Featured Article (Research Paper)

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Population Aging and the Demand for Private Health Insurance in China

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Abstract: This study examines the potential impact of aging on the demand for private health insurance (PHI) in China. Using the provincial data for 2000–2018, we find that a 1-percent increase in each proportion of the elderly population and old-age dependency ratio increases the PHI demand by 4.8 and 5.2%, respectively. A one-percent increase in the child dependency ratio decreases the PHI demand by 1.5%. We employ an instrumental variable approach; the findings support that the proportion of the elderly individuals in the total population, old-age dependency ratio, child dependency ratio, and urban green area significantly affect the PHI demand. The rolling estimate indicates that aging has a significant positive effect on the PHI demand over a rolling window of a fixed sample size. Additionally, by controlling for province and year fixed effects, we find that aging is positively associated with the PHI demand in China.

Keywords: population aging, private health insurance, insurance, China

1 Introduction

Generally, individuals' decisions regarding health insurance demand are based on numerous factors. Risk-averse individuals are willing to pay for insurance that guarantees protection against potential future losses due to unexpected shocks. Age is likely to be a key factor in decisions on health insurance demand because the elderly population is generally exposed to more health risks and higher medical expenditures than the non-elderly population. For example, the prevalence rate of chronic diseases in the elderly population aged 60+ was 3.2 times higher

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and the disability rate was 3.6 times higher than of the entire population in 1993 (Ministry of Health in China). Cai et al. (2012) indicates that the elderly population receives more medical attention than any other population in China. The medical services for elderly individuals often include expensive medical technology, hospitalization, and long-term care, which are more complex and expensive than those for young individuals.

The ever-growing medical demands of the elderly population and the late development of geriatric services are a public healthcare concern in China, as compared to the situation in other countries. For example, individuals aged 55+ accounted for 29% of the population but accounted for 56% of all health expenditure in 2016. Conversely, individuals aged 35 years contributed to 46% of the population but accounted for less than a quarter of health expenditure in the United States. In Australia, the health expenditure of the population aged 60+ is 6 times higher than that of the population aged less than 15, and the health expenditure of the population aged 65+ in China is three times higher than that of the other age groups.

China is expected to become an aging society by the end of the 20th century.¹ The United Nations reports that China is aging more rapidly than a number of other countries in recent years. The age structure of China's population has changed from a pyramid to a spindle in these years. The Chinese government forecasts that by 2025, the population aged 65+ in China will exceed the population aged 0–14, and the growth trend of China's elderly population will be significantly higher than that of children, accelerating the aging process in China (The United Nations, 2015). It also forecasts that by 2050, 26% of the population is expected to be aged 65+ and approximately 8% will be aged 80+ (The World Bank, 2018). China's dependency ratio may increase to as high as 44% by 2050. The dependency ratio compares the size difference between the population in the labor force and those who are working or can work full time. It is a yardstick to measure the pressure on taxable income that will support entitlement programs such as social security.

¹ China's population aged 65 and above reached 88.21 million in 2000, accounting for 6.96% of the total population, which means that China entered an aged society in 2000. There are two international standards for the aging society. First, in 1956, the United Nations recognized that when the number of people aged 65 or above accounted for more than 7% of the total population in a country or region, it means that the country or region has entered the aging process; second, the Vienna conference on aging in 1982 recognized that more than 10% of the population aged 60 or above means entering an aging society. In the fifth population census of 2000, China met both the standards, which means that China had entered an aging society.

Despite that the Chinese government's officially announced the end of its one-child policy and it allows two children in the family, China's birth rate continues to decrease, standing at 15.2 million in 2018 which was the lowest since 1949 and a decrease from 17.2 million in 2017 (China Statistics Bureau 2019).

Aging in China is also showing obvious regional disparities. These disparities exist among provinces and between urban and rural areas in China in both the level and rate of population aging. The population in the coastal regions had aged 10 years earlier than in the central and western regions of China. Before 2000, the annual increase in the aging population was quicker in the coastal regions than in the inland regions. As the internal migrants continued moving from the inland to the coast between 2000 and 2010, the patterns of population aging changed with faster annual increases in the inland regions than in the coastal regions after 2010 (Wang, Sun, and Li 2013). Shanghai was the first city to transform into an aging population society in 1979. After 33 years, Ningxia became an aged society in 2012. Such a dynamic could have significant implications in healthcare.

The China healthcare system incorporates a complex mixture of public and private sector involvement. Although universal healthcare is provided by governments and social health insurance provides basic health risk management for the elderly population, social health insurance can only provide the most basic healthcare; however, private health insurance (PHI) could be essential for elderly individuals to transfer illness risk. Nearly 20 percent of the medical spending of the elderly is financed out-of-pocket, while 13 percent is covered by private insurance.² Social health insurance in China covers the entire population but consists of some out-of-pocket payments, such as deductibles and maximum limits. Financial barriers impeding access to care and financial catastrophe, due to out-of-pocket payments, commonly exist across all socioeconomic groups (Wagstaff, Eddy, and Naoko 2003). PHI is an important supplement of social health insurance in China, which plays a crucial role in complementing social health insurance by expanding the scope of compensation and decreasing the copayment. The government promoted the development of PHI in China and issued the plan for reform of the medical and health system during the 12th Five-Year Plan period, which emphasized the development of diversified health insurance products. In 2014, China issued several documents on accelerating the development of PHI, which provided PHI with a "main" role in deepening the reform of the health system and developing the health service industry. "Several Opinions on Accelerating the

² In Medical Spending of the U.S. Elderly (NBER Working Paper 21270), researchers Mariacristina De Nardi, Eric French, John Bailey Jones, and Jeremy McCauley explore the medical spending of Americans aged 65 and older. The authors make use of data from the 1996 to 2010 waves of the Medicare Current Beneficiary Survey (MCBS).

Development of PHI” has positioned the function of PHI from the perspective of deepening the reform of the medical and health system, developing the health service industry, and upgrading the economic quality and efficiency. All these documents evince the importance of PHI in China.

However, PHI is still limited in China. The proportion of PHI purchased in the entire population in 2008 was 6.9%³ and was still 6.3% in 2010, including 6.0% of urban residents and 6.4% of rural residents. In 2017, the gross original premium income of China’s insurance market was RMB 3658.101 billion (equivalent to 528.23 billion US dollars), of which the gross original premium income of PHI was RMB 438.946 billion (equivalent to 63.38 billion US dollars), accounting for 12%, where, in mature markets, the proportion is generally 20–30%. In China, the proportion of PHI expenditure in the total healthcare expenditure is <2%, while it is generally 10% in developed countries. Ni and Feng (2018) found that the insufficient demand for PHI is because of risk attitude, social insurance, and improper insurance supply. Improper insurance supply refers to the failure to provide health insurance for those with chronic or previous diseases. They also show that unsuitable PHI products, unstable protection from PHI, and low reputation of insurance companies are the reasons for limited PHI consumption.

Therefore, a natural question to be asked is what has caused the demand for PHI. We explore empirically one particular answer to the question in this paper, namely that the demand for PHI was caused by population aging. Particularly, we show the direct impact of aging on the PHI demand. We also consider the impact of sex, family, education, marriage, and urban-rural structure on the PHI demand in China. Our study contributes to the research about aging by providing causal estimates of aging on the demand for PHI. We found that in aggregate, aging nearly always increases the demand for PHI, using panel data of 20 years in China. We then attempted to use different models to test various aspects and designed a benchmark model and subsample estimates. The control for province fixed effects allowed us to account for time-invariant factors related to geography, economy, and population that could affect both aging growth and the demand for PHI. Specifically, we attempted to find an instrumental variable (IV) strategy from the environment. Our estimates are robust due to a variety of sensitivity checks, including an alternative measure of the explanatory variable, rolling estimates, and control of the fixed effect in different regions and years. Our estimates indicate the importance of aging on the demand for PHI. Our findings are helpful in clarifying the mechanism of the aging population on the demand for

3 According to the data of the Fourth China National Health Service Survey.

PHI, and conducive to finding ways to expand the demand for PHI. Our findings also provide a reference to promote the development of China's PHI market.

