Expanding Health Insurance Access for Substandard Populations in China: Product Design, Morbidity, and Pricing

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Expanding Health Insurance Access for Substandard Populations in China: Product Design, Morbidity, and Pricing

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Executive Summary

This report examines China's health insurance market for substandard populations, primarily composed of individuals with pre-existing illnesses (PEIs). Despite the rapid growth of the broader health insurance sector, this segment faces significant coverage gaps. The primary obstacle to developing PEI-inclusive insurance products is the scarcity of reliable pricing data, which stems from limited morbidity rate estimates for substandard populations. The report conducts a multifaceted analysis: (1) a review of the Urban-Customized Commercial Medical Insurance (UCCMI) scheme, the largest category of health insurance for PEIs, focusing on its design features and underwriting rules for PEIs across products; (2) an empirical analysis of chronic illness prevalence among PEIs using the China Health and Retirement Longitudinal Study (CHARLS) database, exploring demographic, socioeconomic, and regional factors influencing morbidity rates; and (3) a theoretical application of the Markov model to estimate critical illness incidence rates among individuals with PEIs, leveraging single-period prevalence data to overcome limitations in historical cohort studies. The report concludes by proposing recommendations for insurers and policymakers, including adopting advanced modeling techniques to improve pricing accuracy, developing tailored insurance products for substandard populations, and strengthening data infrastructure to support sustainable innovation in China's health insurance market. This study provides actionable insights to accelerate the equitable expansion of health insurance coverage for substandard populations by bridging knowledge gaps in PEI morbidity and pricing.

Section 1 Overview

1.1 BACKGROUND

China’s health insurance system has evolved into a multi-tiered, nationwide medical security network, with basic medical insurance as the main body, public critical illness insurance as a supplement, and medical assistance as the bottom-line support. The system also integrates commercial health insurance at the top.

Basic medical insurance is the mainstay of the system, with broad coverage that includes urban employee basic medical insurance and urban-rural resident basic medical insurance. According to the press conference held by the National Medical Security Administration on January 17, 2025, the total income of the national basic medical insurance fund reached 3.48 trillion yuan in 2024, marking a 4.4% year-over-year increase. Total expenditures totaled 2.97 trillion yuan, up 5.5% year-over-year. The participation rate in basic medical insurance is relatively high. As of the end of 2024, the number of participants in basic medical insurance in China was about 1.326 billion, with a stable participation rate of 95%.[1]

Commercial health insurance, an important supplement to basic medical insurance, has developed rapidly in recent years. From 2011 to 2024, the gross premiums of commercial health insurance increased from RMB 69 billion to 977 billion, and the proportion of health insurance in the entire commercial insurance industry also increased from 4.8% to 17.6%. It is the fastest-growing type of life insurance product.

Currently, most insurance products are underwritten for the standard population. In contrast, there are very few products for substandard populations such as individuals with chronic diseases. Nevertheless, the cohort of substandard individuals is substantial, and they are short on insurance coverage and most are exposed to health risks. Consequently, the matter of accelerating the innovation of commercial health insurance products for substandard individuals assumes the status of an urgency that requires a resolution.

1.1.1 DEFINITION OF SUBSTANDARD RISKS IN HEALTH INSURANCE

In health insurance, the term “substandard risk” refers to individuals whose health status, medical history, physical examination findings, occupational hazards, or lifestyle habits at the time of insurance application failed to meet the standard underwriting criteria set by insurance companies. Higher-than-average health risks, a greater probability of illness or injury, or elevated mortality rates characterize

[1] https://www.gov.cn/lianbo/bumen/202503/content_7014817.htm

these individuals. As such, they typically require higher premiums or additional underwriting conditions to purchase health insurance, or they may fail to qualify for coverage altogether.[2]

The population with substandard risks can be grouped into two categories.

The first category comprises individuals suffering from pre-existing illnesses (PEIs). It can be further divided into two subgroups. (1) The first subgroup includes individuals with chronic illnesses, such as hypertension, diabetes, heart disease, or kidney disease. These conditions are widely recognized by the public and typically have a long duration, progress slowly, are difficult to cure, and require long-term medical management. (2) The second subgroup includes individuals with medical histories other than chronic illnesses—those who have experienced specific health issues or received treatments before applying for insurance, raising red flags during underwriting assessments.

The second category includes individuals with special conditions, typically including persons with disabilities or older people, who inherently possess higher risk profiles due to physical or age-related vulnerabilities.

The risk of developing illnesses in all these two categories is higher than that of the standard population, prompting insurers to impose stricter underwriting requirements or coverage limitations.

1.1.2 NEED FOR SPECIALIZED INSURANCE PRODUCTS IN CHINA

The population of individuals with substandard health risks is growing rapidly in China. According to data released by the National Bureau of Statistics, by the end of 2024, there were approximately 200 million people aged 65 and above in China, accounting for 15.6% of the total population. During the 14th Five-Year Plan period, the number of people aged 60 and over is projected to surpass 300 million, representing over 20% of the total population. The accelerated aging of the population has led to profound changes in the demographic structure, resulting in a rapid increase in the number of individuals with chronic diseases and impaired health conditions.

According to the Special Report of the Sixth National Health Service Survey (2018)[3], over 400 million people in China have chronic illnesses. Among those aged 15 and above, the prevalence rate exceeds 34%; among those aged 65 and above, it exceeds 60%. Data from the National Center for Cardiovascular Diseases further indicates that there are approximately 245 million individuals living with hypertension, around 120 million with chronic kidney disease, and approximately 130 million people with diabetes across the country.

Meanwhile, with the rapid development of China's health insurance sector, a growing number of people are placing increased importance on securing adequate medical protection. For individuals

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[2] It should be noted that a substandard population could be different across different insurance products. For example, a population with higher-than-average health risks is substandard for health insurance, but standard for annuity insurance. We focus on health insurance in this report.

[3] https://wjw.xinjiang.gov.cn/hfpc/zhgl10/202102/d40a18c8b75e4307bba22240269b57b3.shtml

classified as substandard risks, obtaining effective commercial insurance coverage remains a major challenge. As mentioned earlier, substandard risks refer to people who already exhibit certain medical conditions or abnormal health indicators at the time of application. Managing the health risks of this group is inherently more complex, making access to insurance coverage more difficult and more urgently needed.

However, in health insurance pricing models, there exists a significant premium differential between substandard and standard risks. While the essence of insurance lies in risk pooling, this principle is predicated on a relatively balanced level of risk among participants. When the risk levels differ substantially between the two groups, offering identical premiums and benefits may lead to the problem of adverse selection—wherein high-risk individuals disproportionately seek insurance, and low-risk individuals exit the pool due to perceived pricing inequities. This dynamic often results in unsustainable loss ratios and undermines product viability. Additionally, undifferentiated pricing violates the principle of actuarial fairness by forcing standard risks to subsidize the costs of high-risk individuals.

Consequently, individuals with substandard risks are frequently excluded from traditional commercial health insurance due to failures in health disclosures, rejection during underwriting, or restrictive policy clauses such as exclusions. This has led to a paradoxical situation where those who most urgently need insurance protection are often unable to obtain it.

1.2 LITERATURE REVIEW

1.2.1 OVERSEAS HEALTH INSURANCE FOR SUBSTANDARD POPULATION

The U.S. Market

The American market for substandard risk insurance represents a classic and mature overseas case study in developing such products. Throughout its evolution, stakeholders have consistently sought a delicate balance between relaxing underwriting requirements to enhance inclusivity and effectively controlling adverse selection and other associated risks.

In the early 20th century, the U.S. insurance market primarily served standard-risk individuals. In 2010, the Patient Protection and Affordable Care Act (ACA) (“Obamacare”) prohibited insurers from denying coverage based on pre-existing conditions (PECs) and mandated equal premiums/benefits for standard and substandard risks. During the 2010–2014 transition, the federal government launched the Pre-Existing Condition Insurance Program (PCIP) to provide interim coverage for high-risk individuals (Lambrew and Montz, 2017). Despite a $5 billion advance allocation to offset losses, the PCIP faced persistent deficits. By 2013, expenditures exceeded projections, prompting a halt to new enrollments in March 2013 to preserve funds. By year-end, the claims ratio surpassed 600%.

The full implementation of the ACA in 2014 marked the end of the PCIP’s historical role. Under the ACA framework, both standard and substandard individuals were included in the insurance coverage system, establishing a critical pathway for substandard populations to receive essential medical protection. The ACA introduced a comprehensive set of mechanisms to stabilize premiums, particularly through its “risk adjustment mechanism,” which preemptively subsidized plans with high-risk enrollees by redistributing funds from those with lower-risk profiles. This aimed to reduce discrepancies in future operational performance among plans (Cox, Semanskee, Claxton and Levitt, 2016).

The Japanese Market

Japan’s healthcare system provides universal coverage for all citizens, from birth to old age, allowing every resident to participate in the health insurance system. There are three types of insurance within the Japanese healthcare system, with medical costs shared among employees, employers, the unemployed, and the government (Uchida, 2012). The first type is Society-Managed Health Insurance (SMHI), primarily covering employees of large companies, with premiums contributed by both employers and employees, set at rates ranging from 3% to 10% of wages. The second type is Japan Health Insurance Association Health Insurance (JHIAHI), which serves employees of small enterprises. The government subsidizes 13% of medical costs in this scheme, while employers and employees contribute 8.2% of wages. The third type is National Health Insurance (NHI), designed for the self-employed and retirees.

This universal insurance system provides fundamental medical protection for individuals with chronic illnesses. Japan emphasizes health checkups and targeted health guidance as a strategic approach to chronic disease management. In 1983, Japan enacted the Elderly Health Act, which introduced the principle of “health at 40, healthcare at 70,” highlighting the need to begin preventive care in middle age. Under this act, citizens aged 40 and above are entitled to free services, including health records, health education, medical consultations, health checkups, medical care, functional training, and home visits. Moreover, Japan does not have provincial, municipal, or district-level Centers for Disease Control and Prevention; instead, chronic disease prevention and control are implemented through a nationally unified legal framework with execution carried out by local governments (Xu, Zhang, Wang, Wu, Narimatsu and Zhao, 2016). Medical insurance companies entrust medical institutions or private companies to conduct specific health checkups annually for insured individuals aged 40 to 74. Based on the checkup results, community-based health professionals provide tailored health guidance to different individuals, forming a horizontal, collaborative structure. This model facilitates the early detection of chronic conditions and reduces disease risks through continuous health management.

1.2.2 INSURANCE FOR SUBSTANDARD POPULATION IN CHINA

China’s substandard risk insurance sector has progressed through three distinct phases (Li, Lin, Mei, Zhang, Wang, Guo, Liu and Zeng, 2025). Initially, policies focused on chronic disease management (2015–2019), integrating insurance with preventive care. This was followed by a period of moderate underwriting relaxation (2020–2022), expanding access for substandard populations. Currently, the sector is standardizing, driven by regulatory frameworks to standardize specialized products.

Types of Substandard Risk Insurance Products in the Chinese Market

Health insurance products targeting substandard risks in China can be broadly categorized into three types based on their underwriting models.

The first category includes urban customized commercial health insurance (UCCMI) products that do not impose restrictions based on the insured's PEIs. These products generally exhibit a "semi-mandatory" nature, featuring extremely low entry barriers and premiums typically priced at around several hundred RMB per year (Xu, 2023a). Coverage is designed to address significant medical expenses such as hospitalization, treatment for specific diseases, and cancer care. Early examples of this model include employer-sponsored supplementary medical insurance schemes. These products typically adopt a "mixed-risk pooling plus collective responsibility" model, wherein individuals with varying health risk levels are grouped to achieve effective risk diversification and balance. This model fundamentally relies on the law of large numbers and broad population coverage.

The second category is characterized by long-term medical insurance with adjustable premiums, which embodies the principle of "early enrollment." This design concept encourages individuals to purchase insurance while healthy, allowing for continued renewal even after illness onset. Such products typically permit continuous enrollment for 20 years, 30 years, or even for life, and incorporate an adjustable premium system in their pricing mechanisms.

The third category consists of short-term insurance products designed for substandard individuals. These products target costs associated with disease progression or complications, etc. Insurers implement meticulous risk management strategies—such as detailed health questionnaires, exclusion clauses, and waiting periods—to select substandard-risk individuals whose risks remain manageable. These products offer high flexibility and precise coverage, making them suitable for individuals aware of their medical conditions but still seeking supplemental insurance. Unlike the first two categories, these short-term plans do not rely on mixed-risk pooling but instead focus on niche markets with higher-risk profiles.

Main Challenges

However, the market faces significant gaps. Domestic scholars highlight product homogeneity, with over 90% of commercial health insurance concentrated in critical illness and medical insurance, neglecting long-term care and disability products critical for aging societies (Wu, 2023). Structural weaknesses persist, including weak integration between insurance, healthcare, and pharmaceutical sectors, leading to fragmented disease management and elevated risks of treatment inefficiencies (Zheng et al., 2023). The absence of specialized substandard risk products further limits market responsiveness to evolving demographic needs.

To address these challenges, scholars propose multifaceted innovations. Global models are cited as templates for tailoring products to chronic disease and aging trends (Zhang, 2016). Technological integration, particularly via wearable devices for real-time health monitoring, offers avenues to shift underwriting from reactive to preventive models (Ning and Wang, 2022). Additionally, cross-sector collaboration—including government-led ecosystems linking insurance, medical care, and pharmaceuticals—is deemed essential for data-sharing, risk mitigation, and sustainable growth (Wang et al., 2024). Such integration could transform substandard risk insurance into a cornerstone of China's health resilience strategy.

1.3 OUTLINE OF THE REPORT

The report begins with an overview of China's health insurance market for the substandard population, which includes people with PEIs and individuals with special conditions (e.g., those with disabilities or older people). The primary challenge identified is the lack of pricing data, which hinders the development of PEI-inclusive insurance.

The report first reviews the Urban-Customized Commercial Medical Insurance (UCCMI) scheme, the largest health insurance category for individuals with PEIs. It analyzes its design features and underwriting rules for PEIs. This section highlights cross-sectional variations in coverage and pricing strategies, offering insights into how UCCMI can better serve substandard populations.

The analysis then shifts to morbidity rate analysis, focusing on the prevalence and incidence of chronic and critical illnesses. Regarding the prevalence rate, the report leverages the China Health and Retirement Longitudinal Study (CHARLS) database to summarize statistics on common PEIs, such as hypertension and diabetes, and examines demographic, socioeconomic, and regional factors influencing these rates. Regarding the incidence rate, the report develops a Markov model to theoretically estimate the incidence of critical illnesses among PEIs, comparing these rates with those of non-PEI populations. The model is based on the backward derivation of incidence rates from one-phase prevalence rates. The advantage of this approach is that, unlike past empirical incidence rates derived from cohort studies, it relies solely on single-period data (which is easier to obtain) to estimate incidence rates, significantly reducing data availability requirements.

Finally, the report concludes with a discussion of the implications of the findings and offers recommendations for the future development of health insurance products for PEI individuals. The study highlights the need for innovative approaches in product design and pricing, emphasizing the importance of leveraging advanced modeling techniques and data analysis.

Section 2 Current Product Design for Pre-existing Illnesses (PEIs)

As discussed in subsection 1.2.2, Urban Customized Commercial Medical Insurance (UCCMI) is the largest category of insurance products for nonstandard populations in China. In this section, we collect data on prevalent UCCMI products and summarize their approaches to addressing the issue of pre-existing conditions.[4]

2.1 URBAN-CUSTOMIZED COMMERCIAL MEDICAL INSURANCE (UCCMI) OVERVIEW

UCCMI is an innovative commercial insurance product. It refers to localized supplementary medical insurance products guided or led by local governments, underwritten by commercial insurers, operated with third-party service providers, and voluntarily purchased by residents (Xu, 2023b). These products are featured with extremely low entry barriers and premiums and promoted by local government.

UCCMI serves as an indispensable institutional supplement to China's multi-tiered medical insurance system, precisely addressing the gaps in coverage left by basic medical insurance. As the most widely accessible universal commercial health insurance product, it bridges the gap between basic medical insurance and commercial health insurance. It serves as a core supplementary pillar to basic medical insurance in mitigating the risks associated with major illnesses.

