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Population Aging, Household Savings and Asset Prices: A Study Based on Urban Commercial Housing Prices

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Abstract: Currently, China's aging population, high savings rate and high housing asset prices coexist, which has become a hot issue in academic research. First, considering the life-cycle hypothesis and overlapping generations model, asset prices are negatively correlated with the population dependency ratio and positively correlated with household savings. Second, based on census data from prefecture-level cities, a pooled regression model and two-stage least squares (2SLS) are used in this empirical research. The child dependency ratio was found to have a significant negative impact on housing prices, while the elderly dependency ratio had a positive impact on housing prices. The positive relationship between household savings and housing prices is highly significant. Finally, the interaction analysis shows that the impact of population aging on housing prices differs under different levels of household savings; thus, population aging affects housing prices through household savings, and the mediator dilutes and weakens this impact. The elderly generation's release of savings could gradually inhibit housing prices. Population aging causes long-run downside risks but not a market meltdown.

Keywords: population structures; household savings; asset prices; commodity housing prices

1. Introduction

The continuous rise in the price of commercial houses in China has over time become one of the country's most important social issues. Difficulties in buying a house are faced by most Chinese people. Academic circles have engaged in much discussion of housing prices. Scholars mainly analyze and express their views from the perspectives of land supply, monetary decisions and bubble speculation and yield no consistent conclusion. Existing studies focus on the impact of financial variables, such as interest rates and credit standards, or the impact of demographic variables. Few scholars analyze the simultaneous impact of demographic and financial factors on housing prices. In the literature, many studies have investigated the effects of the aging population [1–4]. In addition, many studies have investigated housing prices [5–7], and these studies have laid the foundation for our research.

In fact, demographic factors, financial factors and housing prices are often intertwined, and demographic factors and financial factors jointly impact housing prices. On the one hand, issues around population aging in China are becoming increasingly severe. From the perspective of population history, China's first birth peak was in the 1950s, when approximately 100 million people were born.

These people entered old age around 2010, and the proportion of the elderly population is rising. The second birth peak began in 1962, and this generation will enter old age after 2020, suggesting that the aging of the population will be faster after 2020. The total labor force will also start to decline faster. As early as 2000, the China Office for Aging noted in the "Report on Forecasting the Development Trend of China's Population Aging" that the development trend of China's population aging from 2001 to 2100 can be divided into the following three stages: the first stage ranging from 2001 to 2020 is the rapid aging phase, the second stage, from 2021 to 2050, is the accelerated aging phase, and the third stage, from 2051 to 2100, is the stable and severe aging phase. According to the "2015 China 1% Population Sample Survey Bulletin" released by the National Bureau of Statistics on 20 April 2016, the proportion of the population aged 0–14 decreased by 0.08 percentage points, the proportion of the population aged 15–59 decreased by 2.81 percentage points and the proportion of the population aged 60 and over increased by 1.60 percentage points compared with the sixth national census in 2010; these data indicate that the population structure is gradually aging. China's population is aging faster than the world average, and China in the 21st century will irreversibly be a "deeply aging" society. On the other hand, the balance of Chinese residents' savings has continued to rise in recent years. According to data released by the National Bureau of Statistics, the balance of household savings deposits at the end of 2016 was 60.65 trillion yuan, reflecting a 9.9% year-on-year increase. Considering that Chinese parents generally use their savings to buy houses for their children, most of the savings of the elderly flow to the real estate market. Recently, China has enjoyed dividends resulting from the baby boom, a rising savings rate and a booming economy. The aging of baby boomers could affect the number of workers, household savings and investment as the demographic dividend fades. With population aging and high household savings, what is the future of asset prices? Existing studies mainly focus on the impact of either population aging or household savings but not both together.

1.1. The Impact of Population Aging on Asset Prices

Scholars worldwide have studied the relationship between population aging and asset prices in the framework of the overlapping generations model based on the life-cycle perspective. Most scholars believe that population aging is negatively related to asset prices. Poterba [8] establishes a two-generation intergenerational model, considering that the baby boom period will be followed by a period of declining birth rates. When society enters the aging stage, asset demand decreases, and supply exceeds demand in the market. Subsequently, asset prices fall. Abel [9] argues that Poterba's research considers only factors related to asset demand, so he adds the factors of asset supply to the overlapping generations model. The retirement of baby boomers can result in a decline in asset prices when considering the motivation of individual inheritance [10–13]. Mankiw and Weil [14] first focus on the impact of population aging on housing prices, and they argue that population aging will lead to a decline in housing prices. When the "baby boomer" generation reached working age, the rising demand for housing was the main factor responsible for the increase in housing prices in the United States in the 1970s. They propose the "asset meltdown" hypothesis. Simo-Kengne [15] believes that the increase in population aging leads to assets that, in turn, lead to downward pressure on house prices and even asset meltdown. Subsequent studies support the view that population aging can lead to falling house prices [16–19]. Chen et al. [20] use the microdata of the 2000 census and the 2005 population census and consider the "baby boom" to be an important reason for the recent increase in housing demand and housing prices. At the same time, the aging of the population has caused China's housing prices to fall sharply since 2012.

However, some scholars have offered different opinions, arguing that population aging will not lead to a decline in asset prices. Engelhardt and Poterba [21] use Canada's post-World War II data to study the impact of population aging on housing demand and housing prices. Although Canada and the United States have similar population aging conditions, their housing prices show completely different trajectories, and population aging in Canada will cause housing prices to rise. Green and Lee [22] use repeated cross-sectional census data from 1990–2014 to conclude that changes in demographics have little effect on housing demand. Subsequent studies support the notion that population aging does not lead to a decline in housing prices [23–25].

There are also studies that indicate that population aging will not lead to a decline in asset prices in the short term but that the effect will reverse in the long run with the aggravation of aging to ultimately demonstrate an inverted U-shaped relationship. Li and Shen [26] use 1997–2007 panel data for China to draw a relationship between population aging and housing prices. With the increasing elderly dependency ratio, housing consumption first increases and then decreases, eventually leading to a decline in housing prices. Similarly, Farkas [27] explores Hungarian data and finds that the negative impact of population aging on housing prices does not appear directly in the short term. Li et al. [28] predict that China's urban housing demand in 2015–2030 will develop in accordance with the inverted U characteristics of "rising-stable-falling".

1.2. The Relationship between Household Savings and Asset Prices

Regarding the relationship between household savings and housing asset prices, most scholars have studied the impact of housing asset prices on household savings. Gan [29] tracked 12,793 individuals in Hong Kong and concluded that rising housing wealth reduced precautionary savings and stimulated consumption. Chen and Qiu [30] believe that high housing prices have caused distortions in household savings behavior. Young families have increased their savings in response to the high housing prices in preparation to buy a house. Li and Huang [31] use China Household Finance Survey (CHFS) data and report empirically that the increase in housing prices has led to an increase in household savings, and the increased savings are used to purchase housing and repay housing loans.