The rest of the paper is organized as follows. In the next section, we present a related literature review, followed by a description of our sample and the development of our variables and design models. Next, we present estimates of the relationship between population aging and the demand for PHI and discuss the results. We also investigate the mechanism behind population aging and the demand for PHI demand. Section five demonstrates the robustness of our findings to numerous alternative modeling assumptions. The final section concludes our study.

2 Related Literature

Although many theories have been proposed to explain the limited size of the PHI market, we have virtually no evidence on which factors are important. In the simplest economic theory, premiums are most important in the decision on insurance. If premiums are actuarially fair and therefore vary precisely with risk, it should result in a universal purchase of insurance by risk-averse individuals. In a more realistic model wherein an administrative "loading" is added to an insurance premium, the simple theory reveals that the decision to purchase insurance and amount of coverage should depend only on the loading and not on the probability of loss or relative sizes of expected losses across potential purchasers (Bundorf et al. 2012). However, the theoretical framework developed implies that both an individual's income and the extent to which the premium they face for insurance coverage reflect their risk will affect the impact of risk on whether they purchase PHI. Nyman (2003) reported that health insurance contracts are compensatory, such that healthy consumers buy insurance if they are willing to give up other consumer spending options and can get transfer income from other healthy groups when they are unwell. Bundorf et al. (2012) estimate that if premiums for health insurance are generally not perfectly risk-rated, an increasing health risk is associated with a higher likelihood of purchasing PHI. Some studies show that health risk is relevant in the decision to obtain health insurance because it affects an individual's likely future consumption of medical care and individuals vary in their expectations of healthcare utilization. Arrow (1963) finds that health insurance is generally desirable because of this risk-avoidance feature. Health insurance converts unpredictable medical expenses into predictable premiums. Therefore, health insurance plays an important role in reducing the high costs of healthcare and affects the economic well-being of individuals and families.

Age and sex are found with income to be among the more important variables determining health insurance. The importance of demographics is not surprising as health concerns vary considerably with these traits. Some research estimates that the likelihood of a health shock may vary systematically with observable characteristics, such as age. Longevity, which brings disease risk and will increase healthcare expenditures, directly affects the demand for PHI. For example, chronic disease accounts for 86.6% of the total number of deaths and >70% of the total expense in China. The elderly population has a higher risk of chronic diseases and longer treatment periods that correspond to higher healthcare expenditures. The prevalence of chronic diseases in the elderly population was 4 times higher than the average in 2008. Approximately half of China's elderly population suffered from chronic diseases in 2008 (the Fourth China National Health Service Survey, 2008). Some studies have explored how age affects the demand for PHI. Research conducted by OECD countries shows that with population aging, the proportion of an individual's consumption of housing, energy, and healthcare will increase, while the consumption of transportation, entertainment, and education will decrease (Martins et al. 2005). Anderson (1973) conducted a study on health insurance coverage and found an individual age trend that as individuals age, their health insurance coverage increases significantly and that age greatly impacts health insurance demand. Browne and Kim (1993) analyzed insurance market data in 45 countries and found that age structure positively affects the demand for PHI. Using the 2004 data of Michigan, Berhanu and Kenneth (2004) found that the medical expenses consumed by the sample group in old age accounted for half of the medical expenses spent in the lifetime, and the medical expenses of elderly individuals aged 85+ for the rest of their lives accounted for a lifetime. Jonneke, Maarten, and Bas (2012) shows that the age structure significantly affects the demand for health insurance and that an increase in the elderly and children population has a significant effect on the PHI demand. Yaguo and Wenjun (2017) used the data from China's Jiangxi Province from 1996 to 2015 and found that the age structure of the population positively affects the PHI demand.

The presence of dependent children is found to have ambiguous effects. In some studies, having children is associated with greater coverage, being partnered with or without dependent children (Barrett and Conlon 2003; Doiron et al. 2008). Some researchers found that the dependency ratio of young individuals is positively correlated with the depth of life insurance (Beenstock et al. 1986; Browne and Kim 1993; D. B. Truett and L. J. Truett 1990). Yanhong and Guojun (2014) argued that with the decline in fertility rate, although the number of children needed to be raised by parents is reduced, the number of children that parents depend on when they are old will also decrease, which will cause parents to plan their future. To protect themselves from the health risks, they will

increase their willingness to purchase PHI, leading to an increase in the demand for PHI. Compared with the past when the number of children in families was more, today, parents can spend more money on children and pay more attention to their children's health. Thus, many parents buy health insurance products for their children. In other studies, the presence of children has insignificant or even negative effects on coverage (Hopkins and Kidd 1996; Propper 1989). Families with children are also more likely to respond to incentives regarding PHI (Ellis and Savage, 2008). Beck and Webb (2003) found no significant stable relation between the dependency ratio of young individuals and the depth of life insurance.

While research on the impact of age structure on the demand for insurance has been widely acclaimed, the causal link between age structure and demand for PHI remains an unsettled question. Estimating the causal effect of aging on PHI is complicated due to well-documented challenges, including separately identifying the effects of different factors of aging, endogeneity, and measurement error. Such studies also lack the power to detect changes in important but rare outcomes due to relatively small sample sizes and thus may overlook an important component of the decision on PHI. Even if small sample effects are detected, estimating the decision on PHI due to these effects is difficult because other factors also tend to influence decisions on PHI. Moreover, it is difficult to directly apply the findings for the USA to the situation of other countries.

Our study overcomes the identification and statistical power challenges described above and contributes to the historical literature by providing empirical estimates of the relationship between aging and the PHI demand in China. Previous studies, including the studies by Qi et al. (2018) and Ni and Feng (2018), have empirically examined the effect of age structure and other factors on the demand for health insurance in China. Both studies found that the elderly population has a significant impact on the PHI demand in China. Our study differs from other studies in two important ways. First, our model is extremely different from Qi et al. (2018) and Ni and Feng (2018) methodology. Our estimates are identified not only by variation in the cross-section but also from the interaction of regional variation with time variation. We also conduct the IVs (spell out) and a rolling test to check the robustness of the results. Second, we pay attention to the relationship between the mechanism and ways of aging and the PHI demand and test the direction and strength of the impact of population aging on the PHI demand from the empirical level. Thus, we can provide estimates of the full impact of aging on the PHI demand in China.

3 Methodology

3.1 Dependent Variable

The PHI demand is an interpreted variable. The PHI demand is driven by both consumers' purchasing desires and their purchasing power. Therefore, demand for PHI must meet two necessary conditions: (1) consumers are willing to purchase insurance; and (2) consumers must realize the purchase. Insurance density is used as an indicator for the development of insurance within a country and calculated as the ratio of total insurance premiums to the whole population. Therefore, insurance density is an important proxy of insurance demand, and we use the log of the insurance density (DEN) as a proxy for the PHI demand. We define DEN as the ratio of the total income of provincial health insurance premiums to the total population in the province.

3.2 Independent Variable

Population aging is our explanatory variable, which includes two aspects: one refers to the relatively increasing number of elderly individuals and their rising share of the total population; the second is the relatively decreasing number of young individuals and their decreasing share of the total population. It is generally considered that individuals aged ≤ 14 years are children and adolescents, individuals aged ≥ 65 years are considered as the elderly population, and those aged 15–64 years are considered the working-age population (Division Criteria in Aging of Population and its Social and Economic Consequences established by the United Nations, 1956). Individuals aged ≥ 60 years accounted for 10% of the country's total population, and individuals aged > 65 years accounted for 7% of the total population, which is the conventional standard for entering an aging society defined by the United Nations. Therefore, we select the proportion of the elderly population (those aged ≥ 65 years) in each province (OR), old-age dependency ratio (ODR), and the child dependency ratio (KDR) as proxies for China's population aging. ODR is defined as the ratio of the number of persons aged ≥ 65 years in the population relative to the number of persons aged 15–64 years. KDR is defined as the ratio of the population aged ≤ 14 years and the population aged 15–64 years in a country or region.

To infer that the relation between aging and PHI demand, we need to exclude the effect of all other variables that could impact the PHI demand. Below, we describe the various controls that we use in our multivariate tests and theoretical reasons that led us to use them.