In 2020, the Central Committee of the Communist Party of China and the State Council issued the Opinions on Deepening the Reform of the Medical Security System, proposing to "build a medical security system by 2030 with basic medical insurance as the mainstay, medical assistance as the foundation, and supplementary medical insurance, commercial health insurance, charitable donations, and medical mutual aid as complementary components." Since 2020, UCCMI has experienced rapid growth nationwide due to its low enrollment thresholds, high coverage limits, and government endorsement. The premiums have increased from 0.4 billion yuan in 2019 to 12.4 billion yuan in 2022.[5] By November 15, 2023, 622 UCCMI products had been launched (counting annual iterations in the same city as different products) (Xu, 2023a).

Unlike the strict underwriting of traditional commercial health insurance, the underwriting process of UCCMI is highly simplified. Three "no-limit principles" are adopted:

First, there is no age limit (covering 0-104 years old). According to the UCCMI products we collect, 90.80% of UCCMI products have no upper age limit for enrollment, 86.59% have no lower age limit for enrollment, and 99.62% have no occupational requirements. For example, in Shanghai, the average age of the enrollees in 2022 was 47.75 years old, and from the distribution of the age situation of the claims, the age group above 51 years old accounts for 62% of the total claims.

Second, there is no requirement for health notification and no exclusion of PEIs from the benefits. Most of the products do not require the completion of a health questionnaire or submission of a physical examination report and only require that the insured person has participated in the local basic

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[4] A summarization of the other two categories of commercial insurance for nonstandard population can be found in the report by Li et al. (2025).

[5] https://www.xinhuanet.com/money/20230626/cf38189033af412aae223aa06eff64d5/c.html

health insurance (e.g., Employee's Health Insurance, Urban and Rural Resident's Health Insurance). For example, Shanghai UCCMI only requires the insured to enroll in the local social medical insurance, does not require any health screening, and only discounts the compensation ratio for PEIs. In Shanghai UCCMI version 2022, the compensation ratio for hospitalization out-of-pocket medical expenses was 70% for non-PEI conditions and 50% for PEIs; the compensation ratio for domestic high-value drug expenses, proton heavy ion medical treatment and overseas special drug expenses was 70% for non-PEI conditions and 30% for PEI conditions.

Third, the abolition of restrictions on occupational categories aims to expand the scope of insurance coverage through "de-thresholding," alleviating the problem of "selective exclusion" in traditional commercial insurance. For example, Guangzhou's UCCMI product covers insurance for construction workers, and includes firefighters, miners, takeaway riders, and other occupations traditionally denied insurance coverage.

To mitigate adverse selection risks, UCCMI disperses risks through city-level mass enrollment. Although enrollment is non-mandatory, local governments actively promote participation through publicity campaigns.

2.2 UCCMI'S PRODUCT DESIGN FOR PEIS

We collected data on all prevalent UCCMI products. A total of 134 UCCMI products are analyzed in this section.[6] Regarding their features related to substandard risk, almost all products do not differentiate between persons with/without disabilities or the elderly/young (i.e., the second category of substandard risks, as defined in subsection 1.1.1). Therefore, we focus on their handling of PEIs, the first category of substandard risks.

2.2.1 CRITERIA FOR PEIS

The Positive List Model and the Negative List Model

UCCMI's "PEI List Management" is the core risk control mechanism for universal commercial health insurance. It clearly defines the scope of coverage and reimbursement rules for PEIs through a list-based approach, balancing fairness and sustainability. The list model includes two types: the positive list model and the negative list model.

Positive list model: This model explicitly lists the scope of insurable PEIs (e.g., hypertension, diabetes mellitus) and does not provide coverage for diseases beyond the list. For example, Nanjing's "Ninghui Insurance" includes six types of PEIs in its list of compensable diseases: ① malignant tumor; ② renal insufficiency; ③ cirrhosis of the liver, hepatic insufficiency; ④ ischemic heart disease (including coronary heart disease, cardiac infarction), chronic cardiac insufficiency (cardiac function of the third

[6] We would like to thank the team of Xu Xian at Fudan University for sharing part of the product information.

degree and above); ⑤ cerebrovascular disease (cerebral infarction, cerebral hemorrhage); and ⑥Chronic obstructive pulmonary disease, chronic respiratory failure.

Negative list model: This model specifies the types of diseases that are not covered, while the rest of the PEIs are partially covered. For example, the city of Putian's "Puxian Insurance" includes five types of PEIs in its list of non-compensable diseases: ① Tumors: malignant tumors (including leukemia, lymphoma); ② liver and kidney disease: renal insufficiency; cirrhosis, liver insufficiency; ③ cardiovascular, cerebrovascular, lipid metabolism diseases: ischemic heart disease (including coronary heart disease, myocardial infarction), chronic cardiac insufficiency (cardiac function), cerebrovascular disease (cerebral infarction, cerebral hemorrhage; hypertension (level 3; diabetes and with the cardiac function) Grade 3 and above); cerebrovascular disease (cerebral infarction, cerebral hemorrhage); hypertension (Grade 3); diabetes mellitus with complications; ④ lung diseases: chronic obstructive pulmonary disease, chronic respiratory failure; and ⑤ other diseases: systemic lupus erythematosus, paralysis, aplastic anemia, ulcerative colitis.

Word Frequency Statistics

We summarize the frequency of PEIs in all the UCCMI products. Word frequency statistics find that the average number of pre-existing illnesses is 7.44 diseases, with malignant tumors, diabetes, heart disease, chronic respiratory failure, and leukemia having the highest frequency of occurrence.

Table 1

FREQUENCY OF DIFFERENT PEIS IN UCCMI PRODUCTS

Pre-Existing Conditions	Frequency
Malignant tumors (including leukemia, lymphoma)	68
Hepatobiliary diseases: renal insufficiency, liver cirrhosis, liver failure	47
Cardiovascular and metabolic diseases: ischemic heart disease (including coronary heart disease, myocardial infarction), chronic heart failure (grade 3 and above), cerebrovascular diseases (cerebral infarction, cerebral hemorrhage), hypertension (grade 3), diabetes with complications	46
Other diseases: systemic lupus erythematosus, paralysis, aplastic anemia, ulcerative colitis	33
Rare diseases	10
None	14

The most commonly cited PEIs in UCCMI products are dominated by malignant tumors, hepatobiliary diseases, and cardiovascular and metabolic disorders. Malignant tumors, including leukemia and lymphoma, accounting for 28.3% of mentions (68 cases), reflecting their high prevalence and treatment costs. Insurance companies often prioritize these conditions for risk control, implementing measures such as lower reimbursement rates or waiting periods to manage payout risks. Hepatobiliary diseases, such as renal insufficiency, cirrhosis, and liver failure, represent 19.6% of mentions (47 cases) and are a focus due to their prolonged treatment courses and potential for long-term medical expenses. Cardiovascular and metabolic diseases, including ischemic heart disease, chronic heart failure (Grade 3 and above), cerebrovascular disease (e.g., stroke), Grade 3 hypertension, and diabetic complications, account for 19.2% of mentions (46 cases). These conditions are closely tied to aging populations, posing a dual challenge of high coverage demand and elevated payout risks that necessitate tailored protection strategies.

Less frequently cited PEIs include other chronic or high-cost diseases, rare diseases, and cases where no explicit conditions are listed. Conditions like systemic lupus erythematosus, paralysis, aplastic anemia, and ulcerative colitis, which collectively represent 14.1% of mentions (33 cases), are included in some products' risk frameworks despite their lower prevalence, often due to their high treatment costs or need for long-term management. Rare diseases, accounting for only 4.3% of mentions (10 cases), are rarely covered, likely because their extreme treatment costs and pricing challenges (due to limited data) discourage insurance companies from assuming such risks. Additionally, approximately 10% of products do not explicitly list pre-existing conditions, instead managing risk through negative lists (excluding specific diseases) or indirect methods like deductibles and reimbursement rate adjustments, reflecting a more flexible approach to risk mitigation.

2.2.2 UCCMI RISK CONTROL MECHANISM FOR PEIS

The Insurability of PEIs in UCCMI

There are four types of insurability designs in UCCMI products:

First, under the "no distinction for PEIs" design, all liabilities are covered without differentiating between individuals with PEIs and healthy individuals. The same payout amount applies to all insured persons.

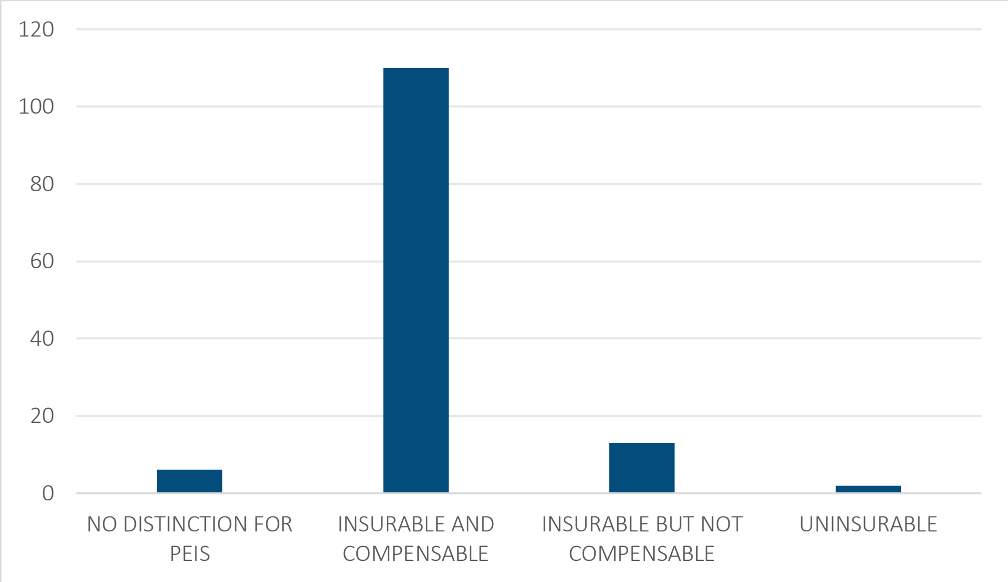
Second, in the "insurable and compensable" design, patients with PEIs can be insured, and UCCMI covers such conditions but adjusts the reimbursement terms. This may involve reducing the reimbursement percentage or increasing the deductible for PEIs. For instance, under Chongqing's UCCMI, "Yu Express Insurance," patients with PEIs can be insured, but the reimbursement ratio for PEI treatment costs is reduced to 10%.

Third, the "insurable but non-compensable for PEIs" design allows patients with PEIs to be insured, but UCCMI does not cover PEIs; only other diseases are eligible for reimbursement. For example, Beijing UCCMI excludes hospitalization costs for five specific categories of PEIs: malignant tumors, liver and kidney diseases, cardio-cerebrovascular and glucose-lipid metabolism diseases, lung diseases, and other diseases (e.g., systemic lupus erythematosus, aplastic anemia, and ulcerative colitis).

Fourth, in the "uninsurable for sick individuals" design, UCCMI products cannot be purchased by individuals with pre-existing conditions. For example, the UCCMI of the city of Shengjing explicitly states that sick individuals cannot be insured under its UCCMI product.

Figure 1

DISTRIBUTION OF DIFFERENT BENEFIT SCHEMES FOR PEIS IN UCCMI PRODUCTS



The distribution of the above four different benefit schemes is reported in Figure 1. The following conclusions can be drawn from it. First, more than 98% of the products allow enrollment of PEIs (only 2% are uninsurable), confirming UCCMI's positioning of "low threshold, wide coverage." However, only 4.6% of the products are completely open to benefits (without distinguishing PEI conditions), showing that insurance companies are prudent in controlling the risk of claims. Second, the mainstream model is conditional coverage. The 84% of mainstream products that can be insured or compensated reflects the balance of product design, which is inclusive and does not exclude patients with PEI conditions from enrollment, but also sets higher deductibles, lower benefit ratios, or only covers specific diseases in terms of benefit limitations.

Compensation Intensity for PEIs

UCCMI products vary significantly along the compensation intensity for PEI (Xu, 2023b). This section analyzes UCCMIs design coverage intensity by examining the distribution of their deductibles and coverage amounts.

Figure 2

DISTRIBUTION OF DEDUCTIBLES FOR INDIVIDUALS WITH PEIS (IN 10,000 YUAN)

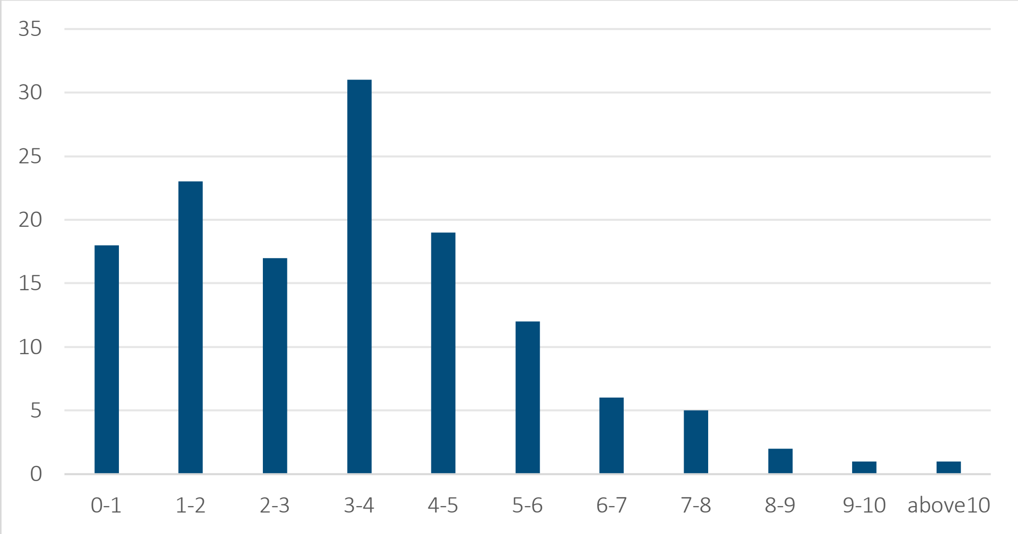


Figure 2 reports the distribution of deductibles for individuals with PEIs among different UCCMI products. The distribution of deductibles for PEI groups reveals three patterns. First, a highly concentrated range is observed, with deductibles between 10,000–20,000 yuan and 30,000–40,000 yuan accounting for the highest proportion of cases. This suggests that UCCMI products prioritize basic protection needs for the PEI population. Second, a short-tailed distribution is evident, with only 0.7% of entries featuring high deductibles exceeding 100,000 yuan, typically associated with high-end medical programs. Third, a segmented design approach is adopted, where over 30% of entries incorporate differentiated deductibles based on participation type (e.g., new enrollees vs. renewals) and renewal status.