Some scholars study the impact of household savings on housing asset prices. Kuang [32] concludes that for every 1% increase in household savings, the household housing area increases by 0.04%. Household savings on the area of household housing do not entail a crowding-out effect but increase the household demand for housing. Wan [33] establishes a link between housing price bubbles and household savings. Speculative savings theory argues that household savings are used for speculative investments, such as the purchase of housing during a "bubble". A family with speculative savings motives has an incentive to save excessively, depending on housing policies and the distortion of the financial markets. Simo-Kengne [15] believes that real estate is a part of savings, and the increase in savings may stimulate demand and prices for small-sized houses.

Some scholars believe that savings and housing prices have an interactive relationship, but no specific research has been conducted. Chen and Yang [34] think that a positive correlation between housing prices and household savings may lead to high housing prices. They explain the reverse causality between household savings and housing prices by observing that saving is a household behavior and has little effect on housing prices at the provincial level. This paper studies the relationship between urban housing prices and the total amount of urban household savings, which are at the same level. Undoubtedly, these variables are closely related. In summary, a series of studies have been carried out on high saving behavior and rising savings rates in China. Although the literature focuses on the relationship between housing prices and household savings (rate), there is still a gap.

1.3. The Contribution of This Paper

The main research work and contribution of this paper are as follows. First, the impact of population aging on asset prices has been commonly studied from the life-cycle perspective and under the framework of the overlapping generations model, and the influence of household savings on asset prices has been analyzed, but a combination of empirical analysis and theoretical research investigating the impact of population aging and household savings on housing prices has rarely been undertaken. Therefore, this paper adds the variable of household savings to revise and expand the model proposed by Abel [9], which provides a theoretical basis for this study. Second, this paper performs a more in-depth empirical analysis using census panel data at the urban level. We adopt an innovative use of complete and balanced panel data from 4 municipalities, 15 sub-provincial cities and 257 prefecture-level cities. Third, the reliability of the estimation results is verified by careful tests and discussions of multiple collinearity, heteroscedasticity, autocorrelation, robustness and the Ramsey RESET test. The research in this paper helps to fill the gaps in the literature discussed above and provides a new perspective for the analysis of the impact of population aging and household savings on housing prices; its findings can help macro-decisionmakers understand the changing trend in the real estate market from multiple angles.

The content and structure of this paper are as follows. The second part describes the theoretical model of this paper. The models proposed by Abel [9] and Geng et al. [35] are used to analyze how population aging and household savings impact asset prices. By combining these with the previous literature, this paper explores the impact mechanism of population aging and household savings on asset prices from the life cycle theory and overlapping generations model. The third part presents the empirical model and data source. The fourth part uses housing prices, which are based on the 2000 and 2010 census data of 257 prefecture-level cities, to represent asset prices, and a pooled regression model and the two-stage least squares (2SLS) method are established for empirical study. The impact of population aging and household savings on urban commercial housing prices is demonstrated at two levels across the country and for 35 subsamples of large and medium-sized cities. The adjustment effect test and mediation effect test are used to explain the influencing mechanism of population aging and household savings on housing prices. The fifth part presents the conclusions and implications.

2. Theoretical Model

2.1. Life-Cycle Theory

Life-cycle theory is the microfoundation reflecting the relationship between population structure and asset prices. The life-cycle hypothesis refers to a typical rational consumer who pursues utility maximization and whose budget constraint is the balance of income and consumption over the life cycle. Consumers' consumption at any age depends on their total income for their lifetime, regardless of current income. Personal consumption will settle at a stable, near-expected average rate. Bakshi and Chen [10] propose two hypotheses about the life cycle. The first hypothesis is the life-cycle investment hypothesis, according to which an investor holds different types of assets at different stages of the life cycle. When people aged 20–40 are in the family formation period and housing is the focus of investment, housing prices increase. With increasing age, the demand for housing tends to stabilize or even decline. The demand for financial assets increases correspondingly. Population aging drives a decline in the total demand for housing, which leads to a decline in housing prices. The second hypothesis is the life-cycle risk aversion hypothesis, in which the risk aversion of investors increases with age. As investors grow older, they become reluctant to take risks with their labor income, and investors' risk aversion requirement increasingly rises under prolonged life expectancy. Older people are more willing to hold high amounts of liquid assets. The life-cycle characteristics of asset allocation resulting from demographic changes affect the supply and demand of assets, which in turn affects the price of assets.

2.2. The Overlapping Generations Model

The overlapping generations model is the microfoundation of modern macroeconomics, popularized by Samuelson's [36] and Diamond's [37] research. In recent years, the overlapping generations model has been widely used to analyze problems in various fields. Shi and Suen [38] analyze the impact of asset bubbles under an overlapping generations model with an endogenous labor supply. Lau [39] introduces an overlapping generations model of real demographic characteristics to examine the economic impact of changes in fertility and mortality. Cipriani [40] studied the impact of population aging on the pension system under the standard overlapping generations model.

D'Albis et al. [41] analyze local pricing issues under the framework of an overlapping generations model of continuous transactions.

Abel [9] and Geng et al. [35] integrate the microlevel and macrolevel to establish a two-stage overlapping generations model and analyze the impact of population aging and household savings on asset prices. The assumptions of the overlapping generations model in this paper are as follows. (1) In a closed economy, there is only one product, which can be used for both consumption and investment. There are countless individuals and manufacturers in the economy. (2) The lifetime of homogeneous representative individuals is divided into young and old ages, and each person maximizes his or her lifetime utility by choosing the optimal level of consumption. (3) There are two production technology functions in the enterprise: that for consumption goods and that for capital adjustment. Among them, consumer goods technology produces consumer goods through the employment of capital and labor. The capital adjustment technology function uses the current capital stock and part of the consumer goods to produce capital for the next period. (4) The individual's utility function is a logarithmic function, and the enterprise's production function is a Cobb–Douglas function. Appendix A provides the reasoning behind the overlapping generations model.

3. Empirical Models and Data Sources

Considering that the development of China's financial market is still immature, the share price is more affected by factors such as macroeconomic events and stock market asymmetry. Volatility is high, and the impact of population structure and household savings is not fully understood. Therefore, based on previous research, this section adopts the method of Tan et al. [42] to represent asset prices with housing prices. The paper uses the 2000 and 2010 census data of 257 prefecture-level cities to establish a pooled regression model and the 2SLS method for empirical study of the impact of population aging and household savings on housing prices.