- (1) *Sex structure of the population.* Female sex is associated with greater coverage (Cardon and Hendel 2001). This is usually interpreted as women having greater expected utilization through child-bearing or greater risk aversion possibly stemming from having preferences exhibiting greater intertemporal substitution. To proxy for the sex structure of China's population, we use the sex ratio (SR), which is defined as the ratio of the total male population to the total female population in a country or region. We calculate SR as the male/female population, which reflects the male-to-female ratio in the total population in each province.
- (2) *Family structure of the population.* Li, Liu, and Glaetzer (2013) found that the family structure in the population structure, i.e. the size of the family population, affects the PHI demand. We use the average family size (FAM) as a proxy for the family structure of China's population. We define FAM as the ratio of the number of households, which is multiplied by the number of individuals per household to the total number of households in each province.
- (3) *Marriage structure of the population.* Marriage structure may also be related to the PHI demand (Qi et al. 2018). The marital status in individuals aged ≥ 15 years mainly includes unmarried, first marriage with a spouse, remarried, divorced, and widowed in the China Statistical Yearbook. To proxy for marriage structure, we use the ratio of first marriages and remarriages with a spouse as a proxy (COU) for marriage structure, which is the ratio of the number of first-marriage spouses and number of spouses who remarried with a spouse aged ≥ 15 years to the number of individuals aged ≥ 15 years.
- (4) *Educational structure of the population.* Pollack and Kronebusch (2004) found that the educational level affect an individual's risk attitude, demand for medical services, and health-related knowledge, which will significantly affect the PHI demand. We use the education years (EDU) per person, which is defined as the education level of the population aged > 6 years in each province in China. EDU is relative to 6 years for elementary school, 9 years for middle school, 12 years for high school, and ≥ 16 years for college and university graduates. EDU is calculated as follows: (no education $\times 0$ + total elementary school population $\times 6$ + middle school population $\times 9$ + high school population $\times 12$ + college and university graduates and above $\times 16$)/population aged > 6 years).
- (5) *Urban and rural structure of the population.* Cui (2014) suggested that the urban and rural structure in China played a positive role in the PHI demand. Thus, we suppose that there are differences in the PHI demand between urban and rural populations. We use the urbanization rate of a province defined as the ratio of the urban population to the total population.

- (6) *Population size.* The higher the population, the higher the PHI demand. We use the natural growth rate (NGR) as a proxy, which refers to the difference between the number of live births and the number of deaths in a year, divided by the midyear population, multiplied by a factor (usually 1000).
- (7) *Social health insurance coverage.* The relation between social health insurance and the PHI demand has been a controversial issue in academia since there are remarkable differences in the health financing system in different countries. Jeffrey and Amy (2005) showed that the provision of even incomplete public insurance can substantially crowd out the PHI demand. They suggest that due to the design of Medicaid – a large part of the premium for existing private policies is spent on benefits that simply replace benefits that would otherwise have been provided by Medicaid. They also found that Medicaid provides an inadequate consumption smoothing mechanism for all but the poorest of individuals, even in the absence of a desire to leave a bequest. However, Peng et al. (2017) examined that the relationship between social health insurance and PHI varies greatly with the development degree of social health insurance. In regions with high development degree of PHI, there exists a significant inversed U-shape relation between social health insurance and the PHI demand. Social health insurance promotes the development of PHI in regions with an average development degree of social health insurance. However, there was no significant relationship between social health insurance and the PHI demand in regions with a low development degree of social health insurance. These studies showed that social health insurance has an important influence on PHI; thus, we use the number of residents who joined the social health insurance plan for urban employees (SHI).
- (8) *Health status.* Health status is relevant in the decision to obtain health insurance because it affects an individual's likely future consumption of medical care (Bundorf et al., 2012). We used an inpatient fatality rate to measure the health status of residents.
- (9) *Income.* Didem et al. (2009) suggested that assets are an important determinant of effective affordability for PHI. We used the income of residents as a proxy (INC) for income level, which includes wage income, net revenue, income from property, and transfer income (e.g. pensions and subsidies).
- (10) *Economic development of each province.* As noted above, purchase intention and actual purchasing power will affect the PHI demand. Economic development will affect consumption, thereby affecting the PHI demand. In theory, with economic development, individuals prefer buying life insurance. Some researchers found that the demand for personal insurance was

positively correlated with income level (Beck and Webb 2003; Browne and Kim 1993). We used GDP per capita (AGDP) as the proxy for economic development in each province, which is the ratio of the total GDP of each province to the total number of individuals in the province.

3.3 Sample Description

Our sample comprises data from 30 provinces, municipalities, or autonomous regions in China between 2000 and 2019,⁴ which are from the China Statistical Yearbook (2000–2019), China Health Statistics Yearbook (2000–2019), and the China Insurance Yearbook (2000–2019). We found that the median value of some variables (PHI density, SHI, INC, and GDP) is much different from their mean value, indicating that the distribution of these variables is skewed. To control for this apparent skewness, we use the natural log of these variables in our multivariate tests so that the distribution of these variables becomes more symmetric.⁵ Table 1 presents the summary statistics of the main variables that we used in our study.

We compute the main variables for a total of 590 province-year observations (30 provinces per year). The median value of the natural log of PHI density is 3.75, which is slightly smaller than the mean 3.889. The mean value of the proportion

Table 1: Summary statistics.

Variables	Mean	Std. dev.	Median	10th percentile	90th percentile
LNDEN	3.889	1.237	3.75	2.335	5.661
OR	9.028	0.00184	0.00133	0.00027	0.00458
ODR	12.569	2.91	12.3	9.208	16.352
KDR	24.87	7.757	24.95	14.13	35.28
GR	104.6	3.807	100.3	109.2	3.807
FAM	3.187	0.361	2.728	3.65	0.361
COU	73.33	2.846	73.75	69.43	76.64
EDU	8.538	1.116	8.463	7.188	9.898
UR	53.25	14.45	50.7	37	77.21
NGR	5.218	2.904	5.105	1.54	8.97
LNSHI	6.278	1.158	6.3	4.758	7.421
HEA	0.422	0.351	0.3	0.16	0.857
LNINC	9.453	0.541	9.410	8.784	10.169
LNAGDP	9.998	0.83	10.08	8.815	11.07

⁴ Data from Hong Kong, Macao, Taiwan, and Tibet were not included.

⁵ We just showed the summary statistics of natural log of these variables in Table 1.

of elderly individuals to the total population is 9.028%. The mean value of the ODR is 12.569 and KDR is 24.87.

3.4 Baseline Estimates

Our first estimating equation simply examines the relationship between aging and the PHI demand. The PHI demand is estimated by regressing the natural log of health insurance density on the proxy for population aging and control variables. We conduct a Hausman test⁶ and an F test⁷ and exclude the random effects and mixed regression models and then apply the fixed effects model. Our benchmark model is as follows:

$$\text{DEN}_{it} = a_0 + \sum_{k=1}^3 \beta_k \text{AGE}_{kit} + \sum_{j=1}^N \beta_j X_{jit} + \varepsilon_{it} \quad (1)$$

where β_k and β_j are the parameters to be estimated and ε_{it} is a random error term. i is equal to 1, 2, ..., 30, which represents 30 provinces; t represents time; a_0 represents the fixed effect of province i , which is inherent in each province and does not change over time; AGE_{kit} represents the explanatory variables; X_{jit} represents the control variables; and ε_{it} represents the error term.

Our second estimating equation examines the impact of aging and the PHI demand in a more structured manner, using a strategy that is system generalized moment estimation (SYS-GMM) to control for unknown factors causing biased and nonuniform problems that may occur in the regression results.

We estimate the following baseline equation:

$$\text{DEN}_{it} = a_0 + \sum_{k=1}^3 \beta_k \text{AGE}_{kit} + \sum_{j=1}^N \beta_j X_{jit} + \beta_l \text{AGE}_{li(t-1)} + \varepsilon_{it} \quad (2)$$

where β_k and β_j are parameters to be estimated and ε_{it} is a random error term. i is equal to 1, 2, ..., 30, which represents 30 provinces; t represents time; a_0 represents the fixed effect of province i , which is inherent in each province and

⁶ The Hausman test evaluates the consistency of an estimator when compared to an alternative, a less efficient estimator that is already known to be consistent. The Hausman test shows that the sample data strongly reject the null hypothesis at the 1% confidence level and significantly reject the null hypothesis.