Figure 3

DISTRIBUTION OF INSURANCE COVERAGE FOR INDIVIDUALS WITH PEIS (IN 10,000 YUAN)

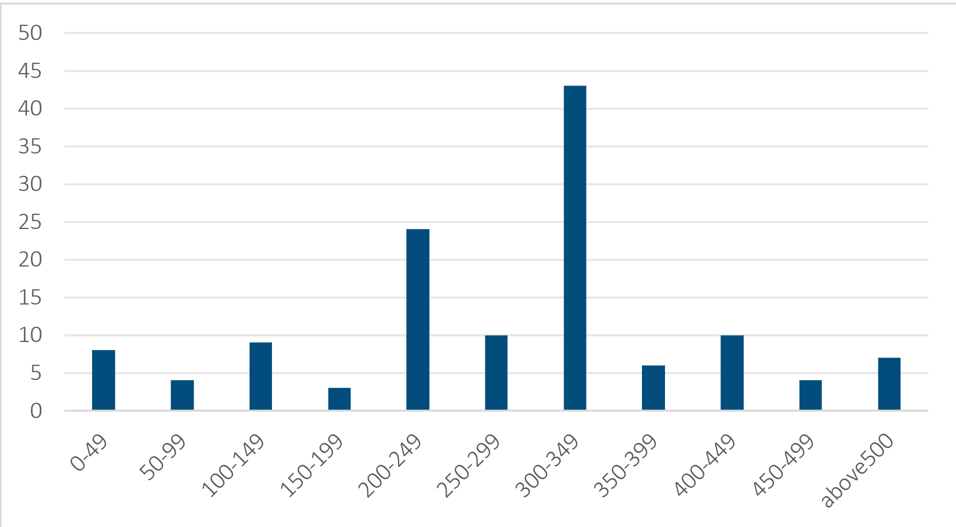


Figure 3 reports the distribution of insurance coverage for individuals with PEIs among different UCCMI products. The distribution exhibits three key patterns: first, a highly concentrated distribution range, where the highest percentage of coverage amounts (34%) falls within the 3–3.5 million yuan range; second, a short-right-tailed distribution, characterized by a relatively small number of products with high coverage amounts (≥5 million yuan), though individual ultra-high coverage amounts (e.g., 6.2 million - 6.5 million yuan) exist; and third, a short-left-tailed distribution, evidenced by only eight products offering coverage amounts in the 0–500,000 RMB range. It indicates most products are generous.

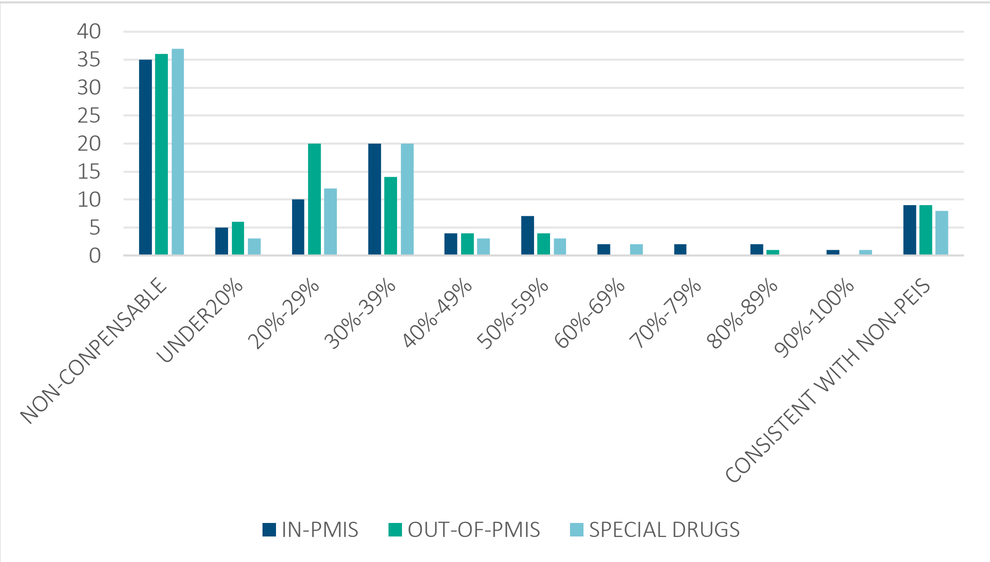
2.2.3 UCCMI'S COMPENSATION FOR PEIS AND NON-PEIS ACROSS EXPENSE TYPES

The compensation for UCCMI products provided to the population with PEIs is categorized into two groups: one for PEIs and another for illnesses unrelated to PEIs.

Within each product, the compensation ratios vary across three expense types: (1) medical expenses covered by the public medical insurance scheme (PMIS), (2) medical expenses not covered by the PMIS, and (3) specialty drugs. This section summarizes the compensation ratios for UCCMI products under these categories.

Figure 4

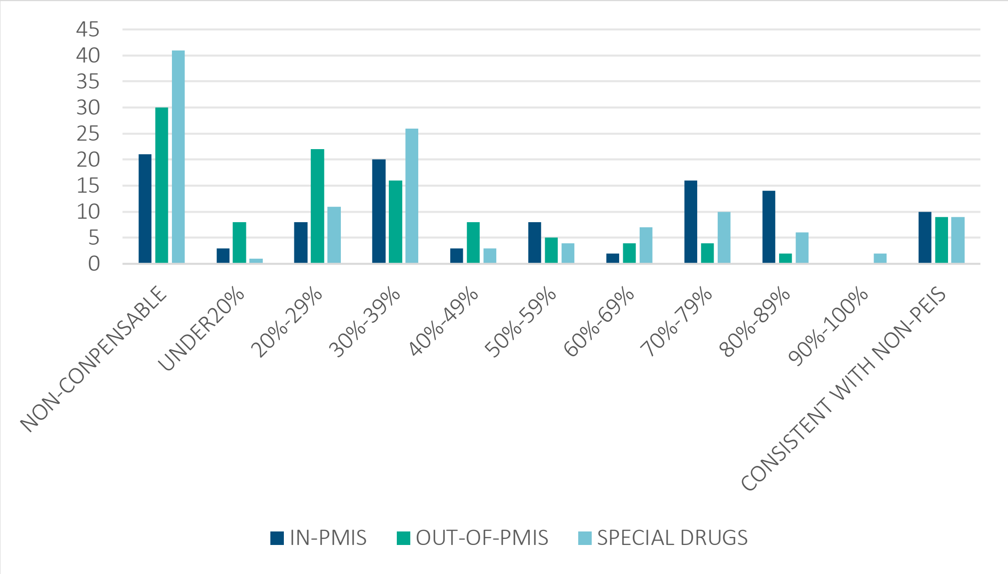
DISTRIBUTION OF COMPENSATION RATIOS OF PEIS



The distribution of compensation ratios for PEIs of individuals with PEIs are reported in Figure 4. It reveals three key patterns: first, in-PMIS reimbursement shows that the mainstream ranges are 30%–39% (21%) and no benefit (36%), with very few products offering high benefits. Second, out-of-PMIS reimbursement has relatively lower ratios compared to in-PMIS reimbursement, where the highest shares are no benefit (38%) and 20%–29% (21%), totaling 59%. There is a notable absence of products with high benefit ratios (≥70%), reflecting insurers' cautious approach to out-of-PMIS expenses. Third, regarding specialty drugs, the compensation ratio is milder than in-PMIS or out-of-PMIS reimbursement. The proportion within the 30%–39% range remains significant (22%), though with a high percentage of no benefit (42%).

Figure 5

DISTRIBUTION OF COMPENSATION RATIOS OF NON-PEIS



The distribution of compensation ratios for non-PEIs of individuals with PEIs is reported in Figure 5. It can be analyzed along three dimensions. First, in-PMIS reimbursement shows a clear differentiation, with no benefit (21 products) and 30%–39% (20 products) being the most concentrated ranges, while a subset of products offers high benefits (70%–89%, totaling 30 products). Overall, in-PMIS reimbursement is relatively favorable, with roughly half of the products providing medium or above benefits. Second, out-of-PMIS reimbursement is dominated by low or no benefit, with nearly half of the products concentrated in the no-benefit (30 products) and 20%–29% (22 products) ranges, and very few products offering high benefit ratios (≥70%), indicating weaker medical expense coverage. Finally, specialty drug coverage exhibits the most significant variability, with the highest percentage of products offering no benefit (41 products), though some products provide high benefits (25 products combined in the 60%–100% range).

Section 3 Morbidity Rate Analysis: The Prevalence of PEIs in China

In this section, we will analyze the prevalence rates of PEIs in China. Prevalence rates are an important component of morbidity rates, providing a foundation for analyzing the incidence rates of critical illnesses among individuals with PEIs, as will be discussed in Section 4.[7]

We will use data from the China Health and Retirement Longitudinal Study (CHARLS) database to comprehensively analyze prevalence rates and identify their key determinants among middle-aged and elderly individuals in China over the decade 2011–2020. We focus on 14 chronic illnesses reported by CHARLS.[8] They comprise most of the PEIs in health insurance products for the substandard population.

Our analysis will explore regional variations in illness prevalence and examine the impact of demographic characteristics, social networks, and socioeconomic status on prevalence rates.

3.1 INTRODUCTION TO THE CHARLS DATABASE

The data of this Study mainly come from the CHARLS database. It is a large-scale interdisciplinary survey project led by the National School of Development of Peking University and jointly organized and implemented by the Center for Social Science Surveys of Peking University and the Youth League Committee of Peking University. This project focuses on collecting high-quality microdata that can represent the family and personal conditions of middle-aged and elderly people aged 45 and above in China.

In terms of sampling methods, CHARLS adopts a combination of multi-stage sampling and PPS sampling. Specifically, 150 counties and districts are randomly selected from 30 provinces and municipalities across the country, excluding Tibet, Taiwan, Hong Kong, and Macao. Then, from these 150 counties and districts, 450 communities (villages) are randomly selected and, finally, 19,000 respondents from 12,400 households are chosen as the survey subjects. To utilize the best data collection models internationally and ensure the comparability of research results at the international level, CHARLS fully draws on the experiences and methods of a series of international aging survey studies represented by the Health and Retirement Study (HRS) in the United States during the survey design process.

[7] The morbidity rate comprises the incidence or prevalence rate. The prevalence rate is a measure of the number of existing cases of a disease in a population at a specific time, while incidence rate measures the rate at which new cases of a disease occur within a population over a specific period.

[8] They are hypertension, diabetes, abnormal blood lipid, cancer, lung disease, liver diseases, heart disease, stroke, kidney disease, stomach disease, mental illness, memory disorder, arthritis and asthma.

3.2 SUMMARY STATISTICS OF CHRONIC ILLNESSES

We adopt the theory of health ecology as the framework for analyzing determining factors and investigating the factors influencing the prevalence rate of chronic illnesses from three perspectives: population characteristics, social networks, and socioeconomic status.

This study incorporates 96,244 observations, spanning data from 2011 to 2020. The average age of the population in the sample is approximately 60 years old, with a balanced gender ratio. Around 80% of the samples are married, and over 75% participate in at least one social activity. The overall income level increased significantly in 2018, with approximately 40% of the population having an education level below primary school. More than 90% of the population has endowment insurance and, since 2018, the number of samples with medical insurance has significantly surpassed those without it. In the sample, over 75% of the population have rural household registration, while about 60% live in rural areas. The geographical regional situation is divided into four variables: the eastern region, the central region, the western region, and the northeastern region. The first three areas account for approximately one-third of the sample.

3.2.1 STATISTICS BY YEAR

This subsection uses data from the five years 2011, 2013, 2015, 2018 and 2020. Due to the small sample sizes in 2012, 2014 and 2016, which are not representative, the data from those three years are excluded from the statistics in this portion of the report.

According to Table 2, the average age of the survey sample in 2011 was 58.54 years old across the long-term follow-up period. The proportions of patients with hypertension, diabetes, and dyslipidemia were 43.72%, 12.20%, and 9.82%, respectively. The five most common illnesses in the sample population were hypertension, arthritis, stomach diseases, diabetes, and heart diseases. The number of patients with hypertension far exceeds that of patients with other diseases.

Table 2

SUMMARY STATISTICS IN 2011

Variable	Mean Value (range or frequency)	Chronic Illnesses	# of People and Proportion
Age (years)	58.84	hypertension	7517 (43.72)
Gender (Male) (n, %)	5964 (46.27)	diabetes	2087 (12.20)
Married or not (Yes) (n, %)	15151 (87.30)	abnormal blood lipid	1660 (9.82)
Social situation[9]	0.65	cancer	166 (0.97)
Personal income (yuan/year)	7444.31	lung disease	1680 (9.78)
Educational attainment[10] (n, %)	9444 (54.50)	liver disease	594 (3.47)
Participate in the endowment insurance (n, %)	4607 (34.70)	heart disease	2075 (12.10)
Participate in medical insurance (n, %)	15986 (93.18)	stroke	475 (2.76)
Non-agricultural household registration (n, %)	3809 (21.96)	kidney disease	967 (5.64)
Geographical region (n, %)		stomach disease	3721 (21.63)
Eastern region	5500 (31.64)	mental illness	252 (1.47)
Central region	4948 (28.47)	memory disorder	329 (1.91)
Western region	5655 (32.54)	arthritis	5597 (32.52)
Northeast region	1282 (7.38)	asthma	767 (4.46)
		Total (suffer from chronic illness)	11698 (67.78)

Summary statistics for 2020 are reported in Table 3. In 2020, the average age of the sample was 63.33 years old. The proportion of patients with hypertension was 39.90% (7,728 people), the proportion of patients with diabetes was 14.74% (2,855 people), and the proportion of patients with dyslipidemia was 26.36% (5,105 people). The five most common diseases in the sample population have remained stable.

[9] Among the eight social activities included in the survey by CHARLS, the number of sample participation is counted.

[10] CHARLS classifies education into below primary school, primary school, secondary school, high school and above. Here, the number of educated individuals is counted, that is, those with a primary school education or above.

Table 3

SUMMARY STATISTICS IN 2020

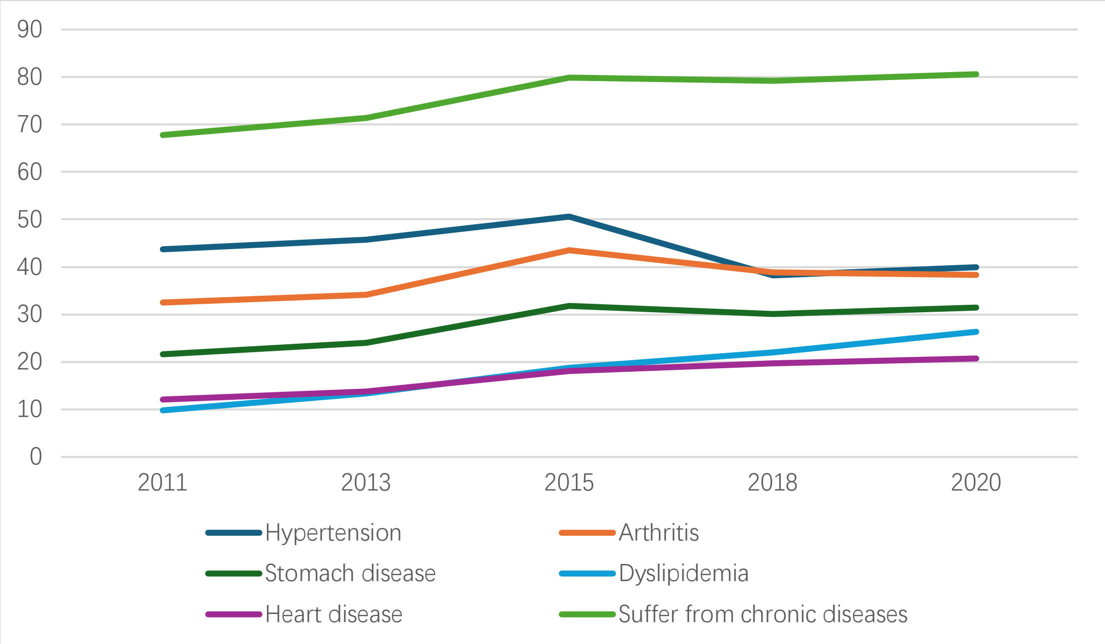
Variable	Mean Value (range or frequency)	Chronic Illnesses	# of People and Proportion
Age (years)	63.33	hypertension	7728 (39.90)
Gender (Male) (n, %)	9093 (46.88)	diabetes	2855 (14.74)
Married or not (Yes) (n, %)	16276 (83.92)	abnormal blood lipid	5105 (26.36)
Social situation	0.78	cancer	491 (2.54)
Personal income (yuan/year)	17860.94	lung disease	2759 (14.25)
Educational attainment (n, %)	11043 (56.94)	liver diseases	1395 (7.20)
Participate in the endowment insurance (n, %)	16479 (84.97)	heart disease	4017 (20.74)
Participate in medical insurance (n, %)	18461 (95.18)	stroke	1381 (7.13)
Non-agricultural household registration (n, %)	4953 (25.55)	kidney disease	2001 (10.33)
Geographical region (n, %)		stomach disease	6090 (31.45)
Eastern region	6388 (32.95)	mental illness	583 (3.01)
Central region	4759 (24.53)	memory disorder	992 (5.12)
Western region	7625 (39.31)	arthritis	7412 (38.28)
Northeast region	980 (5.05)	asthma	1172 (6.05)
		suffer from chronic illnesses	15606 (80.58)

We further summarize the overall trend. From 2011 to 2020, through the tracking data of CHARLS, we find that the prevalence of chronic illnesses showed a significant upward trend. The overall prevalence rate was 67.78% (n = 11,698) in 2011 and increased to 80.58% (n = 15,606) by 2020, with an average annual growth of approximately 1.6%. Among these 14 chronic illnesses, hypertension and arthritis have always been the most common types of diseases.

