How Does Aging Affect Housing Prices?
—The Empirical Evidence from Asian Emerging Markets

Xin Wen

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By: Xin Wen

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__________ Yu Jou (Abby) Pai _________________Chair

___________Yu Shan__________________________ Examiner

__________Yu Jou (Abby) Pai_________________ Examiner

___________Erkan Yonder_____________________ Supervisor

Approved by ___________Parianen Veeren ___________________
Graduate Program Director

July 26, 2021 ___________Anne-Marie Croteau________________
Dean of Faculty

ABSTRACT

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The 21st century is a century that the world is aging. As the engine machine of global world development, Asian emerging markets are going through the population aging process while rapidly developing economics. The aging will bring rather serious changes to economic and social development. Housing, an essential need of human beings, is controlled by market rules and inevitably influenced by economic fluctuation. Therefore, what kind of impact will population aging have on Asian real estate markets? How does it affect the house price? Those are the concentrations of this paper.

Based on the literature research, this paper discovers a correlativity between aging and housing prices, then we deduce an empirical model according to supply and demand theory, life cycle hypothesis, and overlapping generations model; at last, we make transnational empirical tests taking 5 Asian emerging markets with the serious population aging issue, namely China, Hong Kong, South Korea, Singapore, and Thailand. The conclusions are that the rising old dependency rate will lead to a negative impact on housing prices while the decline of the youth dependency rate will bring a positive impact on them. GDP is one of the most important factors that push house prices. The tests in those 5 Asian markets verify the results of the theoretical model.

Keyword: Population Aging; Housing Prices; Asia Emerging Markets

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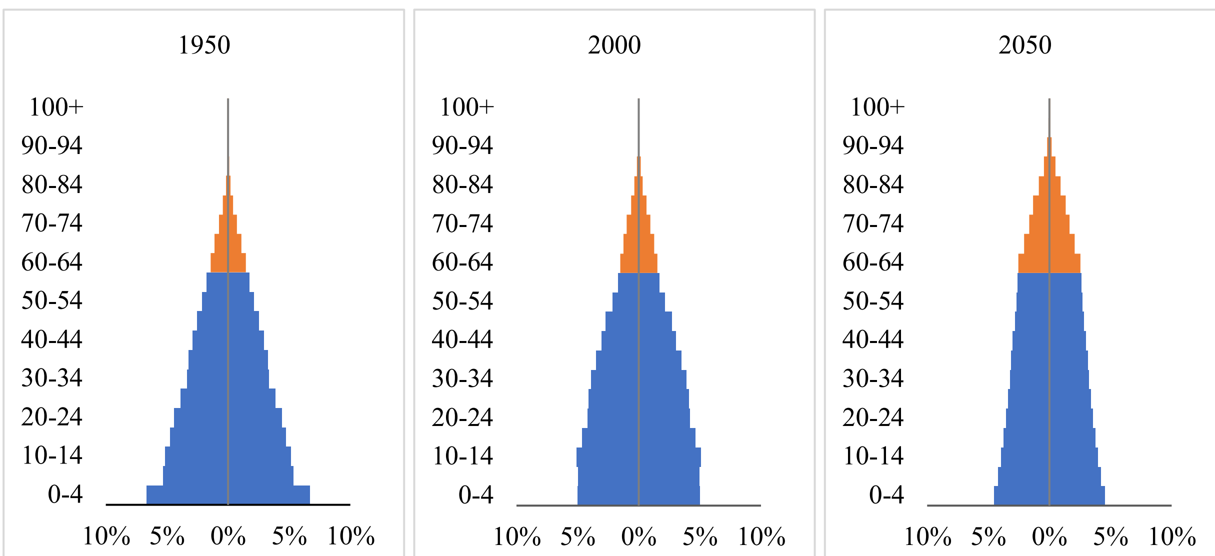
Chapter 1: Introduction

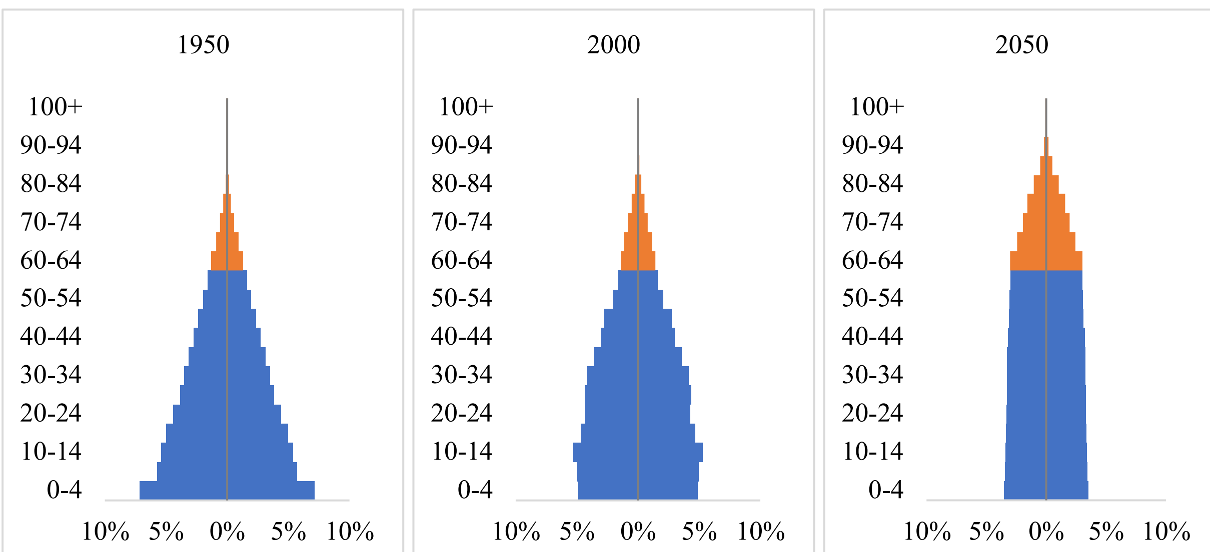
Population aging is not just a problem of one country or a certain region but a worldwide problem. It can be said that the 21st century is the century of global aging, and this phenomenon will continue for a long time. According to the research report of the United Nations Population Division, "Global Population Aging 1950-2050", the global population of 60 and over 65 years old accounted for only 8.0% and 5.1% of the world's total population in 1950. By 2000, it had grown to 10% and 6.9%. It predicts that this figure will reach 18.4% and 13.4% by 2050, which means nearly one-fifth of the global population will be over 60 years old in 2050 (Figure 1-1). Whether the percentage of the senior (over 65) to the total population exceeds 7% is a threshold to measure aging and obviously, the entire world has already entered an aging society in 2005. At the same time, the rate of global aging is also increasing, especially that of the super-aged population. From 1950 to 1955, the average growth rate of the population over 60 was 1.8%, which was equal to the total population growth rate. However, from 2025 to 2030, the growth rate will rise to 2.8%, which is 2 percentage points higher. In the same period, the aging rate of the population over 80 is 3.9%.