⁷ F test is any statistical test wherein the test statistic has an F distribution under the null hypothesis. It is most often used when comparing statistical models that have been fitted to a dataset to identify the model that best fits the population from which the data were sampled.

does not change over time; AGE_{kit} represents the explanatory variables; X_{jit} represents the control variables; $AGE_{li(t-1)}$ represents the explanatory variable of the lag phase; ε_{it} represents the error term.

4 Empirical Results

4.1 Baseline Estimates

The estimates are reported in Table 2, which presents the results of our fixed effects model regression for the sample. Regression 2 in Table 2 shows the results of the dynamic panel model. Most results between the two regressions are similar.

Table 2: Effects of population aging on PHI (baseline estimates).

Dependent variable: LNDEN				
Variable	Fixed effects (1)		SYS-GMM (2)	
	Coefficient	t-Statistic	Coefficient	t-Statistic
OR	0.048**	0.012	0.003	0.524
ODR	0.052***	0.007	0.005**	0.012
KDR	-0.015***	0.005	-0.005***	0.009
GR	-0.036***	0.004	-0.003***	0.003
FAM	-0.323***	0.098	-0.012***	0.002
COU	0.005***	0.006	0.003*	0.055
EDU	0.106***	0.033	0.042***	0.004
UR	0.025***	0.003	0.008**	0.028
NGR	0.030***	0.011	0.019***	0.002
SHI	-0.111***	0.018	-0.046***	0.007
HEA	0.247***	0.069	0.351**	0.029
LNINC	0.000***	0.000	0.000***	0.115
LNAGDP	0.389***	0.048	0.071***	0
LNDEN _{t-1}			0.945***	0.016
Province	Y			
Cons.	3.288***	0.949	0.945	0.614
R ²	0.4738			
AR(1)			0.000	
AR(2)			0.132	
Sargan			0.301	

Note: ***, **, and * indicate significant confidence levels at the 1, 5, and 10%, respectively.

The results of the fixed effects model show that the proportion of the elderly population (those aged ≥ 65 years) in each province, ODR, education, urban and rural structure, NGR of population, health status, income, and GDP per capita have positive and significant associations with the PHI demand in China. A negative relation was found for the KDR, SR, family size, and social health insurance coverage. The SYS-GMM model shows that the ODR, education structure, urban and rural structure, NGR of population, health status, income, and GDP per capita have positive and significant associations with the PHI demand in China with all samples. We found a significant negative association between the KDR, SR, family size, marriage structure, and social health insurance coverage with basic PHI. Most coefficients in the SYS-GMM model are smaller than in the fixed-effects model.

Controlling for other control variables, we found a positive and significant association between population aging and the PHI demand. The coefficient of the proportion of elderly individuals in the total population is significant at 5% in the fixed effects model and suggests that the elderly population will increase the PHI demand. The KDR in both models has a negative and significant impact on the density of PHI. The ODR in both models has a significant positive effect on the PHI demand. We found that a 1-percent increase in aging growth over a 20-year period increases the PHI demand by approximately 0.05% on average.

Most control variables are statistically significant and have the expected sign. The SR has a negative sign on the PHI demand with significance at 1%, which is similar to that in the studies by Cardon and Hendel (2001). This is usually interpreted as women having greater expected utilization through child-bearing or greater risk aversion possibly stemming from having preferences exhibiting greater intertemporal substitution.

Family structure, using the FAM, shows a negative and significant association with the PHI demand. The larger the FAM and the more members in one family, the less the PHI demand. Our result is consistent with the findings of Hong, Gordon, and Glaetzer (2013), who found that the larger the family size, the stronger the ability to withstand risks, and families with fewer members have difficulty in withstanding risks and therefore have higher the PHI demand. China's typical family structure is "4+2+1," which refers to families wherein three generations coexist in various family forms. The structure emphasizes a social living community, including four older individuals (paternal and maternal grandparents), two parents, and one child, based on relationships of marriage, kinship, and adoption. With the 4-2-1 family structure, most of China's elderly individuals rely on the help and care that their children or other relatives provide (Ikels 1997). However, the 4-2-1 family structure will burden the family support system; parents (i.e. middle generation) will have to support two pairs of grandparents and their only child.

Even worse, when both parents become old, the only child (i.e. third generation) will eventually have to support two parents and all four grandparents, totalling six persons.

We found that the marriage structure will positively affect the PHI demand because married individuals will pay more attention to their own health and buy health insurance for them to reduce the risk of disease faced by the whole family. For one family with two working individuals, two incomes will lead to a greater ability to afford PHI. Another reason is that recently, the younger generation chooses not to live with parents, creating many “empty nest families.” As a consequence, parents purchase PHI for security consideration. Therefore, an increase in the married population will increase the demand for health insurance in China.

Our findings indicate that the education structure has a 1-percent significant positive impact on the PHI demand in China, which is consistent with several theoretical arguments that suggest that the educational level will affect a person’s risk awareness and their purchasing insurance (Tao et al. 2018; Holly and Robert 2007).

China’s increasing urban population has a significant role (i.e. a positive coefficient of 0.025 and 0.008) in promoting the PHI demand. According to a study published in the PNAS, >10% of China’s total income inequality is attributed to the rural-urban gap, so urban residents have strong purchasing power. The different medical seeking behaviors between urban and rural residents after disease development also lead to different health insurance needs. Previous studies (e.g. Cui 2014) indicate significant urban-rural inequality in health-related issues, such as healthcare resources, health outcomes in adults and children, prevalence of certain diseases, and unbalanced development between urban and rural areas in medical service supply. Another reason is that urban and rural populations have obvious differences in their residence. Generally speaking, areas where the rural population lives are relatively scattered, but the urban population is highly centralized. Insurance companies are often set up according to the level of regional economic development and population concentration, so the distribution of insurance companies in urban and rural areas may also be uneven, and there are more insurance companies in an urban area. Therefore, an increase in the proportion of the urban population will lead to an increase in the PHI demand in China. The impact of the total population on the PHI demand is positive and significant at 1%, indicating that the increase in the urban population has a positive effect on the PHI demand.

Social health insurance coverage has a negative effect on the PHI demand at 1% significance in our results, which is different from the results of Xiangnan (2011), who found that social health insurance did not squeeze out the PHI through the dynamic panel model analysis. Minglai and Zhexuan (2014) also marked

the same conclusion as that of Xiangnan (2011). Hong and Jun (2012) using the DID model found that, after the new rural cooperative medical system pilot, the probability of adults purchasing PHI increased, but the probability of children purchasing PHI decreased, and the crowding-out effect was more obvious in families with lower income. In terms of social health insurance, whether social medical insurance can promote or inhibit the development of PHI mainly depends on the scope and degree of social medical insurance theoretically. Under a certain critical point, social medical insurance will promote the development of PHI, which then becomes the supplement of social medical insurance; on the contrary, social medical insurance may inhibit the development of PHI, which will become the substitute relationship. Therefore, the relationship between social medical insurance and PHI will be different in different countries or regions, which is closely related to the specific system design of social medical insurance and the level of economic development and other factors. We found that the impact of social health insurance on the PHI demand is negative but not significant in China. Cutler and Gruber (1996) first proposed the crowding-out effect of public insurance on private insurance. Using the linear probability model and two-stage method, they found that between 1987 and 1972, the crowding-out effect expanded as the coverage of Medicaid for pregnant women and children increased. Hong and Jun (2012) indicated that the expansion of the coverage of social health insurance and improvement in the treatment level had an extrusion effect on the PHI demand.

We found a strong positive effect of the health status on Hong and Jun the demand for PHI. An adverse selection occurs in health insurance when there is an imbalance of high-risk, sick policyholders to healthy policyholders. The imbalance can occur due to sick individuals, who require more insurance, use more coverage, and purchase more policies than healthy individuals, who need less coverage and may not buy a policy at all.