3.1. Econometric Model Setting

The benchmark model is set as follows:

$$lnHP_{it} = \alpha + \delta Y10 + \beta_1 AGE_{it} + \beta_2 lnSAVE_{it} + \gamma X_{it} + u_{it} \tag{1}$$

$lnHP_{it}$ is the dependent variable, indicating the logarithm of the housing prices of region i in year t; AGE_{it} represents the age structure of region i in year t, $lnSAVE_{it}$ is the logarithm of the savings balance of urban and rural residents; X_{it} is a series of control variables, including the real estate development investment ratio, population growth rate and proportion of rental houses. To reflect the impact of macroeconomic factors on housing price fluctuations, this paper introduces the annual dummy variable Y10, which was 0 in 2000 and 1 in 2010; u_{it} is a random disturbance item.

Table 1 presents the specific definition of each variable. Housing prices is a dependent variable referring to existing research [34] using the average selling prices of commercial houses (yuan/square meter). Population aging refers to the population's age structure as the proportion of the elderly population in the total population increases over time. In demographics, the indicators that measure the degree of aging of a country's population are (1) the coefficient of old age, which refers to the elderly population as a percentage of the total population; (2) the population dependency ratio, also known as the burden factor, which refers to the percentages of non working-age population and working-age population in the population and can be subdivided into the child dependency ratio and the elderly dependency ratio; and (3) the ratio of elderly to children. The selection of explanatory variables for population aging is based on existing research [26]; population aging is expressed by the population dependency ratio, the child dependency ratio and the elderly dependency ratio. Residents' savings are expressed by the year-end balance of the savings of urban and rural residents. According to the theory of supply and demand, housing prices are determined by supply and demand. Considering the background of China and existing research, the following control variables are added into the model.

Table 1. Specific definition of each variable.

Variables	Variable Symbol	Definition	Unit
Dependent variable	HP	Average sales price of commercial houses = (sales price of commercial houses)/(sales area of commercial houses)	Yuan/ square meter
Explanatory variables	TAGE	Population dependency ratio (population aged 0–14 years old + population aged over 64 years old)/(population aged 15–64 years old)	%
	YAGE	Child dependency ratio = (population aged 0–14 years old)/ (population aged 15–64 years old)	%
	OAGE	Elderly dependency ratio = (population aged over 64 years old)/ (population aged 15–64 years old)	%
	SAVE	Household savings balance	Yuan
Control variables	INVR	rReal estate development investment ratio = (real estate development investment)/ (fixed assets investment)	%
	GPOP	Population growth rate	%
	RENTH	Proportion of rental houses	%

First, we discuss the real estate development investment ratio. This ratio is used to control the influence of the supply side and reflects the flow of social capital into the real estate industry. The real estate industry is a capital-intensive industry, and the amount of real estate development investment will affect the supply of the real estate market.

Second, we turn to the population growth rate. Li et al. [28] summarized the research perspectives of population structure and housing prices considering three aspects: the natural, social and spatial structures of the population. Empirical evidence shows that population growth is an important factor driving real estate prices higher in China, so the population growth rate is taken as a control variable [43].

Third, we include the proportion of rental houses. Currently, the phenomenon of "value purchase, despise lease" in China is widespread. The strategy of "rental and purchase" can avoid the ups and downs of the real estate market and reduce the demand for irrational purchases. Therefore, the proportion of rental houses is used as a control variable.

At the macro level, housing price indicators are mostly based on the mean price of an area, such as in Wang et al. [44]. In addition, Lyons [45] uses the ratio of sale prices to rental prices; Li and Huang [31] use the rising rate of regional housing prices to describe the fluctuation of housing prices. There is also the real housing price index adopted by Takáts [17]. At the micro level, housing price is more indirectly expressed by household housing demand, for example, the number of housing units owned by families, the average housing area as used by Li and Shen [26], and the housing value as used by Han [46]. Due to the limitations of the data in this paper, it is difficult to measure the above indicators, such as the rising rate of housing prices and the ratio of housing prices. Therefore, we have used the mean price of housing per square meter.

The literature [47] has used the hierarchical linear model (HLM) to overcome the limitation of "not considering hierarchical structure of the data". The literature [47] plays an important role in researching residential real estate using multilevel modeling.

3.2. Data Sources and Processing

Based on the 2000 China Regional Economic Statistical Yearbook [48], the average price of commercial housing in 339 municipalities, capital cities and prefecture-level cities (districts) can be calculated for the year 2000. According to the 2010 China Regional Economic Statistical Yearbook [49], the average price of commercial housing in 324 municipalities, capital cities and prefecture-level cities (districts) can be calculated for the year 2010. The population aging data come from the 2000 and 2010 censuses. According to the 2000 China Urban Statistics Yearbook [50] and the 2010 China Urban Statistics Yearbook [51], the savings balance of urban and rural residents in Lasa, Zhaoqing, Heyuan and other cities were not counted in 2000, so these cities are deleted. In 2001, Huaiyin City was renamed Huai'an City, and Xiangfan City was renamed Fuyang City. The final sample size is 514. Table 2 presents the summary statistics of the variables used in our analysis. The means and standard deviations in 2000 and 2010 are reported in Table 2.

Table 2. Descriptive statistics of major variables.

Variables \ Time	2000		2010	
	Mean	**Std**	**Mean**	**Std**
Price of commercial houses (Yuan/square meter)	1268.74	654.10	5038.45	5425.87
Population dependency ratio (%)	42.61	9.64	34.28	7.76
Child dependency ratio (%)	32.46	8.72	22.07	6.79
Elderly dependency ratio (%)	10.19	2.87	12.21	2.60
Household savings (Yuan)	1.67×10^{10}	3.58×10^{10}	1.77×10^{11}	3.71×10^{11}

4. The Empirical Results and Robustness Test

4.1. Model Test

Because the dataset is a short panel data model (time series data sample T = 2, cross-sectional data sample N = 257, T < N), the probability of pseudoregression is much smaller than that of the time series. Based on the process of building a panel data model used in the literature (such as [18,26]), this chapter does not conduct a unit root test on the variables. The choice of the pooled estimation model and the fixed effect model can be judged by the F-test. This paper uses the STATA14 (statistical software that provides users with data analysis, data management and professional charts. It is one of the most commonly used software in econometric analysis) test and finds that the pooled regression model is more suitable.

As shown in Table 3, Prob = 0.2660 > 0.05; thus, the null hypothesis cannot be rejected, and the pooled regression is significantly better than the fixed effect. Similar literature (such as [34]) supports the test results.

Table 3. Model F-test results.