Figure 1-1 Population Pyramids of The World



The overall aging process in Asia is relatively late. The statistics from the World Bank on the Asian population structure show that the proportion of people aged 60 and over 65 remains at a low level from 1950 to 2000 (Figure 1-2). During this period, Asia had an age structure very favorable to rapid economic growth, which is the first demographic dividend (Bloom and Williamson 1998, Kelley and Schmidt 2001, and Mason and Lee 2007). The speed and scale of Asian demographic transition is unprecedented in human history and population aging may be due to two factors: lower fertility and longer life expectancy. When entering the 21st century, the ratio of population aged 60 and over 65 has increased significantly, reaching 21.5% and 15.5% by 2050, the speed is much faster because fertility rates have declined more rapidly than elsewhere, therefore the share of the working-age population is increasing, which has a direct and favorable impact on growth in per capita income and on rise in housing prices. Over time, the population of the Asia will become increasingly concentrated at older ages where in all cases labor income is quite modest, which also reflects the low level of employment and low wages and productivity for the elderly population. The old-age population can negatively affect the housing prices through the lack of demand. It's likely that the senior people already own their house, so the demand is weaker for them to purchase a new one compared to the working-age population. Besides, they may sell off their houses and move to a smaller one or choose to a rented house according to their financial statements. This rapid and massive transition will have important implications for saving and spending on human resources, therefore, we investigate how house prices are associated with population aging by focusing on the hypothesis that aging may affect the housing demand of the older population, which consequently affects house prices. To be specific, we first find the correlation between aging and house prices through literature research, and then prove it by performing the theoretical models and basic mathematical reasoning and put forward corresponding hypotheses. Finally, the panel data of 5 Asian emerging markets (China, Hong Kong, South Korea, Singapore, Thailand) are used for empirical tests. By doing so, this paper answers the following questions: First, how does the aging trend of Asian emerging economics affect the housing market? Second, how dose increase in the old-age population affect real house price in a panel setting?

Figure 1-2 Population Pyramids of Asia



The discussion above is only talking about the rural-urban migrants who will reform of the household registration system, while immigrations are also a group of housing market change as the housing prices within the immigration areas can influence residents' settlement decision. Foreign citizens make up a more and more important part of the population due to two facts. First, the immigrant population become a powerful group in labor force because of the ongoing decline in the birth rate and the rising average age of the autochthonous population. They create value and contribute to a country's GDP and consequently they will have an essential influence on policies. Therefore, their own choose of purchasing or renting a house may affect housing prices both positive and negative way, at the same time, this behavior will affect other residents' decision-making. Second, Asian emerging markets have visa programs to those with wealth who invest a considerable amount in the local economy. It might say that wealthier and higher socioeconomic status immigrants, their higher demand for housing at the extensive margin is larger than native residents thus the local housing prices being affected by capital inflows associated with the wealthy investor immigrants. This suggests a potential role for foreign capital in neighborhood housing price dynamics in cities that receive these inflows. However, in this paper we do not individually consider the immigration effect on housing prices because the macro environments in those 5 Asian emerging markets are different, for example, Singapore and Hong Kong may be the most favorable destinations for immigrants, so the immigration effect can be strong, but others are not easy to say without accurate control factors. Considering about the data availability and comparability within different regions, we ignore the immigration effect in this study.

The study has 3 main findings. First, it provides empirical evidence that an increase in the share of the elderly population to the working-age population is negatively related to housing prices: 1% increase is associated with about 4.6% decrease in housing prices. It also shows that the increase in the young population negatively impacts house prices. Lastly, other macro-economic factors are significantly related to house prices, especially the economic development and per capita income, they are positively related to housing prices.

The remainder of the paper is organized as follows. Chapter 2 reviews the relevant literature, and Chapter 3 states the current situations of aging and housing prices in Asian emerging markets. Chapter 4 presents the theoretical models and hypotheses. Chapter 5 and Chapter 6 presents the empirical strategy, results, and interpretations and Chapter 7 concludes the paper.

Chapter 2: Literature Review

The age structure of the population has a long historical impact on housing prices, but there are big differences in opinions. Some scholars believe that the population age structure is significantly related to housing prices while some question this view and believe that if the selected variables and methods are appropriate, the correlation between them may disappear.

The empirical test of population structure and housing prices can be traced back to Mankiw and Weil (1988). They conducted an empirical test on the relationship between actual per capita housing expenditure and age and found that fluctuations in housing demand affect prices. The results of the study showed that there is a leap in demand for housing among people in their 30s. After their 40s, the demand begins to decline at a rate of about 1% per year. They also found that groups born in the "baby boom" in the United States after World War II increase housing prices in the 1970s, and the subsequent fertility trough may cause housing prices to fall after the 1990s. They even predicted that as the group grows up to working age, house prices would fall by 47% between 1987 and 2007. The study of McFadden (1994) found that Mankiw and Weil's conclusions also apply to the statistics of the United States in 1940, 1960, and 1980. They all believed that the "baby boom" was the main reason for the rapid increase in housing prices from 1969 to 1989. Some scholars used different methods and models to conduct empirical tests on data from different countries and deepened the research on the role of population structure on housing prices. They were no longer limited to the impact of the baby boom but also researched on the impact of aging on property prices.

Lind and Malmberg (2006) found that with the increase in the young population, the housing construction rate will also increase. On the contrary, population aging will lead to a decrease in the demand for real estate, that is, housing construction is negatively related to population aging. Malmberg (2010) believed that the age structure of the population may indirectly affect housing demand through other factors such as per capita income, inflation rate, and taxation. It may also affect housing demand by affecting housing supply. For example, the labor productivity of different aged groups is different. Malmberg (2012) further demonstrated the negative impact of population aging on the real estate market. The research of Ermisch (1996), Myers and Ryu (2008) found that the impact of population age structure on housing demand is not as significant as the M-W model, but they proved that the life cycle does affect housing demand, that is again, the age structure of the population has an impact on housing demand. Due to the lack of data on housing prices in different countries, there are few international studies on the relationship between population structure and housing markets. Davis (2003) found a significant relationship between population structure and house prices in OECD countries. The study of Egger and Mihaljek (2007) also drew the same conclusions in Central and Eastern Europe. Takats (2010, 2012) conducted an extensive cross-country study on this issue for the first time. He used the data of 22 developed countries for more than 40 years and used the old dependency ratio and the total population as the demographic indicators, and they are proved to be significantly related to housing prices. Nguyen (2012) used a similar method to Takats (2010) to examine the relationship between population structure and housing prices in different countries. She used a wider range of data including emerging economies and controlled the financial openness, finally getting similar conclusions.

Some scholars criticized Mankiw's (1989) view. Engelhardt and Poterba (1990) applied the same method to test the relationship between housing prices and birth rates in Canada, but they didn't find that housing demand is significantly correlated to housing prices, and most of the results even proved that they are negatively correlated. Their research results were just the opposite. Therefore, they concluded that the statistical relationship between housing demand and housing prices is still controversial and a sharp drop in housing prices is impossible. Hendershott (1990) and Swan (1995) believed that Mankiw's (1989) empirical method was unscientific and pointed out that the influence of population age structure on housing might disappear if an appropriate model is selected. Yu Chen (2012) used micro-simulation analysis to study England's data from 1981 to 2010 and found that population aging is not the main factor affecting housing prices. It is obvious that in this field many scholars have not reached a consensus.