The income and economic development in the province has a significant role in promoting the PHI demand. In economics, demand is the utility of an economic subject to a commodity or service in a certain period of time, usually related to income. For PHI, most expenditures to buy insurance come from income. The income level of residents reflects the purchasing power of consumers. Therefore, with the increase in income, the PHI demand will increase. Moreover, the economic situation of the region plays an important role in promoting the development of the insurance industry. In China, the development degree of PHI in the eastern developed areas is relatively high; both health insurance density and insurance depth are more advanced than the less developed areas in the central and western regions.

4.2 Subsample Test by Region

Population aging among regions is uneven in China. The regional distribution of China's population aging is in line with the famous "Heihe–Tengchong" population geographical distribution line.⁸ The aging in the provinces in the Yangtze River Delta and several municipalities directly under the central government is particularly prominent. The Sixth National Population Census data show that population aging in western provinces is developing rapidly by 2010 and enters the aging society, except Tibet, Qinghai, Ningxia, and Xinjiang. Especially Chongqing and Sichuan, the degree of population aging ranks in the forefront of the degree of aging. The aging population shows a trend of a gradual slowdown in the eastern region and accelerating in the central and western regions, and this trend is further intensified with the flow of labor population in the central and western regions to the East. Such regional differences may lead to differences in the impact of aging on the PHI demand. We divided our overall sample into three subsamples to reflect differences in the impact of population aging on the PHI demand in various provinces in China. Following the economic statistics criteria of the China Bureau of Statistics, we subgroup our whole sample into geographic locations (i.e. eastern, central, and western regions⁹). The results of the test are shown in Table 3 below.

Table 3 summarizes our estimates of three subsamples from our basic model; population aging still has a significant impact on the PHI demand in China. We found that the proportion of the elderly population in the eastern, central, and western regions is significantly positive on the PHI demand and that the proportion of the elderly population in the central region in China has the greatest impact on the PHI demand. The ODR in the three regional subsamples also has a significant positive effect on the PHI demand, and the ODR in the central region had the greatest impact on the PHI demand among the three regions. The KDR in all regions has a significantly negative effect on the PHI demand, and the KDR in the central region had the greatest impact on the PHI demand among the three regions. The subsample findings by region are consistent with the regression results of the total sample.

⁸ Also called the Aihui-Tengchong Line (and internationally as the Hu line). It is an imaginary line that divides the area of China into two roughly equal parts. It stretches from the city of Heihe to Tengchong, diagonally across China.

⁹ The eastern region includes Beijing, Tianjin, Hebei, Liaoning, Shanghai, Jiangsu, Zhejiang, Fujian, Shandong, Guangdong, Guangxi, and Hainan. The central region includes Shanxi, Inner Mongolia, Jilin, Heilongjiang, Anhui, Jiangxi, Henan, Hubei, and Hunan. The western region includes Chongqing, Sichuan, Guizhou, Yunnan, Shaanxi, Gansu, Qinghai, Ningxia, and Xinjiang.

Table 3: Subsample test by region.

	Dependent variable: LN DEN		
	Eastern region (1)	Central region (2)	Western region (3)
OR	0.025** (0.021)	0.089** (0.024)	0.010** (0.021)
ODR	0.028*** (0.009)	0.043** (0.015)	0.034** (0.018)
KDR	−0.005** (0.013)	−0.017*** (0.006)	−0.003*** (0.008)
GR	0.037*** (0.006)	0.015*** (0.007)	0.014* (0.010)
FAM	0.185 (0.226)	−0.112 (0.136)	0.347 (0.203)
COU	0.018** (0.012)	−0.002*** (0.007)	0.026** (0.015)
EDU	−0.175* (0.075)	−0.057* (0.053)	0.281* (0.058)
UR	0.040*** (0.005)	0.004*** (0.004)	0.003*** (0.006)
NGR	−0.013** (0.021)	−0.060** (0.013)	−0.013** (0.018)
SHI	0.129** (0.031)	−0.058** (0.033)	−0.458* (0.054)
HEA	0.447* (0.100)	−0.518* (0.098)	0.976 (0.444)
LNINC	−0.000*** (0.000)	−0.000*** (0.000)	−0.000*** (0.000)
LNAGDP	0.338* (0.087)	0.156* (0.055)	0.125* (0.071)
Cons.	1.365 (0.789)	5.750 (0.290)	0.706 (0.126)

Note: ***, **, and * indicate significant levels of confidence at 1, 5, and 10%, respectively.

4.3 Subsample Test by Year

The proportion of elderly individuals aged 65+ in the total population was 6.96%, and the elderly dependency ratio was 9.92% in 2000. By the end of 2010, the proportion of the population aged 65+ in the total population had increased to 8.87%, and the elderly dependency ratio was 12.62%. By the end of 2018, the proportion of the population aged 65+ years in the total population had increased

Table 4: Subsample test by year.

	Dependent variable: LNDEM	
	2000–2010 (1)	2011–2018 (2)
OR	0.053*** (0.019)	0.022* (0.013)
ODR	0.052*** (0.009)	0.046*** (0.008)
KDR	−0.045*** (0.007)	−0.002 (0.007)
GR	−0.048*** (0.008)	−0.022*** (0.004)
FAM	−0.228* (0.137)	−0.281** (0.111)
COU	0.002 (0.010)	0.000 (0.007)
EDU	0.167*** (0.045)	0.038 (0.039)
UR	0.005 (0.005)	0.014*** (0.004)
NGR	−0.005 (0.015)	0.037*** (0.013)
SHI	−0.135*** (0.026)	−0.106*** (0.021)
HEA	0.461*** (0.103)	0.159** (0.081)
LNINC	0.000** (0.000)	0.000*** (0.000)
LNAGDP	0.942*** (0.118)	0.193*** (0.041)
Cons.	−2.534 (1.955)	5.328*** (0.905)

Note: ***, **, and * indicate significant levels of confidence at 1, 5, and 10%, respectively.

to 10.92%, and the elderly dependency ratio was 40.4%. We divided the samples into two stages: 2000–2010 and 2011–2018 (Table 4).

The positive relation between aging and the PHI demand is consistent across time. Although the subsample in 2000–2010 (5.3, 5.2, and 4.5%) had higher PHI demand than those in 2011–2018 (2.2, 4.6, and 0.2%), in both cases, the PHI demand increased with aging.

4.4 Subsample Test by Region and Year

To draw a comprehensive conclusion, the eastern, central, and western regions were again regressed by year samples, and the results are shown in Table 5.

Table 5 shows the results for aging on the PHI demand for the different subsamples divided by space and time. Comprehensive conclusions can be drawn

Table 5: Subsample test by region and year.

	Dependent variable: LNDEN					
	Eastern region	Central region	Western region	Eastern region	Central region	Western region
	2000–2010 (1)	2000–2010 (2)	2000–2010 (3)	2011–2018 (4)	2011–2018 (5)	2011–2018 (6)
OR	0.066** (0.024)	0.049** (0.029)	0.029* (0.054)	0.033* (0.031)	0.037** (0.035)	0.037** (0.031)
ODR	0.009*** (0.010)	0.030** (0.016)	0.013** (0.023)	−0.059*** (0.013)	0.018** (0.025)	0.060** (0.037)
KDR	−0.030** (0.015)	−0.007*** (0.005)	−0.015** (0.014)	−0.002** (0.019)	−0.046** (0.014)	−0.017*** (0.008)
GR	−0.051*** (0.008)	−0.011*** (0.008)	−0.024** (0.024)	−0.013** (0.006)	−0.005*** (0.009)	−0.013*** (0.008)
FAM	−0.652 (0.306)	−0.330 (0.131)	0.510 (0.356)	0.464 (0.256)	0.062 (0.281)	−0.084 (0.279)
COU	−0.025** (0.014)	0.017*** (0.007)	0.064** (0.030)	0.030** (0.015)	0.021** (0.013)	0.027** (0.018)
EDU	0.104* (0.099)	−0.030** (0.050)	0.457* (0.105)	−0.036 (0.104)	−0.236* (0.097)	0.002* (0.082)
UR	0.010v (0.009)	0.009*** (0.004)	−0.015** (0.012)	0.028*** (0.009)	0.029** (0.013)	−0.001*** (0.009)
NGR	−0.012** (0.030)	−0.044** (0.014)	0.023** (0.031)	0.055** (0.025)	0.004** (0.029)	0.037 (0.023)
SHI	0.187** (0.034)	0.002** (0.035)	−0.498* (0.092)	−0.031** (0.044)	−0.006* (0.051)	−0.442 (0.112)
HEA	0.390 (0.132)	−0.732 (0.106)	1.507 (1.006)	0.094 (0.131)	−0.344 (0.189)	0.958 (0.395)
LNINC	−0.000*** (0.000)	0.000*** (0.000)	−0.000*** (0.000)	0.000*** (0.000)	0.000*** (0.000)	−0.000 (0.000)
LNAGDP	1.107 (0.209)	0.926 (0.137)	−0.092 (0.454)	0.168* (0.079)	0.081* (0.066)	0.077** (0.050)
Cons.	−1.140 (2.842)	−5.027 (2.034)	−1.721 (7.403)	−0.602 (2.042)	4.235 (2.368)	6.173** (2.727)