Test Summary	F-Test Statistic	F-Test d.f.	Prob.
F-test that all u_i = 0	1.08	5	0.2660

4.2. National-Level Pooled Regression Estimation Results and Discussion

The maximum VIF (variance inflation factor, which is the ratio of variance between explanatory variables when multicollinearity exists and when multicollinearity does not exist. The larger the VIF, the more serious the multicollinearity. When 0 < VIF < 10, there is no multicollinearity. When VIF >= 10, there is multicollinearity) value of model 1 is 3.72, and the VIF values of the remaining three models are also all far less than 10. Therefore, multicollinearity is not an issue. For the problem of heteroscedasticity, the robust standard deviation method is adopted to improve the robustness of the model. Because T is small, each individual has less information, so there is no need to discuss whether there is autocorrelation in the disturbance term, which is generally assumed to be independent and identically distributed. The Ramsey RESET test is performed on model 1, with a *P*-value of 0.17, which is greater than 0.05. The null hypothesis that a "regression setting error" exists cannot be strongly rejected, so there is no regression setting error.

The results of the national pooled regression estimates are presented in Table 4. The estimation results of model 1 show that the population dependency ratio has a significant negative impact on housing prices under certain other conditions. When the population dependency ratio drops by 1%, the house price rises by approximately 0.4%, supporting hypothesis 1. The results of empirical research are consistent with theoretical expectations, and demographic changes are an important factor in housing prices. This result also supports the research viewpoints of Mankiw and Weil [14]. The demographic dividend period stimulates house demand and promotes housing prices. The household savings coefficient is highly significant, which supports the research of Kuang [32]. When household savings rise by 1%, housing prices rise by 0.175%, which supports hypothesis 2 well. Changes in household savings play an important role in housing prices. The dummy variable coefficient is highly significant at 0.78, indicating that with the control variables, including population dependency ratio and household savings, housing prices are 78% higher in 2010 than in 2000.

Table 4. Estimation of the pooled ordinary least square (OLS) and two-stage least squares (2SLS).

Models / Variables	Model 1	Model 2	Model 3	Model 4
	OLS	OLS	2SLS	2SLS
Dummy variables Y10	0.780 *** (14.41)	0.673 *** (12.08)		
Population dependency ratio	−0.004 * (−1.80)		−0.0006 (−0.13)	
Child dependency ratio		−0.013 *** (−3.27)		−0.031 *** (−3.72)
Elderly dependency ratio		0.023 ** (1.96)		0.075 *** (5.12)
Household savings balance logarithm	0.175 *** (9.00)	0.163 *** (7.90)	0.177 *** (3.36)	0.161 *** (3.03)
Real estate development investment ratio	0.010 *** (5.61)	0.007 *** (4.10)	0.010* (1.85)	0.005 (1.03)
Population growth rate	0.015 ** (2.44)	0.033 *** (3.46)	0.014 (1.35)	0.075 *** (4.10)
Proportion of rental houses	0.011 *** (4.61)	0.014 *** (5.27)	0.011 *** (3.05)	0.018 *** (5.10)
Constant term	4.530 *** (16.19)	4.609 *** (15.68)	5.164 *** (6.57)	4.906 *** (6.46)
Number of samples	514	514	257	257
R^2	0.76	0.76	0.32	0.39

Statistics are shown in parentheses; ***, **, and * indicate significance at the 1%, 5%, and 10% levels respectively.

Among the control variables, when the real estate development investment ratio increases by 1%, it will lead to an increase of 1% in housing prices; a 1% increase in the population growth rate will result in a 1.5% increase in housing prices; a 1% increase in population growth will lead to a 1.5% increase in the housing price. The positive impact of the real estate development investment ratio reflects that demand in the Chinese real estate market is far greater than supply. The positive impact of population growth on housing prices reflects that an increase in the absolute number of people will increase the purchase needs of buyers at the relevant age and the investment needs of investors and thus stimulate the rise of housing prices. The positive impact of the proportion of rental houses on housing prices does not match the results in the relevant Chinese studies. The increase in the number of renters reduces the demand for home purchases, which in theory has a certain negative effect on housing prices. However, the empirical result shows the opposite, which reflects imperfections in China's house rental market; instead of decreasing housing prices, the rental market contributes to an increase in housing prices. Overall, this reflects an overvaluation of housing prices in China.

The elderly dependency ratio rose by approximately 6% between 1975 and 2015, while the child dependency ratio fell by more than 30%. Next, the impact of different dependency ratios on housing prices is examined, and so the child dependency ratio and the elderly dependency ratio are used as explanatory variables for further analysis. Model 2 shows that the child dependency ratio is negatively correlated with housing prices and that the elderly dependency ratio is positively correlated with housing prices. That is, when the child dependency ratio drops by 1%, housing prices increase by 1.3%. When the elderly dependency ratio rises by 1%, housing prices rise by 2.3%. The effect of the control variables on housing prices is more significant than in Model 1.

Considering the reverse causal relationship between housing prices and household savings may lead to endogeneity problems. Therefore, this paper uses the lag term of the explanatory variable as an instrumental variable to solve the endogeneity problem. This paper uses the F-test to test the significance of the instrumental variables. Shea's partial R2 of the logarithmic savings balance of model 3 is 0.45, and the F statistic is 132 (far greater than 10). We know that 2SLS often brings about "significance level distortions" that will increase with weak instrumental variables. For this reason, the paper takes the "nominal significance level" of the 5% Wald test to determine the significance of the endogenous explanatory variables, and the minimum eigenvalue statistic is far greater than 5% of the critical value of 8.96. In addition, the first-stage regression results show that the instrumental variables have a very significant effect on the logarithmic balance of variable savings, so we can conclude that there is no weak instrumental variable problem. Model 4 also does not have the problem of weak instrumental variables. Models 3 and 4 both use 2SLS estimation, and the regression coefficient symbols are highly consistent with those of Models 1 and 2. The significance of the main explanatory variables studied in this paper does not change, as shown in Table 4. The estimated results of the other control variables are similar to those obtained in the previous models.

Overall, the empirical results show that the child dependency ratio has a significant negative impact on housing prices, while the elderly dependency ratio has a positive impact on housing prices. This conclusion does not support the "asset meltdown" hypothesis. Possible reasons for this result are as follows. China's one-child policy in the 1970s led to a rapid decline in child rearing, giving households more money to spend on houses. In the first decade of this century, China was in the early stage of aging and releasing a large amount of investment demand. Because of the welfare housing allocation policy, households have additional savings to invest in property purchases. The one-child policy has helped shape the family structure of "one couple and one child" in China, strengthening the motivation of the elderly to help the next generation of young people buy houses. Xu et al. [43] used demographic data from 2000 and 2005 to conclude that the savings of the previous generation were released in 2015, so it is not true that the elderly drive up housing prices. After the release of savings, a general inhibitory effect of the elderly on China's housing prices will appear.

4.3. Robustness Test

There are three common robustness tests. First is to replace samples from the perspective of data. Second is to replace it with similar variables from the perspective of variables. Third is to transform the different estimation methods from the perspective of methods. In order to ensure the robustness and credibility of this paper, three different robustness test methods are adopted.

This paper uses 35 subsamples of large and medium-sized cities to examine whether the impact of various explanatory variables on housing prices remains robust. The robustness results are shown in Table 5.