Chronic illnesses often exhibit characteristics of “dual-core drivers + coexistence of multiple conditions.” On one hand, hypertension and arthritis, which have high prevalence rates, consistently rank among the most common chronic diseases. On the other hand, the proportion of conditions such as heart disease and stomach disease has also been steadily rising.

Figure 6

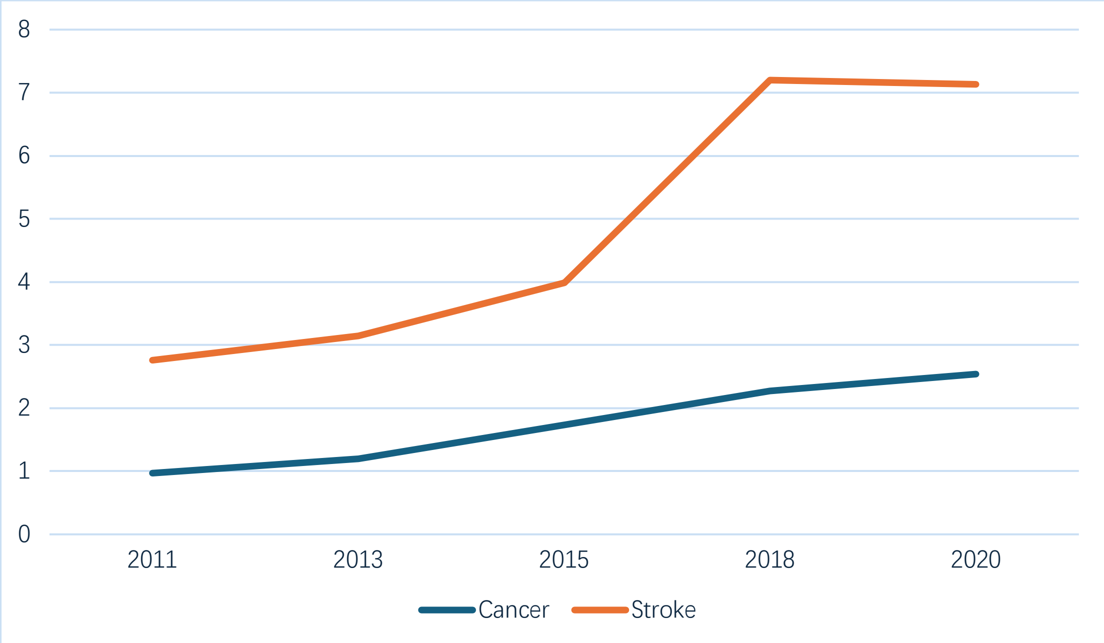
DEVELOPMENT OF PREVALENT RATE OF CHRONIC ILLNESS



We also examine the prevalence rates of two severe diseases: cancer and stroke. The results are reported in Figure 7. Although the absolute proportions of these conditions remain relatively low (both <7.20%), the number of patients has increased significantly over the past decade. As illustrated in Figure 7, the prevalence of cancer rose from 0.97% in 2011 to 2.54% in 2020, while the prevalence of stroke increased from 2.76% in 2011 to 7.13% in 2020. These trends may be attributed to environmental factors, lifestyle changes, and advancements in medical diagnostic techniques.

Figure 7

DEVELOPMENT OF THE PREVALENCE RATES OF CRITICAL ILLNESS (CANCER AND STROKE)



3.2.2 STATISTICS BY REGION

This section statistically analyzes the prevalence rates in 28 provinces from 2011 to 2020. The xix most typical chronic illnesses were selected, namely hypertension, arthritis, stomach diseases, dyslipidemia, heart diseases and diabetes. According to the definition of the National Bureau of Statistics, China's provinces can be divided into four economic regions: the eastern, central, western, and northeastern regions.

Table 4

PREVALENCE RATES OF THE POPULATION IN EACH ECONOMIC ZONE

	Year	Hypertension Rate (%)	Arthritis Rate (%)	Stomach Diseases Rate (%)	Dyslipidemia Rate (%)	Heart Disease Rate (%)	Diabetes Rate (%)
Eastern region	2011	43.91	23.56	17.98	9.35	9.82	11.73
	2013	42.83	23.69	19.58	11.93	10.77	7.74
	2015	44.56	26.88	22.01	14.93	12.30	14.78
	2018	38.99	30.42	25.45	21.97	17.19	14.18
	2020	40.43	29.62	27.24	25.88	18.71	15.71
Central region	2011	42.00	31.37	22.78	11.10	10.47	12.05
	2013	42.90	32.25	23.71	14.17	11.70	7.54
	2015	41.72	34.34	26.45	16.22	13.09	14.95
	2018	37.48	38.77	31.51	24.31	18.57	13.94
	2020	38.18	37.67	32.26	28.35	19.86	14.90
Western region	2011	43.52	42.53	24.19	7.73	12.56	12.13
	2013	45.58	42.90	26.43	10.46	13.57	5.80
	2015	41.52	45.33	29.61	12.61	15.30	12.39
	2018	38.23	48.01	34.45	19.72	19.98	10.97
	2020	38.86	47.67	34.97	23.33	20.10	12.87
Northeast region	2011	43.92	26.83	18.49	12.48	23.95	12.48
	2013	44.26	26.75	19.05	15.69	25.14	7.77
	2015	45.88	29.35	21.44	17.39	26.99	13.53
	2018	39.27	32.80	24.95	25.31	35.49	13.16
	2020	43.61	34.34	28.32	32.92	36.68	15.29

From a regional perspective, although the most common types of diseases are the same in the four major economic regions, there are still relatively obvious differences in the characteristics of the disease spectrum.

The prevalence rates of hypertension and dyslipidemia are the highest in the eastern region, reaching 40.43% and 25.88%, respectively, in 2020. It is still significantly higher than the national average level. The high prevalence rate in this region may be closely related to the accelerated urbanization process, the sedentary lifestyle of residents and the popularity of high-fat diets.

The proportions of stomach diseases and arthritis in the central region are relatively prominent, reaching 32.26% and 37.67%, respectively, in 2020. Take the Hubei Province as an example. The prevalence of arthritis has consistently been higher than 45% (46.53% in 2020), which reflects the long-term damage to joint health caused by high-intensity agricultural labor.

The prevalence rates of arthritis and stomach diseases are the highest in the western region, at 47.67% and 34.97%, respectively, in 2020. The Yunnan Province is particularly typical. In 2020, the prevalence rate of arthritis reached 52.80%, and the prevalence rate of stomach diseases was 31.47%. This may be influenced by factors such as high-altitude climate, dietary habits (such as consuming spicy food), and lower accessibility of medical resources.

The prevalence rate of heart disease in Northeast China is significantly higher than that in other regions, reaching 36.68% in 2020. Take the Heilongjiang Province as an example. The prevalence rate of heart disease was 44.66% in 2018 and remained at a high level of 43.70% in 2020. This may be related to mechanisms such as blood vessel constriction caused by low temperatures in winter and the low control rate of hypertension.

3.3 FACTORS INFLUENCING THE PREVALENCE RATE OF CHRONIC ILLNESSES

Based on the data from the CHARLS from 2011 to 2020 and the theoretical framework of health ecology, this subsection deeply explores the factors influencing the prevalence rate of diseases.

3.3.1 DEMOGRAPHIC CHARACTERISTICS

From 2011 to 2020, the average age of the sample increased from 58.84 years old to 63.33 years old. The acceleration of the aging process directly aggravates the burden of degenerative diseases. The changes in the prevalence of heart disease in Northeast China also fully reflect the influence of age. It increased by 53.2% from 23.95% in 2011 to 36.68% in 2020. As people age, the risk of heart disease significantly increases.

Gender differences also have a non-negligible influence on the prevalence of diseases. Take the data of 2020 as an example. The prevalence of diabetes among men is higher than among women, which is closely related to men’s smoking and drinking habits. However, the prevalence of arthritis among women is significantly higher than among men.

Table 5

COMPARISON OF PREVALENCE RATES BETWEEN MEN AND WOMEN

	Male	Female
Prevalence of diabetes (%)	14.74	13.85
Smoking rate (%)	32.1	2.4
Alcohol consumption rate (%)	28.6	5.2
Prevalence of arthritis (%)	41.2	34.8

3.3.2 SOCIAL NETWORK

There is a positive connection between the degree of participation in social activities and mental health. The CHARLS survey covers eight social activities. Actively participating in social activities can expand one’s social circle, enrich spiritual life, promote information exchange and emotional communication, and play an important role in maintaining mental health. The estimation results of the benchmark regression model can be seen in Table 6. Column (1) only contains the core explanatory variable, social situation; column (2) further incorporates the provincial fixed variable. All regressions controlled for the time-fixed effect.

Table 6

BENCHMARK REGRESSION RESULT

Variable	(1)	(2)
Social situation	0.004***	0.004***
	(0.001)	(0.001)
Constant term	-0.027***	-0.029***
	(0.004)	(0.001)
Provincial-fixed effect	No	Yes
Time-fixed effect	Yes	Yes
Observed value	90977	90977
F value	54.51	54.55

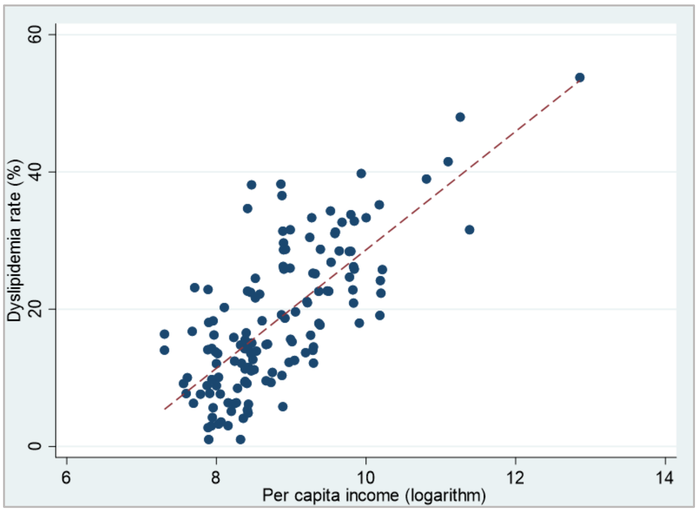
Note: The values in parentheses are robust standard errors; ***, ** and *, respectively, indicate significance at the 1%, 5% and 10% levels.

3.3.3 SOCIOECONOMIC STATUS

Income is one of the main socioeconomic-status factors. The average annual income of the sample population increases from 7,444.31 yuan in 2011 to 20,879.89 yuan in 2018, and the economic level has been significantly improved. However, it is worrying that the prevalence of metabolic diseases has risen accordingly. This phenomenon partially confirms the “nutritional transition theory.” In the early stage of economic development, people’s excessive consumption of high-calorie foods led to a continuous increase in the risk of metabolic diseases (Popkin, 2001). Figure 8 shows that there is a positive relationship between per capita income and the prevalence rate of dyslipidemias in the sample.

Figure 8

RELATIONSHIP BETWEEN PER CAPITA INCOME AND DYSLIPIDEMIAS



Section 4 Morbidity Rate Analysis: Incidence Rate of Critical Illness among Substandard Populations

In this section, we will analyze the incidence rate, another component of the morbidity rate, of critical illness in China among substandard populations. We establish a parametric model based on the backward derivation of incidence rates from single-period prevalence rates. Given limited data and only summary information on mortality and prevalence rates, we estimate the incidence rate from a healthy state to a diseased state using multi-state continuous and time-inhomogeneous Markov models. Our model differentiates between age groups, gender groups, and chronic illness groups, based on the findings in Section 3.[11]

Specifically, we first validate the method for calculating the incidence rates of critical illnesses among the standard population in China. Second, we develop a methodology to estimate the incidence rate for critical illnesses among individuals with PEIs, such as hypertension, diabetes, and hyperlipidemia. This approach allows us to derive the incidence rates of critical illnesses across different age groups in China with underlying diseases. Finally, we address the health insurance premium pricing problem by incorporating the calculated incidence rates of critical illnesses.

The advantage of this model is that, unlike past empirical incidence rates used in cohort studies, it relies solely on single-period data to estimate incidence rates, significantly reducing data availability requirements.

4.1 MODELING INCIDENCE RATE OF CRITICAL ILLNESSES

In actuarial practice, constructing an accurate health insurance model typically requires extensive statistical data. However, national health statistics in China are limited and often rely on disease prevalence rates rather than incidence rates. Without detailed incidence data, this model estimates incidence rates using a multistate approach, leveraging only summary information on mortality and morbidity.

It is crucial to distinguish between prevalence and incidence rates, as they serve different purposes and are collected with varying ease. Prevalence rates represent the proportion of the population currently affected by a disease at a given time, while incidence rates reflect the proportion of new cases occurring annually. These metrics differ significantly: for chronic diseases, the incidence rate may be low, but the prevalence rate remains high due to the cumulative effect of past incidence. Conversely, short-term curable diseases may exhibit high incidence rates but low prevalence rates as cases resolve quickly.

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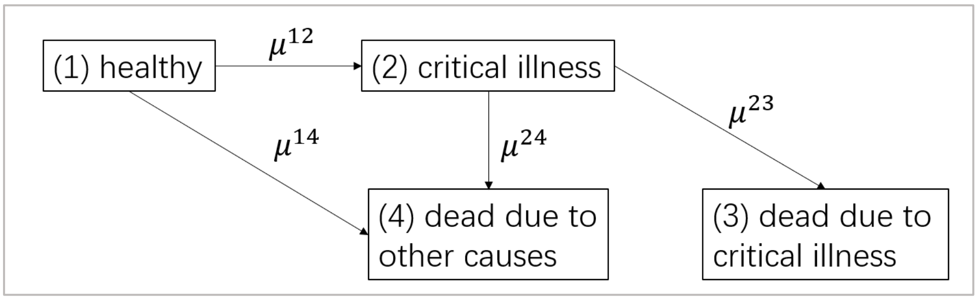
[11] Currently, the model considers age and gender as primary factors but could easily be expanded to include regional and socioeconomic status variations (as stated in Section 3) as prevalence data for PEIs becomes available across these dimensions.

4.1.1 BASIC MODEL

We follow the method proposed by Baione and Levantesi (2014). Letting [0, T] be a fixed finite time horizon and $\{S(t)\}_{t\in[0,T]}$ a Markovian process describing the development of a single policy in continuous time, critical illness is modeled by a multiple state model with state space S = {1 = healthy, 2 = critical illness sufferer, 3 = dead due to critical illness, 4 = dead due to other causes} and a set of transitions according to Figure 9, assuming S(0) = 1.