Note: ***, **, and * indicate significant levels of confidence at 1, 5, and 10%, respectively.

from the regression conclusions of spatial and time samples. We continue to find that aging is strongly associated with the PHI demand in different samples. In OR specification, aging had the greatest positive, statistically significant effect on the probability of purchasing PHI in the eastern region sample from 2000 to 2010 (6.6%). In the Western region from 2011 to 2018, ODR had the most positive effect for individuals to purchase PHI (6%). KDR had the most negative effect on the PHI demand in the central region from 2011 to 2018 (4.6%). Thus, we found a positive relationship between aging and the PHI demand in both regions and time.

4.5 Mechanism of Aging on the PHI Demand

The basic model mainly analyzes the impact of population aging on the PHI demand, but the aging of population can indirectly affect the demand for commercial insurance by influencing path variables. Therefore, we establish the intermediary effect model to find the path variables of population aging, so as to study the internal mechanism of population aging affecting the PHI demand:

$$P_{it} = \gamma_0 + \sum_{k=1}^3 \gamma_k \text{AGE}_{kit} + \sum_{j=1}^N \gamma_j X_{jit} + \varepsilon_{it} \quad (3)$$

$$\text{DEN}_{it} = \beta_0 + \sum_{k=1}^3 \beta_k X_{kit} + \sum_{j=1}^N \beta_j X_{jit} + \beta_l P_{it} + \varepsilon_{it} \quad (4)$$

Among them, P_{it} is the path variable, i.e. the aging population indirectly affects the PHI demand through this path variable. The purpose of setting up the model (3) was to confirm whether P_{it} is the path variable of AGE_{kit} . If $\gamma_k > 0$ and has statistical significance, then P_{it} is the path variable of AGE_{kit} . In model (4), the evidence that aging affects the PHI demand through path variables is that the coefficient β_l of path variables has economic significance and is statistically significant, and due to the absorption of path variables, the coefficient β_k of aging population variables should be significantly lower than that of the model (3). In this study, the number of diagnosed and treated individuals and healthcare expenditure is used as the path variables of the aging population affecting the PHI demand.

4.5.1 Number of Diagnosed and Treated Individuals

The number of diagnosed and treated individuals indicates the total number of individuals who underwent diagnosis and treatment, including the number of visits in hospitals (outpatient, emergency, and inpatient), appointment diagnosis and treatment, single health examination, health consultation, and guidance per

times and excluding the workload of inspection, treatment, disposal, number of immunization, and health management service.

In the results shown in Table 6, in the intermediary effect model, the coefficient of the proportion of elderly individuals in the total population was

Table 6: Aging on the PHI demand by the number of diagnosed and treated individuals.

	Dependent variable: number of diagnosed and treated individuals	Dependent variable: LN DEN
	(1)	(2)
Number of diagnosed and treated individuals		0.068** (0.020)
OR	0.158** (0.026)	0.037** (0.012)
ODR	0.014** (0.014)	0.043*** (0.007)
KDR	−0.034** (0.011)	−0.013*** (0.005)
GR	−0.010*** (0.009)	−0.036*** (0.004)
FAM	0.473 (0.206)	−0.355* (0.098)
COU	0.005** (0.013)	−0.006*** (0.006)
EDU	−0.551* (0.069)	0.144** (0.034)
UR	−0.023*** (0.006)	0.027*** (0.003)
NGR	0.002** (0.022)	0.029*** (0.010)
SHI	0.364** (0.039)	−0.136** (0.020)
HEA	0.059 (0.145)	0.243* (0.068)
LNINC	0.000*** (0.000)	−0.000*** (0.000)
LNAGDP	0.659** (0.100)	0.345** (0.049)
Cons.	13.092*** (1.997)	2.398** (0.976)

Note: ***, **, and * indicate significant levels of confidence at 1, 5, and 10%, respectively.

0.158 and significant at the statistical level of 5%. The ODR was 1.4% at the statistical level of 5%, and the KDR was 3.4% at the statistical level of 1%, indicating that population aging will increase the number of diagnosis and treatment. Column 3 shows that the coefficient of the proportion of elderly individuals in the total population and the ODR decreased from 4.8% and 5.2% to 3.7% and 4.3%, respectively, and the negative effect of the KDR decreased from 1.5% to 1.3% after adding path variable, and the coefficient of diagnosis and treatment times was 0.068 and significant at 5% statistical level. The comparison of the two regression results shows that aging not only has a direct impact on the demand for PHI but also absorbs the original influence coefficient through the number of diagnosed and treated individuals, which indirectly affects the demand for PHI, indicating that the number of diagnosed and treated individuals is the path variable of aging affecting the PHI demand.

4.5.2 Healthcare Expenditure

We used health expenditure as a proxy for another path variable. Medical expenses are one of the largest sources of uncertainty faced by individuals and the type of unlikely and expensive wealth shocks that health insurance is suited to address. The World Bank pointed out that the higher the proportion of individuals aged 60+, the higher the share of medical and health expenditures. This is because the medical services of the elderly population often include expensive technology, hospitalization, and long-term care, which are much more complex than the treatment of the young population. Health expenditure is defined as the ratio of the total medical expenditures of urban residents per capita and the medical expenditures of rural residents per capita to the total population. Although the Chinese government has accelerated the reform of the healthcare system in recent years, the healthcare expenditures of residents have increased year by year in China. PHI can reduce the economic burden of residents in the reimbursement of medical expenses, so increased healthcare spending will also increase the PHI demand.

The impact of healthcare expenditures on the PHI demand is significant at 10% and positive. Healthcare expenditures have increased significantly and rapidly in China. The same phenomenon is reflected in the increase in private per capita health expenditure of Chinese households, which has nearly tripled in the last decade for Beijing, as the region with the highest private health expenditure in China. According to the China Bureau of Statistics, in 2018, the total expenditure on healthcare in China reached over 5.9 trillion yuan, which has soared from <500 billion yuan in 2000. The reasons behind this growth are multifold. The most important factors are the increasing living standards and aging of the population.

The regression results of the effect of aging on The PHI demand through medical expenditure are shown in Column 3. The aging coefficients in Table 7 were 5, 1.4, and -1.8% , which are significant at a 1% statistical level, indicating that with aging, the healthcare expenditure increases. The regression results of adding path variables are different from the benchmark regression. The coefficient

Table 7: Effect of aging on PHI demand by healthcare expenditure.

	Dependent variable: Healthcare expenditure (1)	Dependent variable: LN DEN (2)
Healthcare expenditure		0.478* (0.089)
OR	0.005*** (0.006)	0.040** (0.012)
ODR	0.014*** (0.003)	0.045*** (0.007)
KDR	-0.018^{***} (0.003)	-0.013^{***} (0.006)
GR	-0.011^{***} (0.002)	-0.031^{***} (0.004)
FAM	-0.004^* (0.046)	-0.321^* (0.096)
COU	0.010*** (0.003)	-0.010^* (0.006)
EDU	-0.033^{**} (0.015)	0.122*** (0.032)
UR	0.005*** (0.001)	0.023*** (0.003)
NGR	0.005*** (0.005)	0.027*** (0.010)
SHI	-0.010^{***} (0.009)	-0.107^{**} (0.018)
HEA	0.167** (0.032)	0.167* (0.069)
LNINC	0.000*** (0.000)	-0.000^{***} (0.000)
LNAGDP	0.075* (0.022)	0.353** (0.047)
Cons.	7.349 (0.441)	-0.225 (1.134)

Note: ***, **, and * indicate significant levels of confidence at 1, 5, and 10%, respectively.

of the proportion of elderly individuals in the total population and ODR decreased from 4.8% and 5.2% to 4.0% and 4.5%, respectively, and the negative effect of KDR decreased from 1.5% to 1.3% after adding path variable, and the medical expense was 0.478 at the level of 10%. It shows that aging has a significant absorption effect on the PHI demand and that medical expenditure is another indirect path of aging affecting the PHI demand.