Table 5. Estimation results of robustness test 1 and test 2 and test 3

Variables \ Models	Robustness Test 1		Robustness Test 2		Robustness Test 3	
	Model 5	**Model 6**	**Model 7**	**Model 8**	**Model 9**	**Model 10**
	OLS	**OLS**	**OLS**	**OLS**	**GLS**	**GLS**
Dummy variables Y10			1.060 *** (22.17)	0.881 *** (13.75)	0.780 *** (13.37)	0.674 *** (10.56)
Population dependency ratio	−0.031 *** (−3.78)		−0.008 *** (−3.28)		−0.004 (−1.37)	
Child dependency ratio		−0.043 ** (−3.55)		−0.019 *** (−4.94)		−0.125 *** (−3.74)
Elderly population dependency ratio		0.011 (0.61)		0.029 ** (2.05)		0.023 *** (3.04)
Household savings balance logarithm	0.399 *** (10.68)	0.354 *** (9.89)	/	/	0.175 *** (8.10)	0.163 *** (7.55)
Household savings balance to population ratio	/	/	0.002 *** (2.83)	0.002 *** (3.03)	/	/
Real estate development investment ratio	0.006 ** (2.48)	0.005 ** (2.02)	0.016 *** (8.17)	0.013 *** (5.66)	0.010 *** (4.16)	0.007 *** (3.14)
Population growth rate	0.055 *** (2.95)	0.080 *** (3.00)	0.014 * (1.93)	0.038 *** (3.72)	0.015 ** (2.08)	0.033 *** (3.85)
Proportion of rental houses	−0.002 (−0.31)	0.001 (0.24)	0.010 *** (2.72)	0.013 *** (3.47)	0.011 *** (3.96)	0.014 *** (4.81)
Constant term	2.226 *** (3.56)	2.642 *** (3.97)	6.987 *** (65.04)	6.881 *** (46.93)	4.531 *** (14.14)	4.610 *** (14.52)
Number of samples	514	514	514	514	514	514
R^2	0.83	0.84	0.73	0.74	0.76	0.76

Statistics in parentheses, ***, **, and * indicate significance at the 1%, 5%, and 10% levels.

First, as seen in Models 5 and 6, the population dependency ratio is negatively correlated with housing prices. Compared with the national level, the population dependency ratio has a greater negative impact on the housing prices in the 35 large and medium-sized cities.

Second, there is a negative correlation between the child dependency ratio and housing prices. For every 1% decrease in the child dependency ratio, housing prices rise by approximately 4%. The child dependency ratio has a greater negative impact on housing prices in 35 large and medium-sized cities than the 1% rise at the national level. When the elderly dependency ratio rises by 1%, housing prices increase by approximately 1%, but the effect is not significant, which is basically consistent with the results at the national level. Generally, the impact of population aging on housing prices is more prominent in cities with higher economic development levels. The research of Li et al. [28] supports this conclusion.

Finally, the household savings balance and housing prices are highly significant. At the national level and for the 35 large and medium-sized cities, the positive impact of the household savings balance on housing prices is steady. When the household savings balance rises by 1%, housing prices rise by approximately 0.2% to 0.4%. This shows that households with higher savings are more able to afford and more inclined to purchase houses. The research conclusions of Li and Huang [31] support the conclusions of this paper.

The reviewer is worried that the typology of the data used may distort the results of the study. Then we make a regression analysis according to the suggestion put forward by the reviewer and draw a conclusion consistent with the results of this study. Therefore, we use the household savings balance to population ratio as another method of robustness test to better support the results in this paper. The model does not deal with household savings balance to population ratio logarithmically. The robustness results are shown in Table 5.

From the estimated results of Models 7and 8, we can see that the population dependency ratio is negatively correlated with housing prices, the child dependency ratio is negatively correlated with housing prices, and the elderly dependency ratio is positively correlated with housing prices. The results of the above three explanatory variables are basically consistent with those of the benchmark model. By focusing on the analysis of the household savings balance to population ratio, it can be seen that the household savings balance to population ratio is highly positively correlated with the housing prices. When household savings balance to population ratio rises by 1%, housing prices rise by about 0.2%. The symbols and significance of the control variables have not changed significantly, so we can conclude that the empirical results of the model have not changed substantially when the logarithmic form of household savings balance and the household savings balance to population ratio are used.

In order to further enhance the robustness of the paper, the author uses the generalized least squares method (GLS) to conduct empirical analysis again after consulting relevant literature, and obtains very satisfactory results. The empirical results are as shown in Models 9 and 10 have not changed significantly, and we will not repeat them here.

4.4. The Impact Mechanism of Population Aging on Housing Prices

Numerous studies have found that the relationship between population aging and savings is uncertain. One explanation is based on the characteristics of negative savings in old age described in life-cycle theory. It is believed that with aging, the working population and wage income will decrease, followed by a decrease in savings. Another explanation is based on the life-cycle savings hypothesis, which posits that the aging population increases people's precautionary savings, leading to an increase in savings. The net effect of aging on savings depends on the strength of these two effects. Domestic and foreign scholars have performed extensive research to investigate this issue. Some scholars emphasize that aging leads to a decline in savings. Maddaloni et al. [52] argue that changes in the demographic structure affect asset prices through a saving/investment balance mechanism. Leff [53] shows through empirical research that there is a significant negative relationship between the elderly dependency ratio and savings. By studying the savings rate in different countries, Loayza et al. [54] conclude that when the elderly dependency ratio increases by 3.5%, the savings rate will decrease by 2%. Similarly, Horioka et al. [55] conclude that Japan's rapidly aging population leads to a decline in household savings rates, which can be expected to continue. Brounen et al. [56] studied 1253 Dutch families and concluded that savings behavior varies across generations and is significantly dominant among baby boomers. Other scholars believe that precautionary savings motivation is dominant and that population aging will lead to an increase in savings. Wang [57] uses panel data from 29 provinces and municipalities from 1989 to 2007 to find that the elderly dependency ratio has a significant positive effect on the savings rate. Thus, the longevity effect of aging may exceed the burden effect. Li and Luo [58] use 2010–2014 household data to conclude that the net effect of aging on the household savings rate is positive and that the precautionary savings motivation of aging is greater than the negative effect of saving in old age, allowing China to potentially reap the second demographic dividend. From the above literature, we can conclude that there is a significant correlation between population aging and savings. On the one hand, we could consider the adjustment role of household savings; on the other hand, we could consider the mediating role of household savings, i.e., population aging affects housing prices through household savings channels.