Figure 9

SET OF STATES AND SET OF TRANSITIONS



Let *x* (*x*≥0) denote the age at policy entry, and let *S*(*t*) represent the state of the policyholder at time *t*. The transition probabilities—defining the likelihood that a policyholder is in state *j* at age *x*+*t*, given they were in state *i* at age *x*—are specified as follows:

$${}_tp_x^{ij} = P\{S(x+t) = j | S(x) = i\} \quad i \neq j.$$

And the corresponding transition intensities:

$$\mu^{ij}(x) = \lim_{t\to 0}\left(\frac{{}_tp_x^{ij}}{t}\right) \quad t \in [0,T], i,j \in S, i \neq j.$$

While the probability of a policyholder in state *i* at age *x* to remain in the same state up to age *x* + *t* is:

$${}_tp_x^{ii} = P\{S(x+z) = i \quad \forall z \in [0,t] | S(x) = i\}.$$

Given the transition intensities of the multiple-state model, the corresponding probabilities are solutions of the Kolmogorov forward differential equations. The transition probabilities according to the model in Figure 9 are:

$${}_tp_x^{11} = exp\left\{-\int_0^t [\mu^{12}(x+u) + \mu^{14}(x+u)]du\right\} \tag{4.1}$$

$${}_tp_x^{12} = \int_0^t [\,{}_up_x^{11}\mu^{12}(x+u)\,{}_{t-u}p_{x+u}^{22}]du \tag{4.2}$$

$${}_tp_x^{22} = exp\left\{-\int_0^t [\mu^{23}(x+u) + \mu^{24}(x+u)]du\right\}. \tag{4.3}$$

We exclude the possibility of recovery from the diseased state (i.e., we do not allow transitions from state 2 back to state 1).

Our method estimates transition intensities in scenarios where data is scarce, relying solely on aggregated mortality and morbidity statistics for inference.

First, we have to assign a function to the mortality intensities of the model. We assume that mortality intensities $\mu^{14}(x)$ and $\mu^{23}(x)$ are described by two independent Gompertz–Makeham (GM) functions. Second, a function to the transition intensities from healthy to ill is defined. When the incidence rate of sickness is available, the $\mu^{12}(x)$ can be directly estimated from data. Conversely, if only the prevalence rate of sickness is available, a method based on the probability of being sick could be implemented.

4.1.2 DATA

The data in this model are derived from the life table of China's life insurance industry experience (2023) and the incidence table of China's life insurance industry experience of critical illnesses (2020). The life table is issued by the China Association of Actuaries and is prepared to more accurately reflect the life characteristics and risk status of the current Chinese population. The national population census data and death statistics of various regions in recent years are collected and sorted out as the original data source for the preparation of the life table. Advanced statistical methods and models are used to process and analyze the data to obtain mortality tables for different age groups.

The incidence rate table is issued by the China Banking and Insurance Regulatory Commission, which is used to standardize the assessment of legal reserve and product pricing of critical disease insurance, covering different disease definition versions, and providing incidence data by age and gender.

The accuracy of the above model will be verified by selecting the non-elderly-care men and women table (CL1) in the life table, the experience incidence rate table (CI1) of six diseases (2007 definition) in the incidence rate table and the death rate table due to critical illnesses (K1) as the original data.

Then, we have datasets as follows:

(a) Prevalence rate of critical illnesses in China by age group and gender.

(b) Mortality rates caused by critical illnesses in China by age group and gender.

(c) Mortality table in China by age group and gender, where the mortality rate of the life table is:

$$\mu(x) = \mu^{14}(x) + \mu^{24}(x) + \mu^{23}(x).$$

Table 7 shows prevalence rates of sickness (data of type (a)), while Table 8 shows the mortality rates by main causes of sickness (data of type (b)) for males and females, Table 9 shows the mortality rates (data of type (c)).

Table 7

PREVALENCE RATE OF CRITICAL ILLNESSES IN CHINA BY AGE GROUP AND GENDER (RATES PER 1000)

Age Group	Males	Females
0-9	1.52	1.26
10-19	1.77	2.37
20-29	6.20	11.29
30-39	15.22	29.15
40-49	29.26	52.92
50-59	60.59	64.87
60-69	112.18	93.07
70-79	187.07	145.12

Table 8

MORTALITY RATES CAUSED BY CRITICAL ILLNESSES IN CHINA BY AGE GROUP AND GENDER (RATES PER 1000)

Age Group	Males	Females
0-9	0.36	0.32
10-19	0.51	0.41
20-29	0.89	0.55
30-39	2.85	1.40
40-49	9.55	4.39
50-59	29.17	13.02
60-69	76.57	36.78
70-79	165.98	89.11

Table 9

MORTALITY TABLE IN CHINA BY AGE GROUP AND GENDER (RATES PER 1000)

Age Group	Males	Females
0-9	1.34	1.04
10-19	1.99	1.13
20-29	3.87	1.56
30-39	5.52	1.76
40-49	10.56	3.44
50-59	21.77	8.18
60-69	45.88	25.02
70-79	157.02	111.23

4.1.3 MODEL ASSUMPTIONS

This model has the following assumptions:

(a) The critically ill population has no possibility of recovery, that is, the situation from state (2) to state (1) is not considered.

(b) The death rate due to other causes is the same for critically ill individuals as for healthy individuals.

(c) All mortality rates conform to the Gompertz–Makeham (0,2) function. The specific parameter is solved and shown in Table 10.

Table 10

PARAMETERS OF THE GM MODELS OF HEALTHY AND SICKNESS MORTALITY

Gender	Age	Parameters of p_x^{14}		Parameters of p_x^{23}	
		$exp(\beta_1^h)$	β_2^h	$exp(\beta_1^{dd})$	β_2^{dd}
Male	0-19	0.0003	0.0818	0.2243	0.0150
	20-79	0.0003	0.0818	0.0758	0.0330
Female	0-19	0.0001	0.0949	0.2731	-0.0280
	20-79	0.0001	0.0949	0.0127	0.0516

4.1.4 RESULTS

For pricing purposes, it is suitable to arrange a multiple life table for each reference age of the coverage. Consequently, we have to calculate the values of parameters $\sigma_1, \sigma_2, \dots, \sigma_n$ and then define the transition intensity $\mu^{12}(x)$ by age.

Estimate $\mu^{12}(x)$ for age groups starting from data in Table 7, via the iterative procedure described in (Baione and Levantesi, 2014). In this way, the multiple life table for each reference age is based on the assumption that $\mu^{12}(x)$ is a piecewise constant function.

Table 11

VALUES OF PARAMETERS $\sigma_1, \sigma_2, \dots, \sigma_n$ BY AGE GROUP AND GENDER (RATES PER 1000)

Age Group	Males	Females
0-9	0.43	0.31
10-19	0.53	0.44
20-29	1.05	1.11
30-39	2.49	2.44
40-49	4.62	3.70
50-59	9.76	6.67
60-69	17.89	12.04
70-79	29.65	21.45

Figure 8 shows both raw and graduated prevalence rates, where the graduation methods used are cubic spline.

Figure 9 reports the estimates of transition intensities for males and females according to the proposed approach and graduation. From the numerical results, we can see that the incidence rate of critical illnesses estimated by this model is similar to the results in the empirical incidence table of critical illnesses in China's life insurance industry. Therefore, the feasibility of the model is verified.

Figure 10

RAW AND GRADUATED PREVALENCE RATES

Males Females

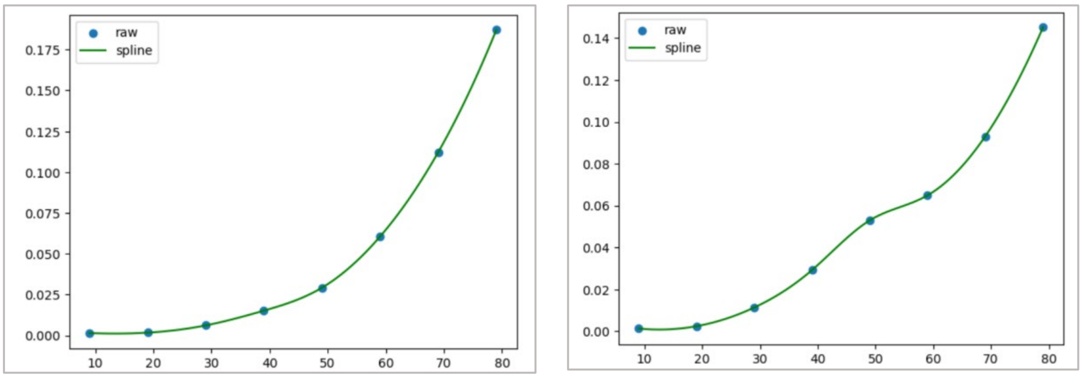
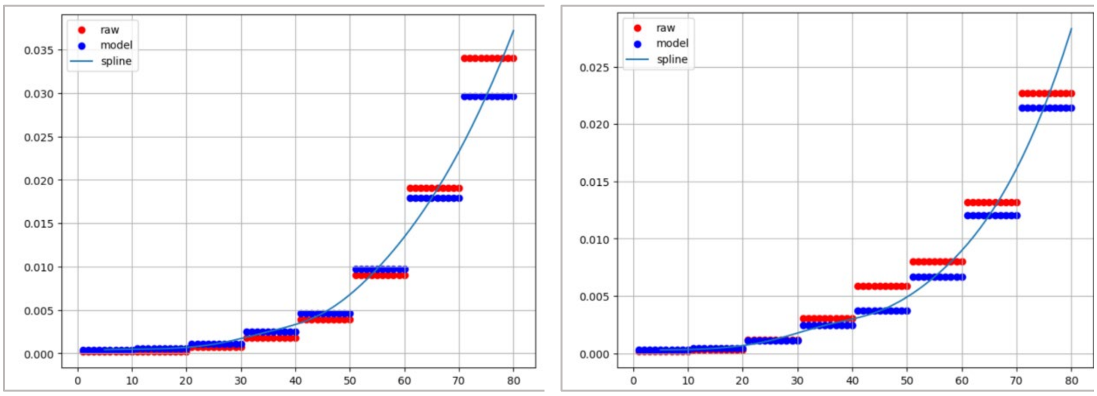


Figure 11

RAW, ESTIMATED AND GRADUATED INCIDENCE RATES

Males Females



4.2 MODELING INCIDENCE RATE OF CRITICAL ILLNESSES OF INDIVIDUALS WITH PEIS

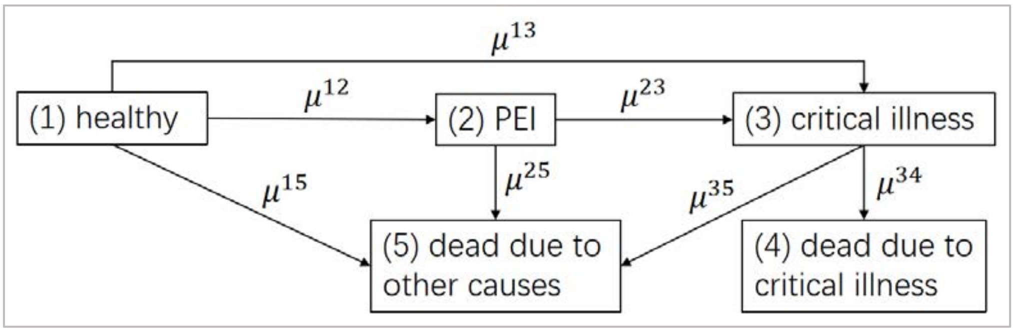
After the validation of the basic model (Baione and Levantesi, 2014), we further augment the model by adding a state to the original four-state Markov model, which is the disease status of the PEIs. The new model can estimate the incidence rate of critical illnesses among the population with PEIs.

4.2.1 AUGMENTED MODEL

Letting [0, T] be a fixed finite time horizon and $\{S(t)\}_{t\in[0,T]}$ a Markovian process describing the development of a single policy in continuous time, critical illness is modeled by a multiple state model with state space S = {1 = healthy, 2 = PEI sufferer, 3 = critical illness sufferer, 4 = dead due to critical illness, 5 = dead due to other causes} and a set of transitions according to Figure 12, assuming S(0) = 1.

Figure 12

SET OF STATES AND SET OF TRANSITIONS



Given the transition intensities of the multiple-state model, the corresponding probabilities are solutions of the Kolmogorov forward differential equations. The transition probabilities according to the model in Figure 12 are:

$$ {}_tp_x^{11} = exp\left\{-\int_0^t [\mu^{12}(x+u) + \mu^{13}(x+u) + \mu^{15}(x+u)]du\right\} \quad (4.5)$$

$$ {}_tp_x^{12} = \int_0^t [\,{}_up_x^{11}\,\mu^{12}(x+u)\,{}_{t-u}p_{x+u}^{22}]du \quad (4.6)$$

$$ {}_tp_x^{13} = \int_0^t [\,{}_up_x^{11}\,\mu^{13}(x+u)\,{}_{t-u}p_{x+u}^{33}]du \quad (4.7)$$

$$ {}_tp_x^{22} = exp\left\{-\int_0^t [\mu^{23}(x+u) + \mu^{25}(x+u)]du\right\} \quad (4.8)$$

$$ {}_tp_x^{23} = \int_0^t [\,{}_up_x^{22}\,\mu^{23}(x+u)\,{}_{t-u}p_{x+u}^{33}]du \quad (4.9)$$

$$ {}_tp_x^{33} = exp\left\{-\int_0^t [\mu^{35}(x+u) + \mu^{34}(x+u)]du\right\} \quad (4.10)$$

We disregard the possibility of recovery from the diseased state (i.e., we do not consider the transition 2 → 1, 3 → 2, 3 → 1).

We have to assign a function to the mortality intensities of the model. Assume that mortality intensities $\mu^{15}(x)$ and $\mu^{34}(x)$ are described by two independent Gompertz–Makeham (GM) functions. For $\mu^{25}(x)$ and $\mu^{35}(x)$, we have no data about the mortality following illness for causes other than critical illness. We assume that the mortality of ill people from causes other than critical illness exceeds the mortality of healthy ones by an extra mortality of γ_1 and γ_2, i.e.:

$\mu^{25}(x) = \mu^{15}(x)(1+\gamma_1)$

$\mu^{35}(x) = \mu^{15}(x)(1+\gamma_2)$.

Once the mortality intensity functions are defined, one can determine the transition intensity from healthy to ill. When the incidence rate of sickness is available, the $\mu^{23}(x)$ can be directly estimated from data. Conversely, if only the prevalence rate of sickness is available, a method based on the probability of being sick could be implemented.

Setting a reference initial age x_0, where all the policyholders are healthy ($S(x_0) = 1$), the prevalence rates of sickness, f_x (where: $x = x_0 + s, s > 0$), can be considered as the probability of being ill at age x for a life aged x_0:

$$f_{x+t} = \frac{{}_tp_x^{12} + {}_tp_x^{22} + {}_tp_x^{23}}{{}_tp_x^{11} + {}_tp_x^{12} + {}_tp_x^{13} + {}_tp_x^{22} + {}_tp_x^{23} + {}_tp_x^{33}} \tag{4.11}$$

Define $\mu^{1+2,3}(x)$ as the incidence rate of critical disease in all populations. There is a relational equation:

$$\mu^{1+2,3}(x+t) = \frac{{}_tp_x^{11}}{{}_tp_x^{11} + {}_tp_x^{12} + {}_tp_x^{22}}\mu^{13} + \frac{{}_tp_x^{12} + {}_tp_x^{22}}{{}_tp_x^{11} + {}_tp_x^{12} + {}_tp_x^{22}}\mu^{23} \tag{4.12}$$

In addition, given the situation of the critically ill population, the proportion of the underlying disease history of the critically ill population can be obtained by:

$$a = \frac{{}_tp_x^{23}}{{}_tp_x^{13} + {}_tp_x^{23}} \tag{4.13}$$

In the above formulas, $\mu^{15}(x)$, $\mu^{25}(x)$, $\mu^{35}(x)$, $\mu^{34}(x)$ are known mortality data, and the unknown parameters are incidence rate data $\mu^{12}(x)$, $\mu^{13}(x)$, $\mu^{23}(x)$. Substituting formulas (4.5)-(4.10) into formulas (4.11)-(4.13) and combining formulas (4.11)-(4.13), the incidence rate data $\mu^{12}(x)$, $\mu^{13}(x)$, $\mu^{23}(x)$ can be obtained by the numerical dispersion method.