In addition to demographic factors, housing prices are also affected by many other factors. Since the analysis of this article is a cross-country real estate market, we mainly read some literature that studies this issue from a regional or global perspective. From the 1960s to 1980s, the utility function of home buyers and the regional price difference were some of the most important study directions for the real estate market. Furthermore, they focused on the study of the relationship between real estate prices and economic cycle changes, mainly including house purchase and income, consumption and savings, with special attention to the impact of housing prices on consumer behavior and consumption elasticity. Since the 1990s, with the reform of the taxation system in Western developed countries and the continuous introduction of new financial derivatives, the focus has shifted to the impact of various tax policies and financial innovation tools on the decision-making of home buyers. Some scholars also discussed the restrictions and constraints imposed by monetary policy on home purchase loans and even examined the relationship between real estate price fluctuations and social equity.

With the growing influence of emerging economies in the global economy, many articles have begun to study the determinants of housing prices in these areas. Mihalijek (2007) studied the determinants of housing prices in transition economies in Central and Eastern Europe. Research showed that the total population, construction costs, and money supply are significantly related to actual property prices. Glindro and Subhanij (2008) selected some determinants to test 9 countries in the Asia-Pacific region and the results showed that the actual mortgage interest rate, land supply index, actual exchange rate, actual stock price, and some institutional factors are related to actual housing prices. Institutional factors act on actual housing prices by influencing market operation patterns. Ciarlone (2015) researched the influencing factors of real housing prices in emerging economies, and the conclusions were consistent with Glindro (2008). Besides, he found that the unemployment rate is also an important factor. Igan and Loungani (2012) studied real estate price data from most developed and developing countries and reached similar conclusions as previous research. The important thing is that they verified the demographic variable—the population growth rate of working age and found it positively correlated with actual housing price changes. Tillmann (2012) used the VAR model and studied in 6 Asian emerging economies, he proved that capital inflows could well explain the rise in asset prices such as real estate.

This study contributes to several strands of the literature. First, the current literature on the effect of population aging on housing prices are most confined to the western developed markets or OECD countries, such as in Liu and Spiegel (2011) and Yoon et al (2014), they discussed the effect of aging from both academic and policy aspects in OECD countries, while there is few transnational research with Asian emerging markets. The economic and cultural differences between them are large, residents' lifestyles and attitudes to housing ownership will have different impact on the housing markets. Therefore, this article uses relevant theoretical models and takes 5 Asian emerging economies as research samples to study the special features of those countries (regions) and to explore the impact of population aging on housing prices as well as to analyze the reasons. Second, this paper finds a significant role of old-age population on the housing prices. As discussed above, the determinants such as real income, real interest rates, credit growth have already been proved to influence housing prices, however, they did not explicitly consider population aging as a driver of real house prices. Using the old dependency ratio, this paper predicts a considerable decrease in real house prices in Asian emerging economics associated with increasing share of population aged 65 and above. Lastly, this paper considers a country-specific factor to examine the relationship between population aging and the housing prices respectively so that the analysis can be more detailed with a different pace of population aging.

Chapter 3: Discussions in Asian Emerging Markets

3.1 Population aging

After World War II, Asia has become a region with strong development momentum and economic activity in the world, characterized by rapid economic growth, social and cultural progress as well as population aging. The demographic change is the most significant transformation that Asia has faced since entering the 21st century, and its speed is unprecedented. According to a report from the Asian Development Bank (ADB), Asia will surpass Europe in the next few decades to become the most aging region in the world. Different from the natural and slow population aging process in developed countries in Europe and America, the population aging in Asian countries (regions) started late but very quickly and has distinctive Asian characteristics. This chapter will use several major indicators to analyze and study the aging process and characteristics of Asian emerging economics, including China, Hong Kong, South Korea, Singapore, and Thailand.

3.1.1 Current situation and future trend

Figure 3-1 shows the changes in the aging rate of these 5 countries (regions) from 1960 to 2019. The aging rate is measured by the proportion of elderly population over 65 to the total population, and the rate shows an upward trend in general. Specifically, Hong Kong's aging rate is far ahead of others. South Korea comes next, and Thailand follows. Singapore and Thailand have slightly higher population aging rates than China. Since around 1990, Thailand’s aging rate has entered a rapid growth pattern.

Figure 3-1 The Population Aging Rate of Asian Emerging Markets in 1960-2019

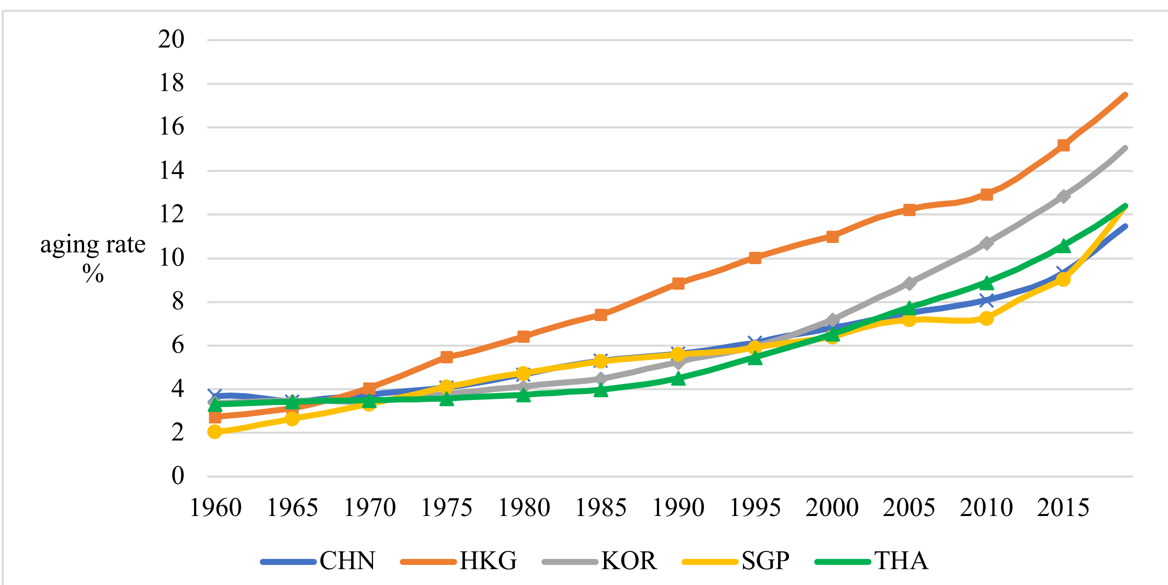


Table 3-1 details the number of the elderly population and the aging rate in 5 Asian countries (regions) from 1960 to 2050. In the last 50 years of the 20th century, the number of elderly people over 65 has grown rapidly. This number in Hong Kong has increased by 8.7 times, Singapore by 7.6 times, South Korea and Thailand by 4.0 and 4.5 respectively. Although the increase in China is the smallest, only 3.5 times, the absolute amount is as high as 61.4 million. According to the criteria for entering an aging society with the proportion of the elderly over 65 exceeding 7%, those 5 countries (regions) have all entered an aging society in the early 21st century. In the next 50 years, the growth rate of the elderly population has slowed down, but it has remained at 3.5 to 5 times. In the same period, the growth rate of the world's elderly population over 65 years old was 3 times. This indicates that Asian emerging markets keep a higher growth rate of the elderly population. With the increase of the number of elderly populations, the proportion of the elderly population will increase significantly. By 2050, South Korea accounts for 38.1% of the total population, while China has the lowest proportion among them but also reaches 26.1%. Although its aging rate is not the highest, the number of the elderly population is huge, and the scale of the elderly population ranks the first in the world.