Through the intermediary effect models (3) and (4), in Tables 6 and 7, we can obtain some internal mechanisms of aging on the PHI demand: with aging, the number of diagnosed and treated individuals and healthcare expenses increase, increasing the PHI demand.

5 Robustness Test

5.1 Alternative Measure of the PHI Demand

In this section, we explore the robustness of our results to an alternative measure of aging and alternative estimation techniques that handle the potential impact of outliers. Specifically, we construct one alternative measure: health insurance penetration, which is used as an indicator of insurance sector development within a country and calculated as the ratio of total insurance premiums to the gross domestic product in a given year. We also used the same control variables as in the regressions before.¹⁰ The results after alternating the explained variables are shown in Table 8.

As shown in Table 8, regardless of the measure of the interpreted variable that we employ, we found a positive association between the proportion of elderly individuals in the total population, ODR, and PHI demand. Our finding of a significant negative effect of the KDR on the PHI demand is also robust to basic estimates. The coefficient in Table 8 is much smaller than in the basic model.

5.2 IV Strategy

Two problems motivate the use of the IV strategy. First, using the proportion of elderly individuals in the total population data, ODR, and KDR to proxy for aging in the earlier years introduces measurement error that may bias the estimate downward. Second, the basic estimate will have omitted variable bias if the PHI demand increases with aging. In this case, the basic estimate will overestimate the

¹⁰ Except variable of GDP per capita, because health insurance penetration is also measured by GDP.

Table 8: Effects of population aging on the PHI demand (alternative measure).

Dependent variable: Natural log of health insurance penetration				
Variable	Fixed effects		SYS-GMM	
	(1)		(2)	
	Coefficient	t-Statistic	Coefficient	t-Statistic
OR	0.00014***	0.00003	0.00004***	0.00005
ODR	0.00014***	0.00001	−0.00006***	0.00003
KDR	−0.00004***	0.00001	-3×10^{-6} ***	0.00001
GR	−0.00010***	0.00001	−0.00003***	0.00001
FAM	−0.00008***	0.00023	0.00045***	0.00024
COU	−0.00003***	0.00001	−0.00001***	0.00002
EDU	0.00039***	0.00007	−0.0001***	0.00012
UR	−0.00002***	0.00007	0.00002***	0.00001
NGR	0.00004***	0.00002	−0.00006***	0.00003
SHI	−0.00021***	0.00004	0.00001***	0.0001
HEA	0.00099***	0.00016	0.00100***	0.00049
LNINC	0.00000005***	9×10^{-9}	0.00000006***	8×10^{-9}
LN DEN_{t-1}			0.79101***	0.03357
Cons.	−0.0001***	0.00011	0.00049***	0.00225
R ²	0.5837			
AR(1)			0.000	
AR(2)			0.155	
Sargan			0.327	

Note: ***, **, and * indicate significant levels of confidence at the 1, 5, and 10%, respectively.

true effect of an increase with aging. We address both problems by instrumenting for aging with ammonia nitrogen emission and urban green area (Table 9).

It is widely accepted that the environment will affect human health. Ammonia nitrogen emission and urban green areas are important constitutes of the environment. The environment is a place for individual’s daily activity, which influence individual’s behavior and cognition, which are conducive to an individual’s physical and mental health; especially, activities of the elderly population are mainly limited in the near living environment, so the living environment has a greater impact on the physical and mental health of the elderly individual. If the living environment is well afforested and less polluted, the health of the elderly individual will be improved, which will increase the life span and affect the aging of the population. Another identifying assumption in our IV estimation is that variations in the ammonia nitrogen emission and urban green area are exogenous to the PHI demand.

Table 9: Two-stage least squares.^a

	Dependent variable: LNDEN		
	(1)	(2)	(3)
OR	0.034* (0.044)		
ODR		0.014** (0.023)	
KDR			−0.071** (0.032)
GR	−0.036*** (0.005)	−0.034*** (0.005)	−0.035*** (0.005)
FAM	−0.438*** (0.140)	−0.342*** (0.089)	−0.697*** (0.186)
COU	0.004*** (0.007)	0.003*** (0.007)	0.005*** (0.007)
EDU	0.108** (0.046)	0.165* (0.054)	0.262* (0.065)
UR	0.024*** (0.003)	0.023*** (0.003)	0.029*** (0.005)
NGR	0.066*** (0.010)	0.080** (0.016)	0.006** (0.031)
SHI	−0.036** (0.028)	−0.037** (0.026)	−0.081** (0.025)
HEA	0.380* (0.086)	0.416* (0.099)	0.439* (0.095)
LNINC	0.000*** (0.000)	0.000*** (0.000)	0.000*** (0.000)
LNAGDP	0.325* (0.058)	0.281* (0.070)	0.394* (0.086)

^aWe just showed the second-stage estimate results from Eq. (6). Note: ***, **, and * indicate significant levels of confidence at the 1, 5, and 10%, respectively.

Therefore, ammonia nitrogen emission and urban green area are valid instruments¹¹ for aging if it does not have any direct effect on decisions on PHI and is not correlated with any other covariates in the equation. The first-stage equation

¹¹ In terms of the instrument's relevance, the Kleibergen–Paap *F*-statistic is always >10. Hence, we can reject the null of weak instrument bias.

is as follows:

$$OR_{it}(ODR_{it}, KDR_{it}) = \beta_0 + \beta_l AMM_{it} + \beta_m GRE_{it} + \sum_{j=1}^N \beta_j X_{jit} + \varepsilon_{it} \quad (5)$$

The second-stage regression is as follows:

$$DEN_{it} = \beta_0 + \beta_k OR_{it} OR_{it}(ODR_{it}, KDR_{it}) + \sum_{j=1}^N \beta_j X_{jit} + \varepsilon_{it} \quad (6)$$

The excluded instruments are the variables AMM_{it} and GRE_{it} .

These results give confidence to the robustness of the initial basic estimates of the effect of aging on the PHI demand. We found that the proportion of elderly individuals in the total population, ODR, and KDR as instrumented by ammonia nitrogen emission and urban green area have significant effects on demand for PHI. Quantitatively, the estimated effects are sizable. These results give confidence to the robustness of the initial basic estimates of the effect of aging on the PHI demand.

5.3 Rolling Estimation

When we analyze the effect of aging on the demand for PHI, using time series data, a key assumption is that the parameters of the model are constant over time. However, the environment often changes considerably and may not be reasonable to assume that a model's parameters are constant. Hence, we use the rolling model to assess our model's stability over time, which computes parameter estimates over a rolling window of a fixed sample size. To address the rolling estimate, we first use the 2000–2010 data; then, each year's observation data will be added to the sample.

Table 10 shows that parameters are truly constant over the entire sample. The figures show that aging increases the PHI demand. This should be interpreted only as a rough approximation of the length of the delay because of the slow development of PHI.

5.4 Two-way Fixed Effects Model

The last concern with interpreting our estimates as the causal effects of aging on the PHI demand is that it fails to consider the correlation of residuals in different regions in different years, which leads to a large bias in the estimation results, and the bias will increase under the influence of time effect. We used the double

Table 10: Rolling estimation.