We suppose that transition intensity from healthy to ill can be described by a piecewise constant function (for k = 0, 1, . . . , n − 2) as follows:

$$\mu^{12}(x) = \begin{cases} 0 & x \le x_0 \\ \rho_{k+1} & x_k < x \le x_{k+1} \\ \rho_n & x_{n-1} < x \end{cases}$$

$$\mu^{13}(x) = \begin{cases} 0 & x \le x_0 \\ \tau_{k+1} & x_k < x \le x_{k+1} \\ \tau_n & x_{n-1} < x \end{cases}$$

$$\mu^{23}(x) = \begin{cases} 0 & x \le x_0 \\ \sigma_{k+1} & x_k < x \le x_{k+1}. \\ \sigma_n & x_{n-1} < x \end{cases}$$

where n is equal to the number of prevalence rates available from statistical data.

To solve the transition probability, we fix the parameters r and s of GM as r = 0 and s = 2.

We suppose that $\mu^{15}(x) \approx GM^{15}(0,2)$. In the formula, we have:

$$\mu^{15}(x) = \exp(\beta_1^h + \beta_2^h x) \quad \beta_1^h, \beta_2^h > 0$$

where β_1^h, β_2^h are the GM parameters for healthy people. While the mortality for critical illness is assumed to follow a $GM^{34}(0,2)$ model, where β_1^{dd}, β_2^{dd} are the GM parameters for dread disease sufferers:

$$\mu^{34}(x) = \exp(\beta_1^{dd} + \beta_2^{dd} x) \quad \beta_1^{dd}, \beta_2^{dd} > 0.$$

To solve for the incidence rate, first, the mortality data is used to fit the parameters in the two GM functions, and then the $\mu^{15}(x)$, $\mu^{25}(x)$, $\mu^{35}(x)$ and $\mu^{34}(x)$ are substituted into the formulas (4.5)-(4.10). By discretizing the definite integral in the above model, $\rho_1,\ \tau_1,\ \sigma_1$ can be obtained, and the incidence rate $\mu^{23}(x)$ of each age group can be obtained iteratively.

4.2.2 DATA

The data used in our analysis can be categorized into four groups:[12] first, mortality data, which are derived from the non-elderly-care-business life tables for men and women (CL1) in China's Life Insurance Industry Experience Life Table (2023); second, critical illness data, which are sourced from China's Life Insurance Industry Experience Incidence Table for Critical Illnesses (2020) and include the experience incidence rate table for six diseases (2007 definition) (CI1), the experience incidence rate table for severe acute myocardial infarction (2020 definition) (CI8), the experience incidence rate table for severe stroke (2020 definition) (CI9), and the mortality rate table due to critical illnesses (K1 and K3); third, prevalence data for PEIs (hypertension, diabetes, and hyperlipidemia), which are extracted from the 2013 National Health Services Survey (Center for Health and Information, 2013); and fourth, diagnose information for individuals with critical illnesses in one city within the Yangtze River Delta. We obtain data (e) from this data source.

To summarize, we have data as follows:

(a) The prevalence rate of people reporting critical illnesses (severe acute myocardial infarction, severe stroke) in China by age group and gender.

(b) The mortality rates caused by critical illnesses in China by age group and gender.

(c) The prevalence rate of people reporting PEIs (hypertension, diabetes, and hyperlipidemia) in China by age group and gender.

(d) The mortality table in China by age group and gender.

[12] We would like to thank the team of Jin Feng at Fudan University for sharing part of the data.

(e) The prevalence rate of PEIs among the critically-ill population.

Tables 12 through 15 show the prevalence rate of the PEIs of each type of critically-ill population (acute myocardial infarction/ stroke) we obtained from the data (e).

Table 12

PREVALENCE RATE OF HYPERTENSION (ICD-10 CODE: I10) OF CRITICALLY-ILL POPULATION

Age Group	Acute Myocardial Infarction		Stroke	
	Male	Female	Male	Female
0-17				
18-24	0.00%		20.00%	0.00%
25-34	32.65%	40.00%	51.28%	19.05%
35-44	55.31%	41.67%	72.35%	47.54%
45-54	61.15%	54.21%	73.67%	53.70%
55-64	70.11%	64.78%	77.97%	67.66%
65-74	74.90%	75.89%	79.89%	77.76%
75 and above	77.31%	79.94%	77.68%	80.25%

Table 13

PREVALENCE RATE OF DIABETES (ICD-10 CODE: E11) OF CRITICALLY-ILL POPULATION

Age Group	Acute Myocardial Infarction		Stroke	
	Male	Female	Male	Female
15-34	20.41%	0.00%	15.91%	4.35%
35-44	26.88%	35.42%	24.88%	22.95%
45-54	32.50%	25.70%	40.13%	12.96%
55-64	39.08%	34.36%	45.21%	35.93%
65 and above	36.33%	36.88%	36.85%	36.98%

Table 14

PREVALENCE RATE OF HYPERLIPIDEMIA (ICD-10 CODE: E78.500) OF CRITICALLY-ILL POPULATION

Age Group	Acute Myocardial Infarction		Stroke	
	Male	Female	Male	Female
15-24	100.00%		20.00%	
25-34	26.53%	0.00%	17.95%	0.00%
35-44	25.63%	18.75%	20.74%	9.84%
45-54	19.05%	21.96%	21.02%	14.81%
55-64	14.25%	19.76%	16.52%	22.93%
65-74	9.86%	16.26%	12.13%	19.97%
75 and above	4.48%	8.14%	5.91%	10.36%

Table 15

PREVALENCE RATE OF HYPERTENSION OR DIABETES OR HYPERLIPIDEMIA OF CRITICALLY-ILL POPULATION

Age Group	Acute Myocardial Infarction		Stroke	
	Male	Female	Male	Female
15-24	100.00%		20.00%	
25-34	55.10%	40.00%	56.41%	19.05%
35-44	71.25%	60.42%	81.11%	52.46%
45-54	75.09%	65.42%	84.71%	61.73%
55-64	81.88%	77.74%	88.99%	80.04%
65-74	83.71%	84.67%	88.75%	87.05%
75 and above	82.31%	84.81%	83.92%	85.57%

4.2.3 MODEL ASSUMPTIONS

This model has the following assumptions:

(a) The ill population has no possibility of recovery. Namely, the situation from state (2) to state (1), from state (3) to state (1), and from state (3) to state (2) are not considered.

(b) The death rate due to other causes is the same for critically-ill individuals as for healthy individuals.

(c) All mortality rates conform to the GM (0, 2) function.

4.2.4 RESULTS

As described in subsection 4.2.1, we calculate the values of parameters $\sigma_1, \sigma_2, \dots, \sigma_n$ and, thus, the transition intensity $\mu^{23}(x)$ by age. Therefore, $\mu^{23}(x)$ is a piecewise constant function. We then can solve for the incidence rate of critical illness conditional on PEIs.

Table 16

ESTIMATED CRITICAL ILLNESS INCIDENCE RATE CONDITIONAL ON HYPERTENSION BY AGE GROUP AND GENDER (RATES PER 1000)

Critical Illness	Age Group	Male			Female		
		Healthy	Hypertension Sufferers	All Population	Healthy	Hypertension sufferers	All population
Myocardial infarction	25-34	0.07	0.28	0.12	0.01	0.06	0.01
	35-44	0.22	1.25	0.54	0.02	0.13	0.05
	45-54	0.55	2.44	1.35	0.07	0.41	0.21
	55-64	0.84	3.60	2.38	0.13	1.11	0.71
	65-74	1.00	5.06	3.73	0.07	2.72	1.93
	75 and above	2.07	6.34	5.12	1.38	3.67	3.07
Stroke	25-34	0.02	0.14	0.04	0.01	0.03	0.01
	35-44	0.03	0.49	0.17	0.02	0.14	0.05
	45-54	0.10	1.09	0.52	0.08	0.50	0.26
	55-64	0.18	1.69	1.02	0.11	1.50	0.92
	65-74	0.24	2.95	2.06	0.07	3.29	2.32
	75 and above	1.38	4.38	3.53	1.58	4.33	3.62

Table 17

ESTIMATED CRITICAL ILLNESS INCIDENCE RATE CONDITIONAL ON DIABETES BY AGE GROUP AND GENDER (RATES PER 1000)

Critical Illness	Age Group	Male			Female		
		Healthy	Diabetes Sufferers	All Population	Healthy	Diabetes Sufferers	All Population
Myocardial infarction	15-34	0.06	0.37	0.07			
	35-44	0.43	1.74	0.54	0.03	0.98	0.05
	45-54	1.06	3.15	1.35	0.16	1.15	0.21
	55-64	1.85	4.28	2.38	0.54	1.80	0.71
	65 and above	3.25	5.72	3.86	1.68	3.18	2.03
Stroke	15-34	0.02	0.11	0.03	0.01	0.09	0.01
	35-44	0.14	0.51	0.17	0.04	0.65	0.05
	45-54	0.36	1.49	0.52	0.23	0.71	0.26
	55-64	0.71	2.13	1.02	0.68	2.45	0.92
	65 and above	1.84	3.30	2.19	2.01	3.83	2.44

Table 18

ESTIMATED CRITICAL ILLNESS INCIDENCE RATE CONDITIONAL ON HYPERLIPIDEMIA BY AGE GROUP AND GENDER (RATES PER 1000)

Critical Illness	Age Group	Male			Female		
		Healthy	Hypertension Sufferers	All Population	Healthy	Hypertension Sufferers	All Population
Myocardial infarction	15-24						
	25-34	0.09	0.92	0.12			
	35-44	0.43	2.13	0.54	0.04	0.67	0.05
	45-54	1.18	3.57	1.35	0.17	1.28	0.21
	55-64	2.19	4.87	2.38	0.61	1.82	0.71
	65-74	3.57	6.42	3.73	1.76	3.70	1.93
	75 and above	5.08	6.33	5.12	3.01	3.95	3.07
Stroke	15-24						
	25-34	0.04	0.23	0.04			
	35-44	0.14	0.54	0.17	0.04	0.36	0.05
	45-54	0.44	1.51	0.52	0.23	1.05	0.26
	55-64	0.92	2.43	1.02	0.77	2.75	0.92
	65-74	1.92	4.36	2.06	2.03	5.49	2.32
	75 and above	3.44	5.75	3.53	3.46	5.91	3.62

Table 19

ESTIMATED CRITICAL ILLNESS INCIDENCE RATE CONDITIONAL ON HYPERTENSION OR DIABETES OR HYPERLIPIDEMIA BY AGE GROUP AND GENDER (RATES PER 1000)

Critical Illness	Age Group	Male			Female		
		Healthy	Hypertension Sufferers	All Population	Healthy	Hypertension Sufferers	All Population
Myocardial infarction	25-34	0.06	0.73	0.12	0.01	0.39	0.01
	35-44	0.19	1.83	0.54	0.02	0.53	0.05
	45-54	0.51	2.92	1.35	0.09	0.76	0.21
	55-64	0.86	3.87	2.38	0.26	1.41	0.71
	65-74	1.46	5.36	3.73	0.64	3.02	1.93
	75 and above	2.66	6.39	5.12	1.59	3.69	3.07
Stroke	25-34	0.02	0.28	0.04	0.01	0.17	0.01
	35-44	0.04	0.66	0.17	0.02	0.47	0.05
	45-54	0.12	1.27	0.52	0.12	0.87	0.26
	55-64	0.23	1.81	1.02	0.30	1.89	0.92
	65-74	0.56	3.14	2.06	0.65	3.75	2.32
	75 and above	1.67	4.49	3.53	1.77	4.38	3.62

The estimates of transition intensities are shown in Figures 13 to 16 for males and females according to the proposed approach.