Table 3-1 The Number and Proportion of the Elderly Population in Asia Emerging Markets in 1960-2050

	Number of elderly populations (ten thousand)					Aging rate (%)				
	1960	1975	2000	2025	2050	1960	1975	2000	2025	2050
CHN	2460.5	3743.0	8601.0	19920.6	35422.6	3.7	4.1	6.8	14.0	26.1
HKG	8.4	24.5	73.4	173.3	274.4	2.7	5.5	11.0	22.0	34.7
KOR	84.2	133.0	337.8	1045.1	1774.7	3.4	3.8	7.2	20.2	38.1
SGP	3.4	9.3	25.7	108.1	206.6	2.0	4.1	6.4	18.1	33.3
THA	90.8	151.5	411.2	1135.9	1954.6	3.3	3.6	6.5	16.1	29.6

3.1.2 Characteristic of population aging

(1) Late to enter the aging society
According to the release of the United Nations "Population Aging and Its Socio-economic Consequences", internationally, whether a country or region's population over 65 accounts for more than 7% of the total population is usually used as a measure of aging. Table 3-2 shows the time when the 5 countries(regions) entered the aging society. The period can be divided into three phases. Hong Kong is far ahead, 19 years earlier than China, followed by South Korea, Thailand, and Singapore. They all occurred at the end of the 20th century and the beginning of the 21st century. However, France, where the aging signal first occurred, entered an aging society in 1850 and Sweden was in the 19th century. Other developed countries in Europe and America were in the first half of the 20th century and gradually entered the "aging" society after World War II[1]. Compared with developed countries, the process of population aging in Asia is relatively late, and the time to enter an aging society is generally about half a century later.

Table 3-2 The Time of Asian Emerging Markets Entered into Aging Society

Country(region)	CHN	HKG	KOR	SGP	THA
Time	2002	1983	2000	2004	2002

[1] Hou Wenrou, *Global Population Trends* (Beijing: World Affairs Press, 1988), 317-319.

(2) Fast aging

Different from Western developed countries (regions), the development of population aging in Asia is not advancing at a uniform rate but is accelerating, and its rate is much faster than that of Western countries. In general, the aging rate doubling time (the time for the proportion of the elderly over 65 to double from 7%) is used to measure the speed of population aging. Table 3-3 shows the doubling time of population aging and Singapore has the shortest doubling time, taking only 17 years, followed by South Korea. Although Hong Kong entered the aging society in the earliest, its growth is more similar to the developed industrialized society in the West. It took the longest time, 30 years. They took an average of 21.6 years to multiply their aging, and the growth rate far exceeded that of OECD countries. Under normal circumstances, it would take them more than 45 years to complete this change[2]. France even spent 140 years, Sweden 85 years, the United States took 70 years, 45 years for Britain and West Germany, and 50 to 100 years for entire Western Europe. Although Asian emerging markets entered the aging society later than the Western countries, the population aging rate grew very rapidly. The entire of them were "running" into the aging society.

Table 3-3 The Aging Rate Doubling Time of Asian Emerging Markets

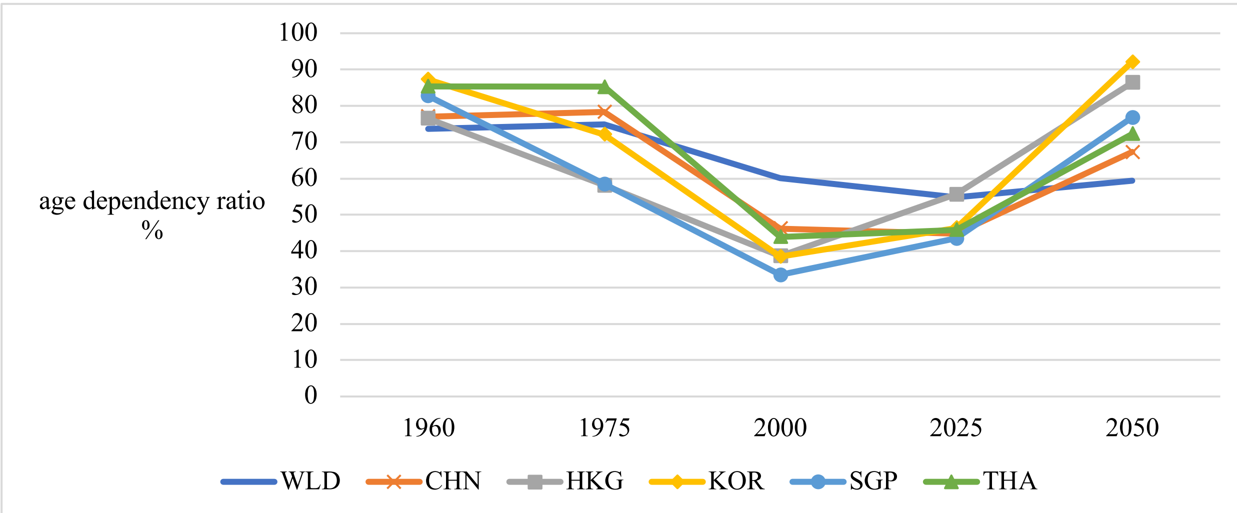
Country(region)	7% doubling time		
	7%	14%	Years
CHN	2002	2025	23
HKG	1983	2013	30
KOR	2000	2018	18
SGP	2004	2021	17
THA	2002	2022	20

(3) Age dependency ratio is in line with the global law

The age dependency ratio is an important indicator to measure population aging, and it can also reflect the dependency burden of the population. This ratio refers to the number of non-working-age population to the number of working-age population in the total population, where the population aged 15-64 is the working-age population, and the population aged 14 and under and 65 and over are the non-working-age population. Figure 3-2 shows this indicator from 1960 to 2050 in 5 Asian countries(regions) and there is a trend of the first decline and then rise. The decline was caused by the decrease in the youth dependency ratio, and the latter increase was due to the sharp rise in the old dependency ratio offsetting the downtrend in the youth dependency ratio, making the total dependency ratio rising again. Overall, Asian emerging markets have a similar pattern with the global one.

[2] Peng D, Hui Y, "Comparison of Population Aging in China and Other Asian Countries," *CPDS* 02 (2009):75-80.