4.4.1. Interaction Analysis

Wooldridge [59] describes the interaction model in his book "Introductory Econometrics-A Modern Approach (Fifth Edition)". Wooldridge [59] states that the use of interaction measures the partial effect of one variable depending on the level of another variable. If two variables are simply multiplied, the partial effect of one variable on the dependent variable is measured when the other variable is zero. If we subtract meaningful fixed values from one variable in the construction of an interaction term, we will obtain the partial effect or marginal effect of another variable on the dependent variable when one variable takes a fixed value.

As Equation (2), the advantage of this method is that the interaction coefficient β_3 reflects the adjustment direction of $lnSAVE_{it}$. β_1 is the marginal effect (or partial effect) of AGE_{it} on housing prices when $lnSAVE_{it}$ takes value A. Without subtracting A, β_1 is the marginal effect (or partial effect) of AGE_{it} on housing prices when $lnSAVE_{it}$ is 0, which is usually meaningless. Zheng et al. [60] take fixed value A as the mean value of a variable in article, so this paper also takes the mean value of household savings (logarithm) according to this method.

In cities with different levels of household savings, is there any difference in the impact of population aging on housing prices? To explore the impact of household savings level, we examine the interaction between household savings and population aging. The interaction model is given by Equation (2).

$$lnHP_{it} = \alpha + \delta Y10 + \beta_1 AGE_{it} + \beta_2 lnSAVE_{it} + \beta_3 AGE_{it} * (lnSAVE_{it} - A) + \gamma X_{it} + u_{it} \quad (2)$$

Here, the interaction between AGE_{it} and ($lnSAVE_{it}$-A) reflects the adjustment of the effect of the household savings level on population aging. Constant A is given (e.g., the sample mean of logarithmic household savings). The advantage of this method is that the interaction coefficient β_3 reflects the adjustment direction of $lnSAVE_{it}$.

The results shown in Table 6 are as follows. First, regarding the population dependency ratio, the coefficient of the interaction between the population dependency ratio and household savings is negative but not significant, suggesting that the level of household savings negatively adjusts the negative impact of the population dependency ratio on housing prices. Thus, the higher household savings is, the weaker the negative impact of the population dependency ratio on housing prices will be. Second, regarding the population dependency ratio, the coefficient of the interaction between the child dependency ratio and household savings is negative and significant at the 5% level, suggesting that the level of household savings significantly negatively adjusts the negative impact of the population dependency ratio on housing prices. Thus, the higher the household savings are, the less negative the impact of child dependency ratio on housing prices will be. Third, regarding the elderly dependency ratio, the coefficient of the interaction between the elderly dependency ratio and household savings is positive and significant at the 5% level, suggesting that the level of household savings significantly positively adjusts the positive impact of the elderly dependency ratio on housing prices. Thus, the higher the level of household savings, the stronger the positive impact of the elderly dependency ratio on housing prices.

Table 6. Comparisons of the effects of population aging on housing prices under different household savings levels.

Variables \ Models	Model 11	Model 12	Model 13	Model14
	OLS	**OLS**	**OLS**	**OLS**
Dummy variables Y10	0.779 *** (14.46)	0.664 *** (13.21)	0.728 *** (14.51)	0.767 *** (15.05)
Population dependency ratio	−0.005 * (−1.92)			
Child dependency ratio		−0.016 *** (−3.85)	−0.013 *** (−3.47)	
Elderly population dependency ratio		0.027 *** (2.98)		0.019 *** (2.76)
Population dependency ratio * (Household savings balance logarithm-A)	−0.0008 (−0.85)			

Table 6. *Cont.*

Variables \ Models	Model 11	Model 12	Model 13	Model14
	OLS	OLS	OLS	OLS
Child dependency ratio * (Household savings balance logarithm-A)		−0.002 ** (−2.33)	−0.002 ** (−2.44)	
Elderly population dependency ratio * (Household savings balance logarithm-A)		0.008 ** (2.08)		0.008 ** (2.34)
Household savings balance logarithm	0.224 *** (7.15)	0.119 ** (2.14)	0.224 *** (7.15)	0.080 * (1.79)
Real estate development investment ratio	0.010 *** (5.60)	0.008 *** (4.13)	0.009 *** (5.33)	0.009 *** (4.92)
Population growth rate	0.016 ** (2.26)	0.039 *** (4.22)	0.028 *** (3.59)	0.015 *** (2.65)
Proportion of rental houses	0.010 *** (3.55)	0.014 *** (5.46)	0.008 *** (3.23)	0.018 *** (7.71)
Constant term	4.110 *** (7.09)	5.248 *** (6.58)	3.977 *** (9.38)	5.513 *** (8.69)
Number of samples	514	514	257	257
R^2	0.76	0.77	0.76	0.77

Statistics are shown in parentheses; ***, **, and * indicate significance at the 1%, 5%, and 10% levels respectively.

4.4.2. Mediating Effect

Next, we discuss the mediating effect of household savings. The first step is to test whether the main effect of population aging on housing prices is significant; the second step is to estimate the impact of population aging on the mediation variable of savings: if household savings is a reasonable mediation variable, its coefficient should be statistically significant. The third step is to estimate the direct effect of population aging and household savings on housing prices. The fourth step is to test the mediating effect.

As seen in Table 7, the impact of the population dependency ratio on housing prices is significantly negative, providing a premise for the analysis of the mediating effect. Second, the population dependency ratio is significantly negatively associated with the coefficient of the mediation variable, indicating that the dependency ratio of population significantly reduces household savings. Finally, the positive impact of the mediation variable household savings on housing prices is significant. After adding the mediation variable, the estimated coefficient of the population dependency ratio is smaller, indicating that the mediation variable dilutes and weakens the impact of the population dependency ratio on housing prices. In summary, the step-by-step test of each parameter estimation is significant, and we determine that the aging population affects housing prices through household savings. Further, the Sobel test and bootstrap test show that the indirect effect is −0.0326, the direct effect is −0.0123, and the mediating effect accounts for 72.6% of the total effect. The child dependency ratio gives similar results to those of the population dependency ratio, and the analysis is not repeated here.

As seen in Table 7, the elderly dependency ratio has a significant positive impact on housing prices, providing a premise for the analysis of the mediating effect. Second, the elderly dependency ratio is not significant, and the Sobel test and bootstrap test are needed for further testing. The indirect effect is 0.0653, the direct effect is 0.0401, and the mediating effect accounts for 62.0% of the total effect. Finally, the positive impact of the mediation variable household savings on housing prices is significant. After adding the mediation variable, the coefficient of the elderly dependency ratio is estimated to be smaller, indicating that the mediation variable dilutes and weakens the impact of the elderly dependency ratio on housing prices.

Table 7. Impact of population aging and mediation variable on housing prices.