Figure 13

ESTIMATED CRITICAL ILLNESS INCIDENCE RATE CONDITIONAL ON HYPERTENSION

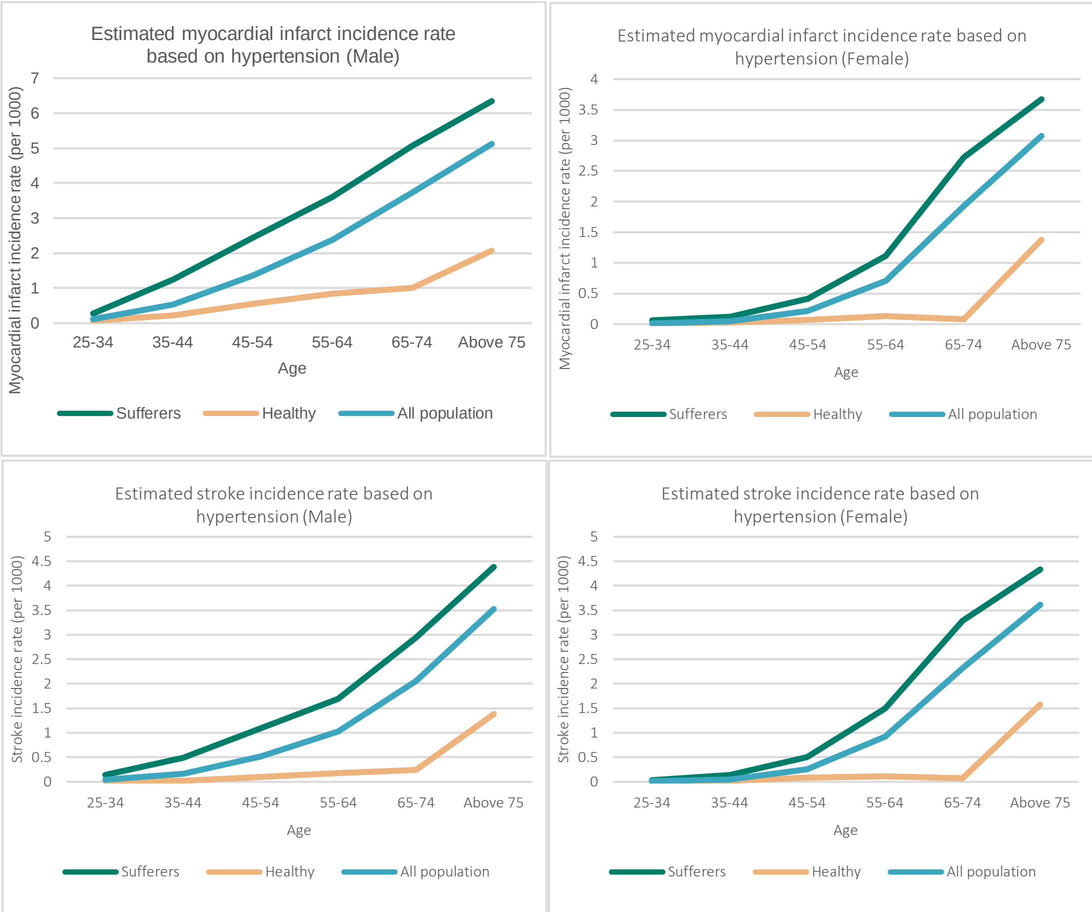


Figure 14

ESTIMATED CRITICAL ILLNESS INCIDENCE RATE CONDITIONAL ON DIABETES

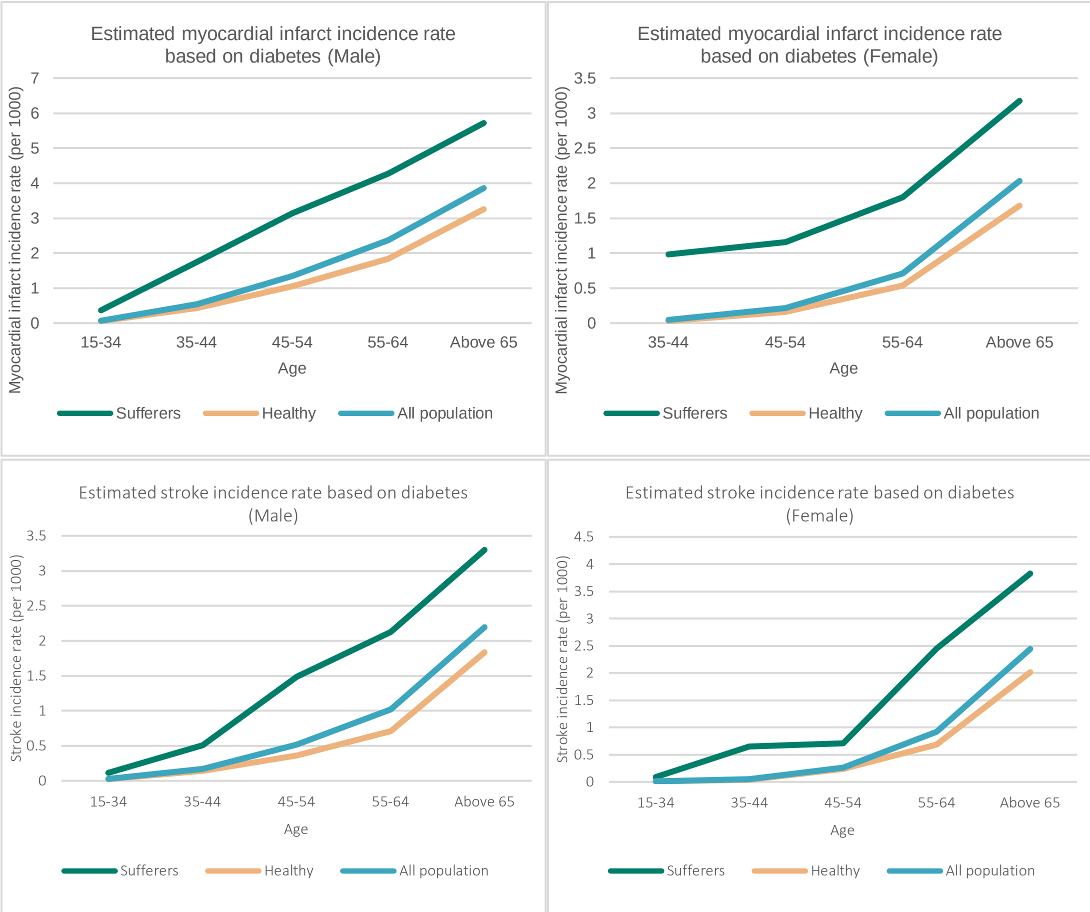


Figure 15

ESTIMATED CRITICAL ILLNESS INCIDENCE RATE CONDITIONAL ON HYPERLIPIDEMIA

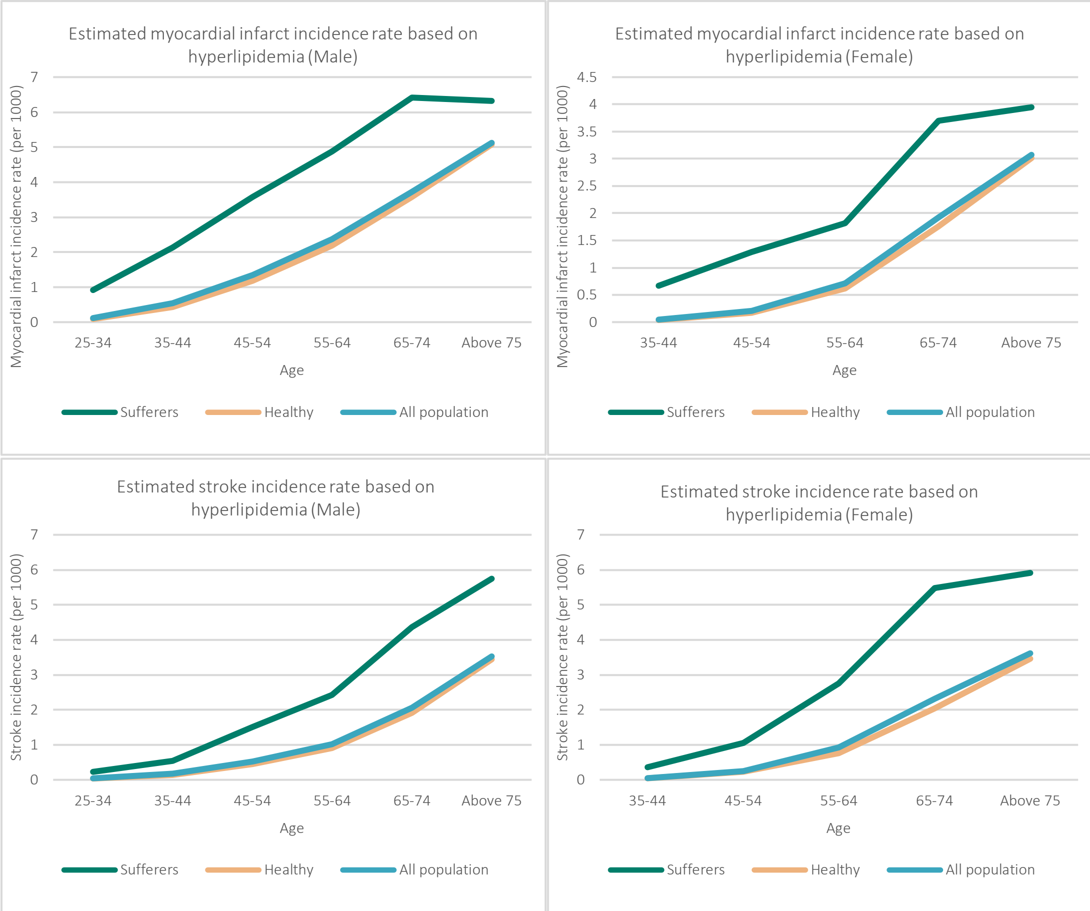
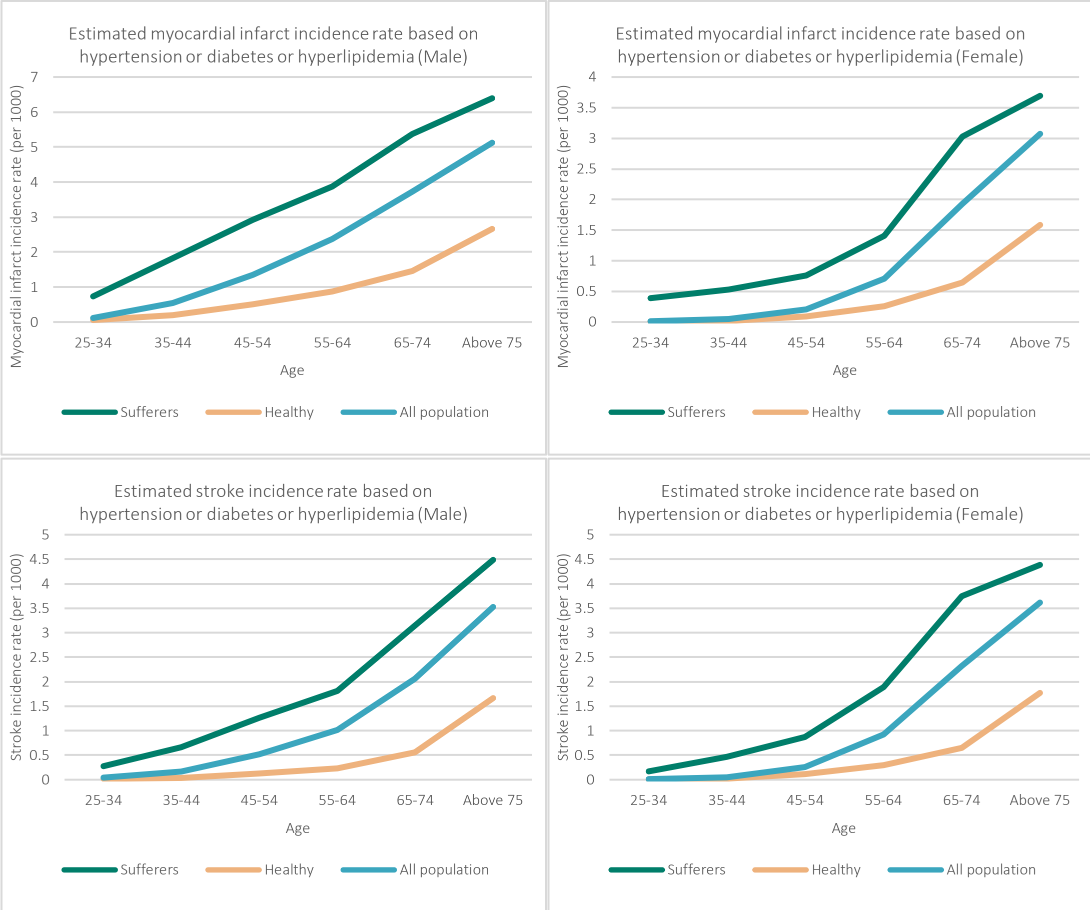


Figure 16

ESTIMATED CRITICAL ILLNESS INCIDENCE RATE CONDITIONAL ON HYPERTENSION OR DIABETES OR HYPERLIPIDEMIA



From the above numerical results, we can see that for patients with hypertension, the incidence rate of critical illnesses is about 5-10 times higher than that of healthy people. Among them, the incidence rate of acute myocardial infarction in female patients has increased more. From the perspective of age, the impact of hypertension on the incidence rate of critical illnesses is generally increasing with the increase of age. However, in the population aged 75 and above, the impact of hypertension on the incidence rate of critical illnesses has decreased. The possible reason is that for the elderly, the prevalence of hypertension has greatly increased, and its impact on health is not as significant as other factors.

For patients with diabetes, the incidence rate of critical illnesses is about 1-4 times higher than that of healthy people, and the incidence rate of female patients has increased even more. From the perspective of age, the impact is usually smaller and smaller with the increase in age. The possible reason is that it is difficult to adhere to regular treatment and management plans due to busy work, the fast pace of life and other reasons.

For patients with hyperlipidemia, the incidence rate of critical illnesses is about 1-8 times higher than that of healthy people, and the incidence rate of female patients has increased even more. From the perspective of age, the impact is usually smaller and smaller with the increase in age. The possible reason is that the blood vessel wall is relatively smooth, soft, and elastic in the young and middle-aged. Hyperlipidemia will deposit a large amount of lipids on the blood vessel wall, likely leading to the thickening and weakening of the blood vessel wall, leading to atherosclerosis. However, due to the aging and reduced elasticity of the vascular wall, the further damage of hyperlipidemia to the vascular wall is relatively mild in older adults.

4.2.5 ROBUSTNESS TESTS

We will conduct a robustness test on the model by testing the sensitivities of the two most important parameters:

(a) The prevalence rate of people reporting PEIs (hypertension, diabetes, and hyperlipidemia) in China by age group and gender.

(b) The prevalence rate of PEIs among the critically-ill population.

First, we replace parameter (a), which used the data from the 2013 National Health Services Survey (Center for Health and Information, 2013) mentioned earlier, with the data from the Blue Book of Meinian Health Check-up Data in 2023.[13] The results are as follows:

[13] The data in the "Blue Book" is sourced from samples extracted by Meinian Onehealth Healthcare from nearly 600 physical examination centers across the country in 2023. The sample size reached 19.81 million, covering 31 provinces, autonomous regions, and municipalities directly under the central government in China. https://finance.sina.com.cn/stock/roll/2024-06-17/doc-inayzwya0067216.shtml

Table 20

ESTIMATED CRITICAL ILLNESS INCIDENCE RATE CONDITIONAL ON HYPERTENSION BY AGE GROUP AND GENDER (RATES PER 1000)

Critical Illness	Age Group	Male			Female		
		2013 NHSS	2023 Meinian	Diff.	2013 NHSS	2023 Meinian	Diff.
Myocardial infarction	25-34	0.28	0.28	0.33%	0.06	0.07	16.12%
	35-44	1.25	1.26	1.15%	0.13	0.14	11.19%
	45-54	2.44	2.33	-4.69%	0.41	0.51	22.79%
	55-64	3.60	3.61	0.24%	1.11	1.12	0.50%
	65-74	5.06	4.75	-6.29%	2.72	2.36	-13.24%
	75 and above	6.34	6.20	-2.31%	3.67	3.59	-2.33%
Stroke	25-34	0.14	0.13	-10.77%	0.03	0.03	6.12%
	35-44	0.49	0.37	-24.15%	0.14	0.15	6.44%
	45-54	1.09	1.06	-3.05%	0.50	0.61	22.40%
	55-64	1.69	1.63	-3.65%	1.50	1.52	1.79%
	65-74	2.95	2.73	-7.50%	3.29	2.92	-11.32%
	75 and above	4.38	4.41	0.53%	4.33	4.24	-2.29%

Table 21

ESTIMATED CRITICAL ILLNESS INCIDENCE RATE CONDITIONAL ON DIABETES BY AGE GROUP AND GENDER (RATES PER 1000)

Critical Illness	Age Group	Male			Female		
		2013 NHSS	2023 Meinian	Diff.	2013 NHSS	2023 Meinian	Diff.
Myocardial infarction	15-34	0.37	0.34	-8.07%			
	35-44	1.74	1.81	3.86%	0.98	0.92	-6.16%
	45-54	3.15	2.70	-14.21%	1.15	0.98	-15.40%
	55-64	4.28	3.91	-8.51%	1.80	1.62	-10.04%
	65 and above	5.72	5.50	-3.81%	3.18	3.30	3.95%
Stroke	15-34	0.11	0.14	22.53%	0.09	0.08	-4.60%
	35-44	0.51	0.56	10.62%	0.65	0.63	-4.01%
	45-54	1.49	1.63	9.38%	0.71	0.61	-13.72%
	55-64	2.13	2.50	17.59%	2.45	2.90	18.53%
	65 and above	3.30	3.76	14.03%	3.83	4.01	4.92%

Table 22

ESTIMATED CRITICAL ILLNESS INCIDENCE RATE CONDITIONAL ON HYPERLIPIDEMIA BY AGE GROUP AND GENDER (RATES PER 1000)

Critical Illness	Age Group	Male			Female		
		2013 NHSS	2023 Meinian	Diff.	2013 NHSS	2023 Meinian	Diff.
Myocardial infarction	25-34	0.92	0.70	-23.97%			
	35-44	2.13	1.69	-20.50%	0.67	0.55	-17.68%
	45-54	3.57	3.11	-12.77%	1.28	1.04	-19.04%
	55-64	4.87	4.49	-7.85%	1.82	1.58	-13.08%
	65-74	6.42	6.13	-4.38%	3.70	3.39	-8.52%
	75 and above	6.33	6.27	-0.88%	3.95	3.87	-1.92%
Stroke	25-34	0.23	0.21	-9.69%			
	35-44	0.54	0.51	-6.69%	0.36	0.32	-10.03%
	45-54	1.51	1.42	-5.95%	1.05	0.98	-6.83%
	55-64	2.43	2.30	-5.35%	2.75	2.62	-4.73%
	65-74	4.36	4.14	-5.07%	5.49	5.26	-4.22%
	75 and above	5.75	5.32	-7.34%	5.91	5.59	-5.41%

We can observe that the changes in all numerical results are within 25%, indicating that the model is robust. What's more, the larger the age, the smaller the difference between the two data sources. The reason is that the difference between the two types of PEI prevalence data in the older age group is small, possibly because the incidence rate of PEI among young adults has increased in recent years.

Second, we test the sensitivity of the data (b), namely the administrative health insurance claim data in one city within the Yangtze River Delta. We investigate the scenario where there is an increase in the PEI prevalent rate for individuals with critical illnesses by 5% in all illnesses, genders, and age groups. The results are as follows:

Table 23

ESTIMATED CRITICAL ILLNESS INCIDENCE RATE CONDITIONAL ON HYPERTENSION BY AGE GROUP AND GENDER (RATES PER 1000)

Critical Illness	Age Group	Male			Female		
		2013 NHSS	2023 Meinian	Diff.	2013 NHSS	2023 Meinian	Diff.
Myocardial infarction	25-34	0.28	0.32	15.31%	0.06	0.07	12.50%
	35-44	1.25	1.36	9.04%	0.13	0.14	12.00%
	45-54	2.44	2.64	8.18%	0.41	0.45	9.22%
	55-64	3.60	3.86	7.13%	1.11	1.20	7.72%
	65-74	5.06	5.40	6.68%	2.72	2.90	6.59%
	75 and above	6.34	6.76	6.47%	3.67	3.90	6.25%
Stroke	25-34	0.14	0.15	9.75%	0.03	0.04	26.25%
	35-44	0.49	0.52	6.91%	0.14	0.16	10.52%
	45-54	1.09	1.16	6.79%	0.50	0.55	9.31%
	55-64	1.69	1.80	6.41%	1.50	1.61	7.39%
	65-74	2.95	3.13	6.26%	3.29	3.50	6.43%
	75 and above	4.38	4.67	6.44%	4.33	4.60	6.23%

We can observe the changes in all the incidence rates are within 30%, indicating that the model is robust.