Figure 3-2 The Age Dependency Ratio of Asian Emerging Markets



Furthermore, we divide the dependency ratio into the old and youth dependency ratio. The old dependency ratio refers to the proportion of a country's population over 65 to the labor population aged 15-64; the youth dependency ratio refers to a country or region whose population aged 0-14 accounts for the labor force. According to this standard, Figure 3-3 and Figure 3-4 respectively describe the changes in Asian countries(regions) from 1960 to 2020. The old dependency ratios in all are on the rise, while the youth dependency ratios drop significantly. The rapid increase in the elderly population will offset the demographic dividend brought by the decrease in the newborn population and will bring a rise in the age dependency ratio in the next 50 years. From then on, those Asian emerging economies will gradually enter a high population burden level.

Figure 3-3 The Old Dependency Ratio of Asian Emerging Markets in 1960-2020

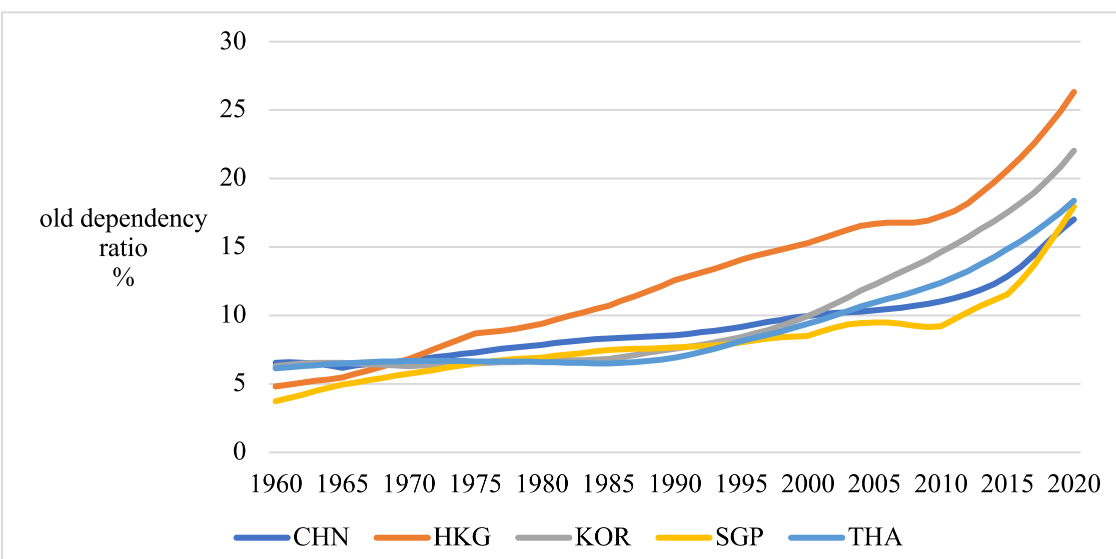
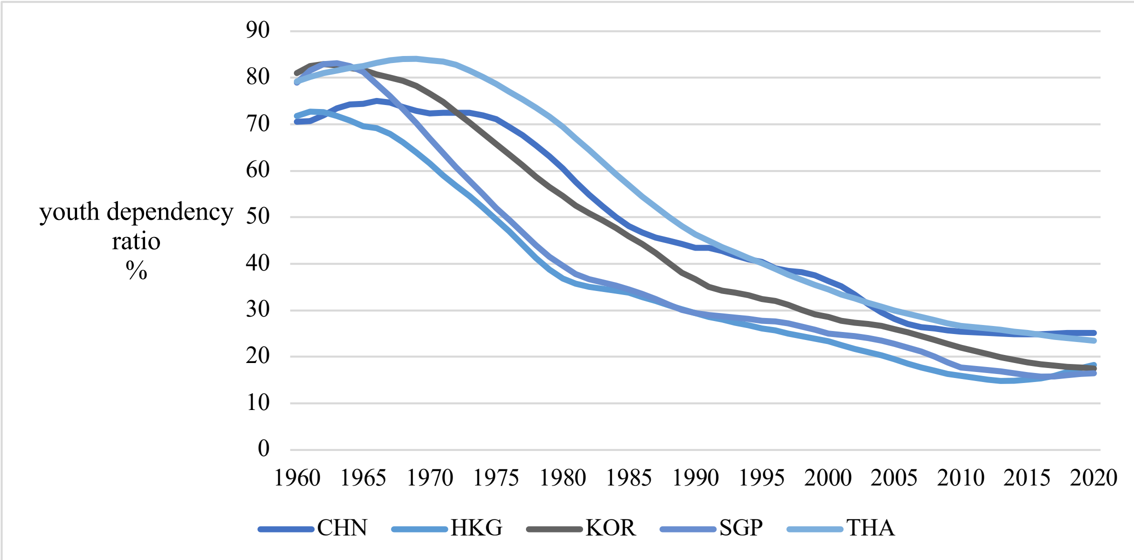


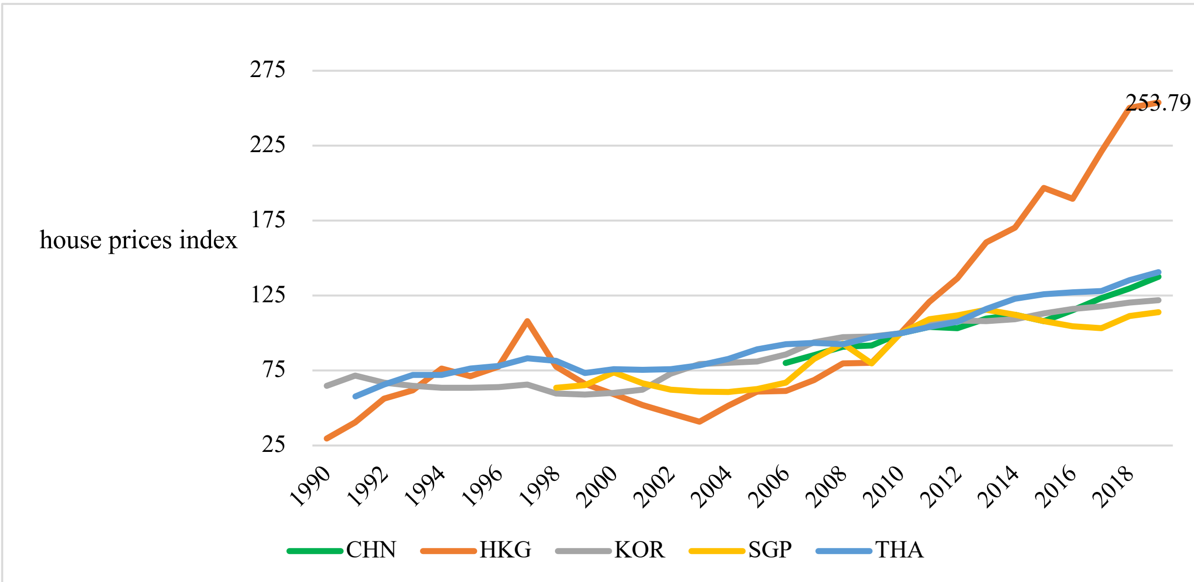
Figure 3-4 The Youth Dependency Ratio of Asian Emerging Markets in 1960-2020



3.2 Housing Prices

This section analyzes the changes in housing prices in Asian countries (regions) from 1990 to 2019 for a total of 29 years. Different countries (regions) have different calculation methods for house price index, so it is difficult to compare with each other. To solve this problem, the nominal residential property price index is calculated by the CEIC database and then deflated with CPI to obtain the actual house price index. Figure 3-5 describes the changes, and the house price indices are generally going up. When the Asian financial crisis broke out in 1997, the economies of Asian countries (regions) were affected with varying degrees, including the real estate market. As a result, the real house price index declined during the period from 1998 to 2000. Among them, the housing market in Hong Kong has been the most affected, the housing price index began to decline in 1998 and did not start to rise until 2004. The index of Hong Kong is in the lead, being 253.8 in 2019. South Korea’s house price index is stable. Thailand’s house price index has been at a low level due to the financial crisis, and it has only shown a slight uptrend in recent years. Singapore, however, under the influence of the financial crisis and government control policies, has maintained growth amidst fluctuations.