Variables \ Models	Model 15	Model 16	Model 17
	OLS	OLS	OLS
Dummy variables Y10	0.780 *** (14.41)	0.766 *** (14.70)	0.738 *** (14.27)
Population dependency ratio	−0.004 * (−1.80)		
Elderly dependency ratio		0.016 * (1.75)	
Child population dependency ratio			−0.009 *** (−2.93)
Household savings balance logarithm	0.175 *** (9.00)	0.178 *** (9.26)	0.168 *** (8.35)
Real estate development investment ratio	0.010 *** (5.61)	0.008 *** (4.91)	0.009 *** (5.36)
Population growth rate	0.015 ** (2.44)	0.013 ** (2.23)	0.024 *** (3.18)
Proportion of rental houses	0.011 *** (4.61)	0.016 *** (6.22)	0.010 *** (4.48)
Constant term	4.530 *** (16.19)	4.145 *** (15.98)	4.731 *** (15.83)
Number of samples	514	514	514
R^2	0.76	0.76	0.76

Statistics are shown in parentheses; ***, **, and * indicate significance at the 1%, 5%, and 10% levels respectively.

In the interests of space, the results of the first and second steps of the mediating effect test are not reported. If readers would like to review this information, please ask the author.

5. Conclusions and Implications

Based on the theoretical analysis of how population aging and household savings impact asset prices and combined with the real-world background of China, this paper uses housing prices as an example to analyze empirically how the population structure and household savings affect housing prices in China at the national level and in 35 large and medium-sized cities. The main conclusions are as follows. First, the static comparative analysis of the overlapping generations model shows that a lower proportion of the working population and a higher degree of population aging will lead to a decrease in asset demand, which will decrease asset prices. Higher savings could increase asset prices. Second, the decline in the population dependency ratio is an important factor contributing to the rise in housing prices from a national perspective. The child dependency ratio has a significant negative impact on housing prices, while the elderly dependency ratio has a positive impact. The positive relationship between household savings and housing prices is highly significant. Third, the population dependency ratio and child dependency ratio have a greater impact on housing prices in the 35 subsamples of large and medium-sized cities than at the national level, and the elderly dependency ratio has no significant impact on housing prices. An increase in household savings of 1% results in an increase of 0.2–0.4% in housing prices. Fourth, the interaction analysis shows that the effect of population aging on housing prices differs under different levels of household savings; furthermore, population aging affects housing prices through household savings, and the mediator dilutes and weakens this impact. However, with the release of savings from the previous generation, Chinese housing prices are gradually suppressed. In general, the aging of the population means that housing prices face downside risks in the long run, but it will not lead to market meltdown.

This paper preliminarily shows that real estate is developing a bubble from the perspective of China's housing prices, especially considering the false prosperity of housing prices in the eastern region, which entails a great potential risk. China should prepare for sharp fluctuations in housing prices to prevent the risks to economic development caused by a sharp fall in housing prices. Relevant information should be made open and transparent to guide the public to formulate reasonable expectations and rational investment. In addition, by transforming the mode of economic development, we can compensate for the negative impact of population aging on asset prices. With the advent of population aging, the extensive growth mode of the labor factor supported by the demographic dividend cannot sustainably promote economic growth. Society needs to accelerate industrial upgrading and technological innovation to promote entrepreneurship and innovation. Savings are still an important factor in housing price increases. Residents must be encouraged to use more savings for non-housing purposes, and the elderly must be guided to use more savings for personal pensions rather than buying houses for their children or bequeathing houses to the next generation. Savings are also invested in real estate, so implementing property taxes is a way to prevent two generations of savings from being invested in real estate at the same time.

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Appendix A. Reasoning behind the Overlapping Generations Model

Appendix A.1. Population Structure

According to the Diamond's Overlapping Generations (OLG) model framework [37], homogeneous individuals experience two life stages: t in their youth and $t + 1$ in their old age. In the t period, there are N_t adults and $N_{(t-1)}$ elderly people, and $N_{(t+1)}$ is a young individual born in $t + 1$. Suppose that the representative individuals work only when they are young, and when they enter old age, they no longer work and only consume.

Appendix A.2. Enterprise Behavior

According to the basic assumptions, the consumption goods technology function takes the form of a Cobb–Douglas function:

$$Y_t = AK_t^{\alpha}N_t^{\beta}\mu \tag{A1}$$

For the Cobb–Douglas function, we make two changes: one is that we no longer assume that constant returns to scale, and the other is that we add a random interference term. In this way, we relax the assumptions and make the production function closer to the actual production function, where Y_t is the total output of consumption goods technology in period t, A is the technical parameter, K_t is the aggregate capital stock at the beginning of period t, and N_t is the labor input. α is the elasticity coefficient of capital output, β is the elasticity coefficient of labor output, and μ is the influence of random interference, where μ is less than 1.

According to Appendix A.1. population structure description, assuming the birth rate is $n_{(\text{empht}+1)}$, then:

$$n_{t+1} = \frac{N_{t+1}}{N_t} \tag{A2}$$

Referring to Geng et al. [35], capital adjustment technology adopts K_t and I_t to produce the next phase capital stock K_{t+1}, that is, K_{t+1} can be expressed as $K_{t+1} = Z(K_t, I_t)$. According to the demand of capital adjustment technology $\frac{\partial Z^2}{\partial I_t^2} < 0$, so the capital adjustment technology is assumed that:

$$K_{t+1} = aI_t^{\varphi} K_t^{1-\varphi} \tag{A3}$$

where K_t and $K_{(t+1)}$ are the aggregate capital stock of periods t and $t+1$, respectively, $a > 0$ is the technical parameter, and I_t is the aggregate quantity of output from the consumption goods technology used in the capital adjustment technology, that is, the total investment in the form of consumer goods.

Capital adjustment technology determines the price of capital. Referring to Abel's [9] model, the price of capital at the end of period t, q_t, is the amount of consumption goods in period t that must be used to produce an additional unit of capital for use in period $t + 1$. Expressed as a mathematical formula,

$$q_t = \left(\frac{\partial K_{t+1}}{\partial I_t}\right)^{-1}; \tag{A4}$$

that is,

$$q_t = \frac{1}{a\varphi}\left(\frac{I_t}{K_t}\right)^{1-\varphi} \tag{A5}$$

When $0 < \varphi < 1$, q_t is the increasing function of investment capital ratio, $\frac{I_t}{K_t}$; when $a = 1$ and $\varphi = 1$, q_t is the capital price of neoclassical growth model.