We also calculate the odds ratio (OR) and compare the results documented by prior literature. The OR is a statistical measure commonly used in medical research to quantify the strength of association between an exposure (such as a risk factor) and an outcome (such as a disease). For example, we can observe from Table 16 that the incidence rate of stroke among individuals with hypertension is 9.2 times that of healthy people (people aged under 65). We can observe from Table 17 that the incidence rate of stroke among individuals with diabetes is 6.0 times that of healthy people (people aged under 65).[14] Prior meta-analysis literature shows that ORs are 5.75 and 2.7, respectively (Gao, Zhang, Li, Song and Hu, 2014). Our results are comparable with the ORs documented in the literature and relatively more conservative.

4.3 PRICING OF CRITICAL ILLNESS INSURANCE

Critical illness insurance provides the policyholder with a lump sum if the insured individual contracts a critical illness, which is included within a set of diseases specified by the policy conditions. Based on the estimation of the incidence of critical illness in subsection 4.2, we can calculate the corresponding reasonable premium price for critical illness insurance

4.3.1 INTRODUCTION TO THE PRICING MODEL

Critical illness coverage is typically offered as a rider benefit attached to life insurance or endowment policies. Under this arrangement, the insurer pays the sum insured in advance (upon diagnosis of a

[14] The overall OR 6.0 is a bit overestimated as the OR in the subgroup (female, 35-44) is relatively high (16.25). The ORs of all other subgroups are between 3.0-9.0.

covered critical illness) instead of waiting for death to occur. Depending on the type of CI coverage, we can define different formulas to calculate pure premium rates, for example:

Stand-alone CI policy with an N duration limit for healthy people, where the sum insured is payable upon the occurrence of one of the diseases specified by the policy conditions:

$$_{(1)}A_{x:N}^{(DD)} = \int_0^N {}_tp_x^{11}\,\mu^{13}(x+t)\cdot exp(-\delta t)dt.$$

And for people with PEIs:

$$_{(1)}A_{x:N}^{(DD)} = \int_0^N {}_tp_x^{22}\,\mu^{23}(x+t)\cdot exp(-\delta t)dt$$

where $exp(-\delta t)$ is the value at time 0 of a monetary unit to be paid at time t, i.e., the discount factor (where δ is the force of interest).

The critical illness full acceleration benefit of term life insurance with an N duration limit for healthy people: when critical illness occurs, the insurance company pays the sum insured in the case of death (in this example set to 1 monetary unit) in advance; if not, the insured amount is paid if the policyholder dies before the expiry of the contract:

$$_{(2)}A_{x:N}^{(DD)} = \int_0^N {}_tp_x^{11}\,[\mu^{13}(x+t)+\mu^{15}(x+t)]\cdot exp(-\delta t)dt.$$

The previous equation can be rewritten as follows:

$$_{(2)}A_{x:N}^{(DD)} = {}_{(1)}A_{x:N}^{(DD)} + \int_0^N {}_tp_x^{11}\,\mu^{15}(x+t)\cdot exp(-\delta t)dt.$$

And for people with PEIs:

$$_{(2)}A_{x:N}^{(DD)} = {}_{(1)}A_{x:N}^{(DD)} + \int_0^N {}_tp_x^{22}\,\mu^{25}(x+t)\cdot exp(-\delta t)dt.$$

4.3.2 NUMERICAL RESULTS

We now price the following critical illness insurance products: The stand-alone critical illness policy with a 10-year duration limit for individuals with PEIs. We calculate the critical illness insurance rate for individuals with different PEIs.

Table 24

CRITICAL ILLNESS INSURANCE RATE FOR THE POPULATION WITH HYPERTENSION (PER 1000 YUAN)

Critical Illness	Age Group	Male			Female		
		Healthy	Hypertension Sufferers	All Population	Healthy	Hypertension Sufferers	All Population

Myocardial infarction	25-34	0.57	2.10	0.88	0.06	0.48	0.10
	35-44	1.58	9.06	3.90	0.18	0.95	0.35
	45-54	3.66	16.27	9.03	0.49	3.02	1.54
	55-64	4.81	20.47	13.56	0.88	7.39	4.70
	65-74	4.33	21.60	15.99	0.41	14.82	10.53
	75 and above	5.73	17.36	14.06	5.24	13.86	11.62
Stroke	25-34	0.13	1.07	0.32	0.07	0.26	0.09
	35-44	0.19	3.55	1.23	0.16	1.07	0.36
	45-54	0.65	7.31	3.48	0.61	3.65	1.88
	55-64	1.03	9.68	5.85	0.73	9.92	6.12
	65-74	1.04	12.67	8.88	0.39	17.88	12.68
	75 and above	3.83	12.05	9.71	5.99	16.34	13.65

Table 25

CRITICAL ILLNESS INSURANCE RATE FOR THE POPULATION WITH DIABETES (PER 1000 YUAN)

Critical Illness	Age Group	Male			Female		
		Healthy	Diabetes Sufferers	All Population	Healthy	Diabetes Sufferers	All Population
Myocardial infarction	15-34	0.44	2.83	0.53			
	35-44	3.11	12.59	3.90	0.23	7.45	0.35
	45-54	7.09	20.89	9.03	1.20	8.40	1.54
	55-64	10.57	24.24	13.56	3.57	11.90	4.70
	65 and above	13.97	24.34	16.52	9.18	17.26	11.09
Stroke	15-34	0.19	0.88	0.21	0.07	0.69	0.08
	35-44	1.01	3.70	1.23	0.28	4.96	0.36
	45-54	2.42	9.97	3.48	1.71	5.16	1.88
	55-64	4.10	12.14	5.85	4.54	16.18	6.12
	65 and above	7.92	14.16	9.45	11.00	20.75	13.31

Table 26

CRITICAL ILLNESS INSURANCE RATE FOR THE POPULATION WITH HYPERLIPIDEMIA (PER 1000 YUAN)

Critical Illness	Age Group	Male			Female		
		Healthy	Hypertension sufferers	All population	Healthy	Hypertension sufferers	All population
Myocardial infarction	15-24						
	25-34	0.67	6.92	0.88			
	35-44	3.10	15.36	3.90	0.29	5.07	0.35
	45-54	7.88	23.67	9.03	1.25	9.34	1.54
	55-64	12.50	27.53	13.56	4.09	12.04	4.70
	65-74	15.30	27.25	15.99	9.64	20.10	10.53
	75 and above	13.94	17.31	14.06	11.40	14.89	11.62
Stroke	15-24						
	25-34	0.27	1.73	0.32			
	35-44	1.04	3.95	1.23	0.33	2.73	0.36
	45-54	2.96	10.11	3.48	1.66	7.67	1.88
	55-64	5.25	13.83	5.85	5.12	18.14	6.12
	65-74	8.28	18.64	8.88	11.09	29.57	12.68
	75 and above	9.48	15.74	9.71	13.07	22.17	13.65

Table 27

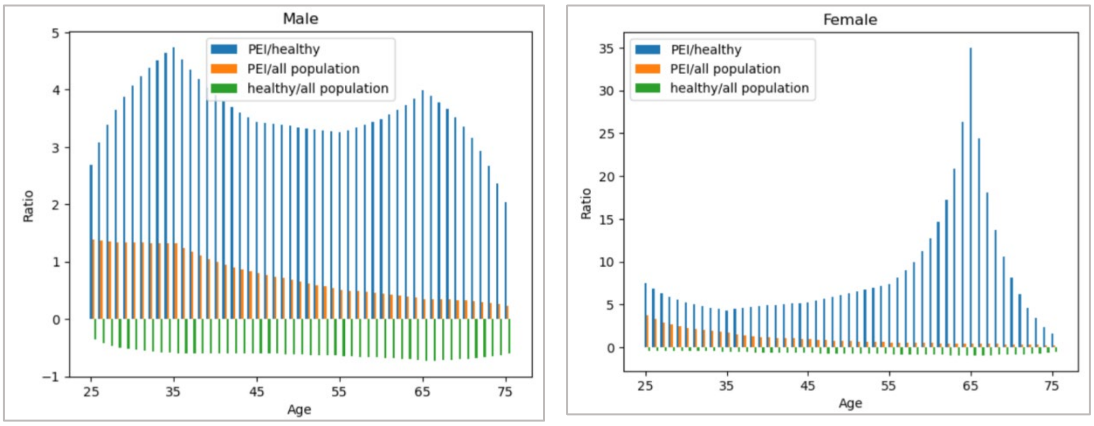
CRITICAL ILLNESS INSURANCE RATE FOR THE POPULATION WITH HYPERTENSION OR DIABETES OR HYPERLIPIDEMIA (PER 1000 YUAN)

Critical Illness	Age Group	Male			Female		
		Healthy	Sufferers	All population	Healthy	Sufferers	All population
Myocardial infarction	15-24						
	25-34	0.43	5.54	0.88	0.06	3.02	0.10
	35-44	1.42	13.22	3.90	0.15	4.00	0.35
	45-54	3.46	19.43	9.03	0.65	5.52	1.54
	55-64	4.96	21.98	13.56	1.72	9.35	4.70
	65-74	6.28	22.86	15.99	3.52	16.45	10.53
	75 and above	7.35	17.49	14.06	6.03	13.95	11.62
Stroke	15-24						
	25-34	0.15	2.09	0.32	0.08	1.32	0.09
	35-44	0.29	4.78	1.23	0.18	3.56	0.36
	45-54	0.82	8.47	3.48	0.88	6.33	1.88
	55-64	1.30	10.34	5.85	2.01	12.52	6.12
	65-74	2.41	13.49	8.88	3.59	20.34	12.68
	75 and above	4.61	12.33	9.71	6.73	16.52	13.65

We further calculate the ratio of insurance rates across different population groups to intuitively illustrate the results for pricing purposes. We use critical illness insurance for myocardial infarction as an example. Figure 17 shows the ratio of critical illness insurance premiums (with hypertension as the PEI) for different population groups. We observe that the premiums charged vary significantly across groups. Specifically, the blue bars indicate that if the insurance product covers myocardial infarction, the premium for hypertensive individuals should be approximately 4–5 times higher than that for healthy individuals among males and 5–10 times higher among females.

Figure 17

RATIO OF CRITICAL ILLNESS INSURANCE RATES FOR DIFFERENT GROUPS OF PEOPLE



Section 5 Conclusion

This report analyzed the challenges and opportunities within China's health insurance market, with a particular focus on the needs of individuals with PEIs. First, we reviewed the UCCMI scheme, the largest category of health insurance for PEIs, focusing on its design features and underwriting rules for PEIs across products. Insurers adopt cautious risk management strategies, such as conditional compensation, adjusted reimbursement ratios, and PEI list controls, to mitigate financial exposure. Second, we conducted an empirical analysis using data from the CHARLS, showing that chronic illness prevalence among PEIs is unevenly distributed across age groups, genders, and regions. These findings underscore the main factors in product pricing models to ensure fairness and sustainability. Third, the theoretical application of the Markov model illustrated how single-period prevalence data can estimate critical illness incidence rates, offering a pragmatic solution to data limitations while improving pricing accuracy.

This report fills a critical gap in China's health insurance landscape by offering the first systematic analysis of UCCMI PEI insurance products, morbidity patterns, and pricing barriers. Its methodology provides a feasible framework for deriving incidence rates from prevalence data, addressing the challenge of missing historical incidence data for high-risk populations.

This report holds multifaceted practical significance. For insurance companies, the report provides a holistic solution spanning product design to risk pricing. Insurers can leverage risk control strategies and limited data to develop specialized insurance types tailored to high-risk populations. For hospitals, the report offers critical insights into regional health disparities, such as the high prevalence of chronic diseases in underserved areas. These findings enable hospitals to anticipate critical illness incidence rates and strengthen chronic disease monitoring systems, improving early intervention and resource allocation. For pharmaceutical companies, the report's data and analysis on chronic disease incidence provide a market foundation for developing related drugs. By advocating for the inclusion of drug development in localized insurance coverage lists and designing outcome-based reimbursement models, pharmaceutical firms gain entry points to participate actively in the health insurance ecosystem.

Although we propose a method that reduces data requirements, we advocate for strengthening data infrastructure to support sustainable innovation in China's health insurance market. The current lack of comprehensive and reliable data on morbidity rates and health outcomes for PEI individuals has been a significant barrier to product development. By investing in robust data collection, analysis, and sharing mechanisms, insurers and policymakers can create a more informed and responsive insurance ecosystem. This includes fostering collaboration among insurance companies, healthcare providers, and government agencies to ensure that data is both accessible and actionable.

Overall, future efforts should focus on enhancing data infrastructure, fostering collaboration among stakeholders, and continuously refining modeling techniques to ensure that health insurance products effectively meet the needs of high-risk populations. Ultimately, bridging these gaps for substandard populations is not merely a commercial imperative but a societal one: expanding coverage for substandard populations will reduce catastrophic healthcare expenditures, improve public health outcomes, and advance the progress toward inclusive, sustainable healthcare for all.

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References

Baione, Fabio, Susanna Levantesi, 2014. A health insurance pricing model based on prevalence rates: Application to critical illness insurance. *Insurance: Mathematics and Economics* 58, 174-184.

Center for Health, Statistics, Ministry of Health of the People's Republic of China Information, 2013. An Analysis Report of National Health Service Survey in China, 2013.

Cox, Cynthia, Ashley Semanskee, Gary Claxton, Larry Levitt, 2016. Explaining health care reform: risk adjustment, reinsurance, and risk corridors. Henry J. Kaiser Family Foundation.

Gao, Dongqi, Hongda Zhang, Hong Li, Wenjing Song, Xiaoyu Hu, 2014. Meta-Analysis of Risk Factors for Stroke Incidence in the Chinese Population. *Journal of Military Medical Science* 26, 58-61. (in Chinese).

Lambrew, Jeanne M, Ellen Montz, 2017. States Be Warned: High-Risk Pools Offer Little Help At A High Cost. *Health Affairs Forefront*.

Li, Yang, Cunjie Lin, Hao Mei, Chu Zhang, Mingyan Wang, Weiqin Guo, Guangyao Liu, Chunyang Zeng, 2025. Research on the Development of Insurance for Individuals with Pre-existing Conditions in China. *Insurance Theory & Practice* 02, 48-70. (in Chinese).

Ning, Wei, Qingshan Wang, 2022. Research on the Development of 'Substandard Body' Health Insurance Products. *Marketing Management Review* 11, 106-108. (in Chinese).

Popkin, Barry M, 2001. The nutrition transition and obesity in the developing world. *The Journal of nutrition* 131, 871S-873S.

Uchida, Yasuo, 2012. The health care system in Japan, Health Care Systems in Europe and Asia. Routledge, pp. 81-102.

Xu, Wanghong, Yong Zhang, Jiwei Wang, Fei Wu, H. Narimatsu, Genming Zhao, 2016. Comparison of Chronic Disease Prevention and Control Strategies between China and Japan and Policy Implications. *Chinese Journal of Prevention and Control of Chronic Diseases* 24, 593-596. (in Chinese).

Xu, Xian, 2023a. Adhering to the Principle of "More Inclusive" and Exploring Ten Iterative Directions- Interpretation of the "2023 Knowledge Graph of City-Customized Commercial Medical Insurance (People's Livelihood Insurance)". *Shanghai Insurance*, 12-18. (in Chinese).

Xu, Xian, 2023b. Innovation in Insurance for People with Pre-existing Conditions: A Look at People's Livelihood Insurance Development, China Banking and Insurance News. China Banking and Insurance News, p. 006. (in Chinese).

Zhang, Weigong, 2016. Industry Dilemmas and Innovative Breakthroughs in Commercial Health Insurance Products. *Tsinghua Financial Review* 11, 44-46. (in Chinese).

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