Figure 3-5 Real House Prices Index of Asian Emerging Markets in 1990-2019



Chapter 4: Theoretical Analysis and Hypothesis Proposal

Many factors affect property prices, and the channels and mechanisms are different. For example, the actual construction cost will affect the supply cost of housing, and builders' investment strategies, and thus affect the supply behavior of the housing market. This is a short-term and observable factor. However, just like the laws of operation of all economic markets, the housing market is also influenced by some potential and long-term mechanisms. Population aging is one subtle factor. This chapter attempts to analyze the impact of population aging on housing prices by constructing a theoretical model based on the supply and demand theory and the overlapping generation model and provide theoretical support for the empirical evidence later.

4.1 Supply and demand balance in the housing market

Any market is composed of both supply and demand. When the supply and demand reach a certain balance, the market reaches an equilibrium state, and the price currently is the equilibrium price. The core idea of the equilibrium price of commodities is formed by the self-regulation of market supply and demand. When supply or demand deviates, the market mechanism will gradually resolve this non-equilibrium state and bring supply and demand back to an equilibrium state. Like any other commodity, housing is also affected by the relationship between supply and demand. This section will study the relationship between population aging and housing prices based on the principle of the price determination mechanism. The price function of housing can be obtained as follows:

$$HP=H\ (D,\ S) \tag{1}$$

housing demand specifically refers to effective demand, which is the number of houses that consumers are willing and able to buy at a certain price in a certain period. Housing prices are affected by many factors. Through literature reviews, the following factors are listed:
(1) Price factor (*HP*). The relativity of price and ability to pay determines the demand to a certain extent. As a commodity, housing must be affected by the law of prices.
(2) Consumer income (*INCOME*). The increase in income will increase the original demand. Furthermore, it will also lead to new demands, such as better, larger, and more comfortable houses.
(3) Demographic factors (*AGING*). According to previous studies, the age structure, gender ratio, and regional distribution of the population all have impacts on housing prices. This article focuses on analyzing the impact of population age structure, especially aging.
(4) Policy influencing factors (*RATE, M2, UN*). Economic policy can affect the housing prices in many ways. For example, monetary policy can affect consumer decision-making through interest rate (*RATTE*) and money supply (*M2*); employment policy (*UN*), increasing employment rates and reducing the number of unemployed people could improve national income, thereby affecting housing demand.

The basic housing demand function is:

$$D(Q)=H\ (HP,\ INCOME,\ AGING,\ RATE,\ M2,\ UN) \tag{2}$$

In the supply function, as demand, supply also refers to the effective supply.
(1) Housing price (*HP*), the real estate investors mostly follow the short-sighted expectation function, who make different decisions with different prices, that is, when the price rises, the supply will increase, and vice versa. In the case of fixed costs, high prices mean high profits. Under the basic demand for profits, supply will naturally increase.
(2) Housing development costs (*RATE, INCOME*). The costs of real estate are mainly land costs, financing costs, and labor costs. In the final analysis, land cost is determined by the expected housing price, the financing cost can be expressed by the loan interest rate (*RATE*), and the labor cost is reflected by the income of the people (*INCOME*).
(4) Policy factors (*RATE*). Macro-economic policies and situations will affect any industry, housing market is no exception. Also, as the housing industry related to people's livelihood, it is subject to more government control policies, which is a major factor affecting supply. Macro policies mainly affect the supply of real estate through the adjustment of interest rates and the introduction of preferential tax policies.

The basic housing supply function is:

$$S(Q)=H\ (HP,\ INCOME,\ RATE) \tag{3}$$

According to the price formation mechanism, a poor estimate of the housing price function is generated:

$$HP=D\ (INCOME,\ AGING,\ M2,\ RATE,\ UN) \tag{4}$$

Through the analysis of the housing market equilibrium, we have reached proposition 1: housing prices are affected by factors such as population age structure, income, economic growth, money supply, real interest rates, and unemployment rate.

4.2 Overlapping generation models

The above is only based on the analysis of the literature and the price determination mechanism to crudely estimated the housing price function. This section will learn from Takat's (2012) research method, further analyze the impact of aging on housing prices through mathematical reasoning. We construct a two-period overlap model based on Diamond (1965). This model has 3 basic assumptions: first, everyone survives for two periods, young and old age, the young at *t*, and the old at *t+1*; Young people earn income from work and save for consumption in old age, while the elderly have no income, and only rely on savings from his youth; Last, savings in the model are saved through benchmark assets. Benchmark assets are identical assets that can be divided.

After deriving and simplifying, the model of the old dependency ratio is expressed as:

$$OLD_t = \frac{N_{t-1}^Y}{N_t^Y} = \frac{N_{t-1}^Y}{N_{t-1}^Y(1+d_{t-1})} = \frac{1}{1+d_{t-1}} \tag{5}$$

Where *N* refers to the number of the total young generation and *d* represents population change rate, that is the speed of the young generation at t grow up to old at *t+1* (The detailed process is shown in Appendix A).

According to mathematical analysis, the old dependency ratio is negatively correlated with assets value, that is, the heavier the burden of supporting the elderly in a society, the lower the value of assets. In summary, this section draws three other basic propositions: Proposition 2: the old dependency ratio is negatively correlated with housing prices, and an increase in this ratio will bring a decline in housing prices. Proposition 3: economic growth is positively correlated with housing prices, and economic development will bring an increase in housing prices.

However, the reasoning above is performed on the same properties of assets and is a completely idealized model. Chen (2013) constructed a three-phases overlapped generation model[3] (adolescent period from 1 to 14 years old, youth from 15 to 64, and those over 65). Through the equilibrium of the real estate market and the maximization of household utility, we get:

$$HP_t = \frac{1}{Av\zeta\left(1-\frac{1}{\zeta}\right)+\frac{\zeta(1-\zeta)OLD_t h_{t-1}(2+wYOUTH_t+\delta)}{Wt+OLD_t b_t^0}} \quad (6)$$

Where HP_t is housing prices, OLD_t and $YOUTH_t$ represent the old and young dependency ratio, others are exogenous variables. According to the partial derivative of the model, these two ratios are changing in the opposite direction with the housing price. Proposition 2 is confirmed with the three-phases model and proposition 4 is obtained: the youth dependency ratio is negatively correlated with housing prices, and a decrease in this ratio will lead to an increase in housing prices.

