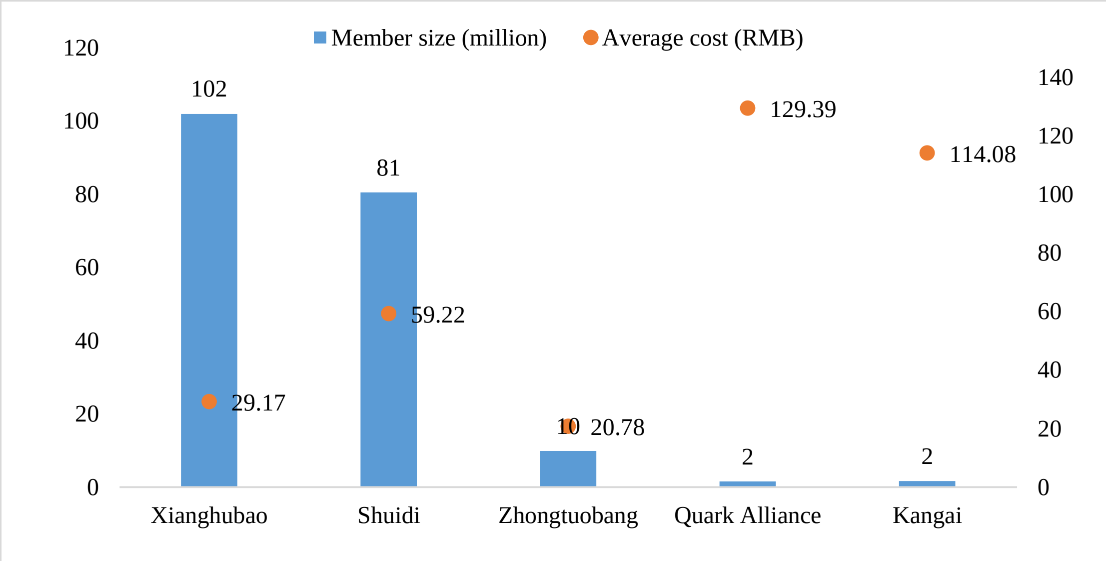

Fig. A2. MA plan's member size and coverage cost (million & CNY)

Note: This figure reports the membership of several young and middle-aged MA plans with CI cover as well as members' cost share in 2019.

A.5 Proofs

Proof of Theorem 1: We compare the individual' ECC under to two models. According to the ECC forms in Equations (3) and (4), we need to compare $\alpha^I qb + \frac{1+\alpha^I}{n}[r\rho[(n-N)b]]$ with $\frac{\alpha^M}{n}E[(b(n-N)-Nd)_+]$. With the condition that $\alpha^M = \alpha^C$ and $qb = \frac{1}{n}E[b(n-N)]$, it is clear to lead to that ECC^{CIns} is greater than ECC^{MA}. Thus, the MA model is more efficient than the conventional insurance.

Proof of Lemma 3:

If MA model is relatively fair, the ENR of any group i satisfies

$$p^i(t^i - E[S] - \pi_0) = Const.$$

where $Const$ is the constant ENR value. Thus, we have $t^i = E[S] + \pi_0 + \frac{Const}{p^i}$.

(i) It is obvious that t^i increases (decreases) with p^i (q^i) when $Const < 0$.

(ii) Similarly with (i), we can obtain the conclusion for $Const < 0$.

(iii) When $Const = 0$, we have $t^i = E[S] + \pi_0$.

Proof of Theorem 2:

Under an MA coverage model with heterogeneous risk,

(i) when the MA platform does not require a profit margin, we have ENR=0 for all groups. By Lemma 3, for relatively fair MA we have $t^i = t^j$, for any $i, j = 1, 2, ..., m$.

It is also intuitive that when $t^i = t^j$, for any $i, j = 1, 2, ..., m$, we also have ENR=0 and thus the MA plan is relatively fair.

(ii) when the MA platform requires a profit margin, then we have ENR<0. By Lemma 3, then the relatively fair MA plan satisfies $t^i > t^j$, if $q^i < q^j$ for any $i, j = 1, 2, ..., m$.

A.6 Variable definitions

Table A6
Variable definitions

Variable	Definition
Lapse_ratio	Each cohort's quotient of the number of lapses and the number of in-force policies at the beginning of the current period.
Lapse_dummy	A dummy variable that equals one if the member lapses and zero otherwise.
Male	A dummy variable that equals one if the gender is male and zero otherwise.
Age	Age of the member.
Cost per member	The shared cost per member in public disclosure of the current period.
Average_invited_friends	Each cohort's average number of friends who were invited to participate in the MA plan by him/her.
SMS_notification_ratio	The ratio of members who follow the SMS notification of the MA platform.
Invited_friends	The number of friends who were invited by a member to participate in the MA plan.
SMS_notification	A dummy variable that equals one if the member follows the SMS notification of the MA platform.
GDP	GDP in the member's province.
Premium	Premium of insurance market GDP in the member's province.