In a perfectly competitive economy, each unit of production acquires its marginal product, so labor compensation is equal to the marginal cost of labor. According to Equation (A1), the individual's wage rate is:

$$w_t = \frac{\partial Y_t}{\partial N_t} = \beta \frac{Y_t}{N_t} \tag{A6}$$

Because capital is used for the production of consumption goods and the next phase of capital, the total rental to capital v_t includes the income from the production of consumption goods and capital adjustment. The total rental to capital is:

$$v_t = \frac{\partial Y_t}{\partial K_t} + \frac{\partial K_{t+1}}{\partial K_t} \times q_t = \alpha \frac{Y_t}{K_t} + \frac{1-\varphi}{\varphi} \frac{I_t}{K_t} \tag{A7}$$

The (gross) rate of return on capital held from period $t - 1$ to period t, R_t, equals the rental on capital, v_t, divided by the price paid for the capital in period $t - 1$, q_{t-1}. Therefore,

$$R_t = \frac{v_t}{q_{t-1}} = \frac{\alpha Y_t + \frac{1-\varphi}{\varphi} I_t}{q_{t-1} K_t} \tag{A8}$$

Appendix A.3. Individual Behavior

According to the basic hypothesis, the utility function of individuals born at the beginning of period t is Ut, and c_{1t} and c_{2t} represent the consumption of young and old individuals in period t. $c_{(2t+1)}$ indicates the consumption of individuals in period $t + 1$. The logarithmic utility function in period t is:

$$U_t = lnc_{1t} + blnc_{2t+1} \tag{A9}$$

where β is the elasticity of consumption substitution of the two periods, and $b \geq R_{t+1}$.

Under the income constraint, representative individuals choose consumption and savings to maximize the lifetime utility. The lifetime budget constraint of a consumer born at the beginning of period t is:

$$c_{1t} + s_t = c_{1t} + \frac{c_{2t+1}}{R_{t+1}} = w_t \tag{A10}$$

It can be shown that the optimal value of consumption in period t is:

$$\text{Max } U_t = lnc_{1t} + \beta lnc_{2t+1} \tag{A11}$$

$$s.t. \quad c_{1t} + \frac{c_{2t+1}}{R_{t+1}} = w_t \tag{A12}$$

We construct a lagrangian function to determine:

$$c_{1t} = \frac{1}{1+b} w_t \tag{A13}$$

In period t + 1, the aggregate capital stock in the economy is $K_{(t+1),}$ and it is jointly owned by N_t individuals born at the beginning of period t. The total return of this capital is $v_{(t+1)}$ $K_{(t+1)}$, which comes from the savings returns in adulthood:

$$v_{t+1} \frac{K_{t+1}}{N_t} = \frac{1}{N_t} \left(\alpha Y_{t+1} + \frac{1-\varphi}{\varphi} I_{t+1}\right) \tag{A14}$$

Here, it can be shown that the optimal value of consumption in period t + 1 is:

$$c_{2t+1} = \frac{1}{N_t} \left(\alpha Y_{t+1} + \frac{1-\varphi}{\varphi} I_{t+1}\right) \tag{A15}$$

$$c_{2t} = \frac{1}{N_{t-1}} \left(\alpha Y_t + \frac{1-\varphi}{\varphi} I_t\right) \tag{A16}$$

Appendix A.4. Market Clearing and Equilibrium Analysis

The total output of the economy in period t is equal to the sum of the aggregate investment, the aggregate consumption of the young and the aggregate consumption of the old in period t.

$$Y_t = I_t + C_{1t} + C_{2t} \tag{A17}$$

Let C_{1t} be the aggregate consumption in period t of the cohort of young consumers:

$$C_{1t} = N_t c_{1t} = N_t \frac{1}{1+b} w_t = \frac{\beta}{1+b} Y_t \tag{A18}$$

Let C_{2t} be the aggregate consumption in period t of the cohort of old consumers:

$$C_{2t} = N_{t-1} c_{2t} = N_{t-1} \times \frac{1}{N_{t-1}} \left(\alpha Y_t + \frac{1-\varphi}{\varphi} I_t\right) = \alpha Y_t + \frac{1-\varphi}{\varphi} I_t \tag{A19}$$

Recall that Y_t is the total output of consumption goods technology in period t, I_t is the aggregate quantity of output from the consumption goods technology used in the capital adjustment technology. Substitute Equations (A18) and (A19) into Equation (A17) and obtain:

$$I_t = Y_t - C_{1t} - C_{2t} = \varphi \frac{(1-\alpha)(1+b) - \beta}{1+b} Y_t = \psi Y_t \tag{A20}$$

Let $\psi = \varphi\frac{(1-\alpha)(1+b)-\beta}{1+b}$. In a closed economy, total investment I_t is equal to total savings S_t. Substitute Equation (A20) into Equation (A5) and take the logarithm:

$$lnq_t = -lna\varphi + (1-\varphi)(lnS_t - lnK_t) \tag{A21}$$

To obtain the expression of asset prices, we introduce the investment capital ratio I_t/K_t, it can effect the growth rate of the capital stock and the price of capital. The function form is:

$$\frac{I_t}{K_t} = \frac{\psi Y_t}{K_t} = \mu\psi A K_t^{\alpha-1} N_t^{\beta} \tag{A22}$$

Substituting Equation (A22) into Equation (A5), we can obtain:

$$q_t = \frac{1}{a\varphi}\left(\frac{I_t}{K_t}\right)^{1-\varphi} = \frac{1}{a\varphi}\left(\mu\psi A K_t^{\alpha-1} N_t^{\beta}\right)^{1-\varphi} \tag{A23}$$

Taking the logarithm for Equation (A23), then substituting Equation (A1) into lnq_t, we can obtain:

$$lnq_t = \beta(1-\varphi)lnn_t + (1-\varphi)ln\mu A\psi - lna\varphi - (1-\varphi)(1-\alpha)lnK_t + \beta(1-\varphi)lnN_{t-1} \tag{A24}$$

Appendix A.5. Static Comparative Analysis

The partial derivative of Equation (A21) provides

$\frac{\partial lnq_t}{\partial lnS_t} > 0$;

Thus, higher savings increase asset prices.

The partial derivative of Equation (A24) provides

$\frac{\partial lnq_t}{\partial lnn_t} > 0$;

That is, a lower population birth rate and a higher degree of population aging will lead to a decrease in asset demand, which will make asset prices lower.

According to the theory of Section 2, on the one hand, changes in the population dependency ratio can cause changes in housing prices based on the theory of supply and demand, and oversupply means that housing prices tend to decline. On the other hand, according to the established overlapping generations model, there is a negative relationship between population aging and asset prices. The increase in the population dependency ratio, which reflects population aging, will have a negative impact on housing prices. The economic system is a closed economy, and total investment is equal to the total savings. When total investment It or the total savings St increases relative to the capital stock Kt, the asset price qt rises. The increase in household savings leads to an increase in investment demand, so the probability of investment speculators entering the real estate market is large, and asset prices are pushed up. Therefore, the short-term relationship between household savings and asset prices is reflected in the increase in household savings and the rise in asset prices; as household savings increase, asset prices rise.

Hypothesis 1 (H1). *An increase in the population dependency ratio will cause a decline in housing prices.*

Hypothesis 2 (H2). *An increase in the household savings balance will cause an increase in housing prices.*

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