[3] Guojin C, Qi Lee & Jie Z, "Research on the Relationship between Population Structure and Housing Prices—The Analysis of the Inter-Generational Overlap Model and Chinese Provincial Data," *The Economist* 10 (2013): 40-47.

Chapter 5: Empirical Specification

Takats (2010, 2012) and Nguyen's (2012) series of studies have shown that many developed countries have gone through such stages: the dependency ratio of the population has risen, especially the old dependency ratio, housing prices have fallen, and vice versa. This chapter tries to investigate the laws in 5 Asian emerging markets from the year 1990 to 2019.

5.1 Model setting and index selection

According to the analysis discussed above, there is a certain relationship between population aging and housing prices. However, the impact of population aging in Asian emerging economics on housing prices needs rigorous empirical tests. Based on the research results of Takats (2010, 2012), we construct a housing price function, and the basic measurement model is as follows:

$$\text{Ln } RHPI_{i,t}=\alpha_0+\alpha_1 OLD_{i,t}+\alpha_2 REGION_{i,t}+,\alpha_3 X_{i,t}+\xi_{i,t}$$

Where i and t represent the country(region) and time.

5.1.1 Dependent variable

The dependent variable here is the real house price index, $RHPI_{i,t}$. Since the classification of real estate and the statistical methods of housing prices in various countries (regions) are different, the home price index cannot be used directly. For example, the Bank of Thailand publishes Property Price Index in the form of single-family, terraced houses, apartments, etc., the National Bank of Korea's Housing Price Index (HPI), Singapore's Private Housing Price Index (PPI), etc. For comparison, we choose the nominal house price index from the CEIC global statistical database with 2010 as the base period, then use CPI to adjust to the real housing price index.

5.1.2 Independent variable

The independent variable is the old dependency ratio (% of people aged over 65 to working-age population), $OLD_{i,t}$, to measure population aging. The sample data comes from World Bank statistical database. According to proposition 2 in Chapter 4, the regression coefficient is expected to be negative. In addition to population factors, housing prices are also related to economic growth rates, economic development stages, money supply, interest rates, and others, which must be investigated after controlling. Therefore, we select some other more important control variables, $X_{i,t}$, based on proposition 1 and the availability of data:
(1) Youth dependency ratio ($YOUTH_{i,t}$), is measured by the number of people aged 0-14 to the working-age population in each country(region). It is the same as the old dependency ratio. According to proposition 4, the regression coefficient is expected to be negative.
(2) Real GDP per capita (*GDPP*), represents economic development and income level. Use the real GDP per capita with 2010 as the base period. According to proposition 3, it is positively correlated with housing prices.
(3) The proportion of money supply in GDP (*MS*), represents the degree of currency oversupply and financial development. The ratio of the M2 supply to the nominal GDP of the year is used to measure the impact of money supply on housing prices. According to existing research, the excess money supply is first absorbed by asset prices with less supply elasticity and the real

estate becomes an "absorber" of excess money, thereby pushing up housing prices. Therefore, the regression coefficient is expected to be positive.
(4) The real interest rate (*RATE*). The interest rate affects the housing price by affecting the financing cost of both supply and demand. The regression coefficient is expected to be positive.
(5) Unemployment rate (*UN*), the rise in the unemployment rate affects the economic prosperity, thus affecting house market. The change in supply and demand causes housing prices to fall, so it is expected to be negatively correlated with the housing price index.
Finally, we add dummy variable (*REGION*) to prevent the data of one region having too much influence on the equation and to check whether all five countries (regions) are consistent with the hypothesis respectively.

5.2 Data descriptive statistics

In order to eliminate the dimension problem, we adopt the method of Zou (2014) to logarithmize the housing price index and the real GDP per capita, denoted as *InRHPI* and *InGDPP*. As the transformation only linearizes the relationship, it will not change the characteristics of the data. The regression results are expected to be the same as above. The following table is a statistical description of all processed variables.

Table 5-1 Descriptive Statistics

VARIABLES	N	mean	sd	min	max
lnRHPI	112	4.482	0.351	3.390	5.536
OLD	112	13.09	3.753	7.122	24.94
YOUNG	112	24.59	6.538	14.87	44.90
lnGDPP	112	9.603	0.929	7.896	10.96
MS	112	1.774	1.095	0.536	5.176
RATE	112	4.160	3.265	-2.335	13.13
UN	112	3.364	1.619	0.250	7.860

It can be seen from the results that there are great differences among those 5 Asian countries (regions). The highest old dependency ratio has reached 24.94%, which is larger than the world average of 11.4%. At the same time, the young dependency ratio is lower than the world average of 45.4%. With the increase of the aging population and the decrease of the young dependency ratio, the aging process in Asia is far faster than the world average and the developed countries.

5.3 Correlation test

From Table 5-2, the old dependency ratio and youth dependency ratio are both significantly negatively correlated with the housing price index. The real GDP per capita (*LnGDPP*) is positively correlated; the correlation between the real interest rate (*RATE*), the proportion of M2 supply in GDP (*MS*), the unemployment rate (*UN*), and housing prices is the same as the previous estimate.

Table 5-2 Pearson Correlation Matrix

	lnRHPI	OLD	YOUNG	lnGDPP	MS	RATE	UN
lnPHPI	1.0000						
OLD	-0.5449	1.0000					
YOUNG	-0.4413	-0.65587	1.0000				
lnGDPP	0.0388	0.3551	-0.7695	1.0000			
MS	0.3222	0.7344	-0.5495	0.3714	1.0000		
RATE	-0.4176	-0.2135	0.2287	0.0396	-0.0367	1.0000	
UN	-0.2881	0.0545	-0.4047	0.5175	0.2618	0.3654	1.0000

Besides, all correlation coefficients are between (-0.8, 0.8), which can explain the absence of multicollinearity between variables. The VIF test is used to further test multicollinearity. The results in Table 5-3 show that the average VIF is lower than 3, and the VIF of all variables does not exceed 10, so there is no multicollinearity between variables.

Table 5-3 Variance Inflation Factors

VARIABLES	VIF	1/VIF
OLD	5.30	0.188755
YOUNG	3.48	0.287765
lnGDPP	3.13	0.319056
MS	2.44	0.409319
RATE	1.53	0.652309
UN	1.94	0.515495
MEAN VIF	2.97	

5.4 Panel data stationarity test

To avoid spurious regression, the data for the cointegration test must be stable. Therefore, it's necessary to conduct a stationarity test on all data. According to the model setting and the choice of control variables, we perform 7 serial input unit root tests.

Table 5-4 Unit Root Tests

VARIABLES	level (p**)	1st difference (p**)
lnRHPI	0.0134	0.0000
OLD	0.0198	0.0000
YOUNG	0.0294	0.0000
lnGDPP	0.1102	0.0000
MS	0.1317	0.0000
RATE	0.0635	0.0000
UN	0.0169	0.0000

The level value of each series is not stable, but after the first-order difference they are stationary series, all variables are first-order single integer series I (1). The sample data may have a cointegration relationship, so we do the cointegration test next.

5.5 Panel cointegration test

Since the previous section has verified that there is no multicollinearity between variables, here we use the Pedroni test, and the results are shown in Table 5-5.