	Dependent variable: LN DEN							
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
OR	0.033** (0.019)	0.040** (0.018)	0.040** (0.017)	0.042** (0.016)	0.045** (0.015)	0.045** (0.014)	0.043** (0.013)	0.048** (0.013)
ODR	-0.032*** (0.009)	-0.048*** (0.009)	-0.048*** (0.009)	-0.050*** (0.008)	-0.049*** (0.008)	-0.050*** (0.007)	-0.049*** (0.007)	-0.052*** (0.007)
KDR	-0.010*** (0.007)	-0.010*** (0.007)	-0.011*** (0.007)	-0.013*** (0.007)	-0.013*** (0.006)	-0.014*** (0.006)	-0.015*** (0.006)	-0.015*** (0.006)
GR	-0.048*** (0.008)	-0.035*** (0.007)	-0.031*** (0.007)	-0.029*** (0.007)	-0.027*** (0.006)	-0.028*** (0.005)	-0.031*** (0.005)	-0.036*** (0.005)
FAM	-0.228 (0.137)	-0.258 (0.132)	-0.306 (0.126)	-0.345 (0.119)	-0.345 (0.113)	-0.340 (0.109)	-0.315 (0.104)	-0.347* (0.100)
COU	0.002*** (0.010)	0.006*** (0.009)	0.003*** (0.009)	0.001*** (0.008)	-0.000*** (0.007)	-0.002*** (0.007)	-0.004*** (0.007)	0.006*** (0.006)
EDU	0.167** (0.045)	0.165** (0.044)	0.154** (0.042)	0.140** (0.040)	0.128** (0.039)	0.129** (0.037)	0.116** (0.036)	0.126** (0.034)
UR	0.005*** (0.005)	0.005*** (0.004)	0.005*** (0.004)	0.005*** (0.004)	0.006*** (0.004)	0.007*** (0.004)	0.008*** (0.004)	0.020*** (0.003)
NGR	-0.005** (0.015)	-0.000** (0.014)	0.007** (0.014)	0.011** (0.013)	0.013** (0.012)	0.015** (0.012)	0.017** (0.011)	0.025** (0.011)
SHI	-0.135** (0.026)	-0.137** (0.025)	-0.135** (0.024)	-0.131** (0.022)	-0.125** (0.021)	-0.122** (0.020)	-0.116** (0.019)	-0.117** (0.019)
HEA	0.461 (0.103)	0.483* (0.099)	0.478* (0.095)	0.482* (0.090)	0.463* (0.086)	0.420* (0.081)	0.411* (0.077)	0.275* (0.072)
LNINC	0.000*** (0.000)	0.000*** (0.000)	0.000*** (0.000)	0.000*** (0.000)	0.000*** (0.000)	0.000*** (0.000)	0.000*** (0.000)	0.000*** (0.000)
LNAGDP	0.942 (0.118)	0.973 (0.114)	0.972 (0.109)	0.988 (0.104)	0.993* (0.100)	0.944* (0.096)	0.908* (0.093)	0.507* (0.059)
Cons.	-2.534 (1.955)	-4.258 (1.790)	-4.180 (1.697)	-3.942 (1.596)	-4.011 (1.476)	-3.227 (1.367)	-2.440 (1.300)	2.006 (1.040)

Note: ***, **, and * indicate significant levels of confidence at the 1, 5, and 10%, respectively.

fixed-effects model to control the possible systematic measurement error. We performed the estimation using the following equation:

$$\text{DEN}_{it} = a_0 + \sum_{k=1}^3 \beta_k \text{AGE}_{kit} + \sum_{j=1}^N \beta_j X_{jit} + \mu_{it} + \varphi_{it} + \varepsilon_{it} \quad (7)$$

where β_k and β_j are parameters to be estimated and ε_{it} is a random error term. i is equal to 1, 2, ..., 30, which represents 30 provinces; t represents time; a_0 represents the fixed effect of province i , which is inherent in each province and does not change over time; AGE_{kit} represents the explanatory variables; X_{jit} represents the control variables, μ_{it} is used to control regional fixed effects; φ_{it} is used to control time fixed effects; and ε_{it} represents error term (Table 11).

Consistent with our findings of the basic model, Table 11 shows that aging growth leads to significant increases in the PHI demand.

Table 11: Two-way fixed effects model.

Dependent variable: LNDEM	
OR	0.045*** (0.012)
ODR	−0.036*** (0.006)
KDR	0.005 (0.005)
GR	−0.029*** (0.004)
FAM	−0.215** (0.094)
COU	0.008 (0.006)
EDU	0.213*** (0.033)
UR	0.024*** (0.003)
NGR	0.043*** (0.010)
SHI	−0.043** (0.020)
HEA	0.176*** (0.068)
LNINC	−0.000* (0.000)
LNAGDP	0.383*** (0.047)
Cons.	0.376 (0.973)
Province	Y
Year	Y

Note: ***, **, and * indicate significant levels of confidence at the 1, 5, and 10%, respectively.

6 Conclusions

Understanding how aging affects the demand for PHI is essential in crafting efficient PHI policies in China. The causal effects of aging on the PHI demand are difficult to identify because of endogeneity and measurement errors.

This study sheds light on the issues by estimating the causal effect of aging on the PHI demand. We found significant evidence that population aging has a significant positive impact on the PHI demand in China considering sex, education, income, and health conditions simultaneously through the use of the following: (1) health insurance density as an approximation for the demand for health insurance, (2) proportion of the elderly population to the total population as an approximation for population aging, (3) KDR as an approximation for population aging, and (4) ODR as an approximation for population aging. In terms of mechanism, the intermediary effect model showed that with aging, the number of diagnosed and treated individuals and healthcare expenses increases, which increases the PHI demand.

We found the unbalanced PHI development between China's eastern and western regions. In 2016, the top 10 provinces and municipalities in health insurance premium income were located in more developed regions, such as Guangdong, Jiangsu, Beijing, Zhejiang, and Shanghai; the top 10 incomes for health insurance premiums accounted for 69% of the national total, and the last 10 only accounted for 7%. The findings from the subsample by region showed that the proportion of the elderly population, ODR, and KDR in the central region in China has the greatest impact on the PHI demand. The results of the subsample by year showed that the subsample in 2000–2010 (5.3, 5.2, and 4.5%) had higher PHI demand than those in 2011–2018 (2.2, 4.6, and 0.2%). We used the subsample by region and year. In OR specification, aging had a most positive, statistically significant effect on the probability of purchasing PHI in the eastern region sample from 2000 to 2010 (6.6%). ODR had the most positive effect for individuals to purchase PHI (6%) in the western region from 2011 to 2018. KDR had the most negative effect on The PHI demand in the central region from 2011 to 2018 (4.6%). Thus, we found evidence of a positive relationship between aging and PHI demand in both regions and years.

We also found that other variables affect the PHI demand. SR had a negative effect on the PHI demand. The family and marriage structures of China's population had a significant impact on the PHI demand. More specifically, the larger the family size, the lower the PHI demand, and the larger the proportion of the married population, the higher the PHI demand due to the responsibility of the married population for families' needs to raise children and support the elderly population. Additionally, the education and urban-rural structures in China significantly increase the PHI demand as educational level increases and the proportion of the urban population increases, people's demand for health insurance increases accordingly. The increasing urban population in China has a significant role in promoting PHI demand. Social health insurance

coverage is found to have a negative effect on the PHI demand. Health status has a positive effect on the demand for PHI. Economic development and income also have an extremely important impact on the demand for health insurance.

Further, we performed four robustness tests to examine the effect of population aging on the PHI demand in China and obtained the same results. The findings from our IV regressions showed that the proportion of elderly individuals in the total population, ODR, and KDR as instrumented by ammonia nitrogen emissions and urban green areas have significant effects on the demand for PHI. We documented that the abovementioned result is robust to an alternative measure. The rolling model assessed our model's stability over time, which computed parameter estimates over a rolling window of a fixed size through the sample and suggested that aging has a significant positive effect on the PHI demand. We also documented robustness using the two-way fixed effects model.

Our results support that population aging positively affects the PHI demand. However, there is still some room for further study. For example, some demographic indicators cannot be measured by macro data (e.g. religious beliefs and occupational categories). As more data become available, future research from a wider sample will lead to a greater understanding of the impact of population aging on health insurance demand. Moreover, time-series studies of the demand for health insurance could lead to greater knowledge of the growth and maturation of insurance markets.

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