Table 5-5 Pedroni Residual Cointegration Test

Alternative hypothesis: common AR coefs. (within-dimension)				
	Statistic	Prob.	Weighted Statistic	Prob.
Panel v-Statistic	-1.447304	0.9261	-3.735450	0.9999
Panel rho-Statistic	2.827816	0.9977	2.845214	0.9978
Panel PP-Statistic	0.853968	0.8034	-5.302284	0.0000
Panel ADF-Statistic	1.741318	0.9592	-1.006027	0.0572
Alternative hypothesis: individual AR coefs. (between-dimension)				
	Statistic	Prob.		
Group rho-Statistic	3.789258	0.9999		
Group PP-Statistic	-2.412478	0.0079		
Group ADF-Statistic	-1.859166	0.0315		

Panel ADF and Group ADF have better small sample properties than other statistics, and the sample in this paper is a small size, so the results of Panel ADF and Group ADF are reliable. At a significance level of 5%, the hypothesis of no cointegration relationship is rejected. Therefore, there is a long-term co-integration relationship between housing prices and selected indicators.

Chapter 6: Results

6.1 Empirical analysis

This chapter conducts a quantitative analysis on sample data of 5 Asian emerging markets. The basic results of econometric regression are shown in the following table.

Table 6-1 Regression Table I

Panel A: Regression Model						
lnRHPI	(1)	(2) CHN	(3) HKG	(4) KOR	(5) SGP	(6) THA
OLD	-0.0457**	-0.002**	-0.298***	-0.009	-0.023**	-0.032*
	(-3.39)	(-2.06)	(-3.41)	(-0.58)	(-2.25)	(-2.03)
YOUNG	-0.044***	-0.009	-0.21*	-0.006	-0.07***	-0.01
	(-5.58)	(-0.12)	(-2.03)	(-0.27)	(-3.08)	(-1.26)
lnGDPP	0.174***	0.546***	0.686	0.649*	0.156***	0.549**
	(4.06)	(5.57)	(1.2)	(1.91)	(4.38)	(2.56)
MS	0.0964*	0.003	0.613**	0.101	0.05	0.283**
	(1.889)	(0.07)	(2.77)	(0.89)	(0.18)	(2.40)
RATE	-0.004	-0.005**	-0.005	-0.005	-0.006	-0.003
	(-0.43)	(-2.65)	(-0.25)	(-0.63)	(-0.82)	(-0.77)
UN	-0.083***	-0.037*	-0.251***	-0.44*	-0.091***	-0.054
	(-4.30)	(-2.15)	(-3.24)	(-2.02)	(-5.21)	(-1.60)
Constant	7.324***	-0.316	34.206	-1.907	8.05	-0.988
	(11.82)	(-0.08)	(1.41)	(-0.49)	(1.66)	(-0.33)
Observations	112	12	29	24	20	27
R-squared	0.7563	0.997	0.875	0.969	0.965	0.976
Panel B: Error Correction Model						
D(lnRHPI)	(1)	(2) CHN	(3) HKG	(4) KOR	(5) SGP	(6) THA
D(lnRHPI) (-1)		0.098	0.206	0.586***	0.198	0.281**
		(0.12)	(1.42)	(3.39)	(1.21)	(2.22)
D(OLD)		-0.003*	-0.087*	-0.004	-0.04**	-0.029**
		(-2.06)	(-2.11)	(-0.11)	(-2.99)	(-2.21)
ECM (-1)		-0.298	-0.327*	-0.565***	-0.95*	-1.072***
		(-0.60)	(-1.97)	(-4.09)	(-1.76)	(-6.06)
Observations		10	26	23	19	24
R-squared		0.5780	0.6922	0.7247	0.8228	0.7857

t-statistics in parentheses *** p<0.01, ** p<0.05, * p<0.1

The impacts of the old dependency ratio, youth dependency ratio, and real GDP per capita on the housing price index are the same as the theoretical model. The empirical results confirm that the increase in both the old dependency ratio and youth dependency ratio will indeed cause a decline in the housing price index, while the increase in real GDP per capita will promote the housing price index. A rise in the one-year real interest rate will significantly reduce the housing price index; M2/GDP is positively correlated with the housing price index, and the unemployment rate is negatively correlated with it. From the regression coefficients and symbols of the specific variables, the following results can be drawn:

(1) Old dependency ratio is significantly negatively correlated with the housing price index, for every 1% increase in the old dependency ratio, the housing price index decreases by 4.6%. This is in line with proposition 2 and matches the previous prediction. In terms of housing demand, the elderly has a lower need, and there is almost no willingness to buy houses. From the perspective of supply, the elderly will eventually choose to sell their houses or bequeath them to the next generation, which increases the supply of the housing market to a certain extent. Therefore, aging significantly affects the housing price in terms of reducing demand and increasing supply. According to Xu's research (2012), in 16 OECD countries where population aging is serious, the old dependency ratio also has a great negative impact on housing prices.
(2) Youth dependency ratio is significantly negatively correlated with the housing price index. The decline in the youth dependency ratio allows families to invest more money for housing consumption, thus pushing up housing prices.
(3) There is a significant positive correlation between real GDP per capita and the housing price index, which is consistent with proposition 3. The increase in real GDP per capita represents a better economic development, and residents may have a higher income for housing consumption, thus promoting housing prices.
(4) The real interest rate is negatively related to housing prices. An increasing interest rate means a rise in capital value. People are more willing to deposit on the one hand and reduce borrowing on the other. Therefore, there is less governable money, leading to a decrease in the housing price index.
(5) The degree of economic monetization (*MS*) is significantly related to the housing price index, and the correlation coefficient is larger, 0.0964, indicating that the higher the degree of monetization, the higher the housing price will be affected by it. Currency is not only a transaction medium, but also a tool for storing value. With the growth of M2/GDP, real estate can resist inflation and achieve the function of maintaining and appreciating residents' wealth. Therefore, housing has become one of the residents' targets for investment and financial management, and their demands for housing expand. The excess supply of money and the high degree of monetization have a greater boost to the real estate market price.
(6) The unemployment rate has a significantly negative impact on the housing price index. The rise in the unemployment rate, on the one hand, means that the demand for housing is reduced, On the other hand, people are worried about the depression and less confident in the housing market, thus leading to a fall in house prices.
According to the error correction model, the error correction coefficients in 4 countries (regions) are significant, which indicates the old dependency ratio has a significantly negative impact on the housing prices in a short term. The coefficient of China is insignificant, it may because of the small size of sample and poor fitting function.

6.2 Robustness check

In order to avoid cross-sectional correlation and heteroscedasticity problems in the regression model, as well as to verify the reliability of the model, this section does a robustness test. Here, we replace the old dependency ratio with the population aging rate, that is, the percentage of the population aged 65 and over in the total population.

Table 6-2 Regression Table II

Panel A: Regression Model						
lnRHPI	(1)	(2) CHN	(3) HKG	(4) KOR	(5) SGP	(6) THA
OVER65	-0.1248***	-0.007*	-0.5***	-0.015*	-0.031**	-0.045*
	(-3.42)	(-1.92)	(-3.57)	(-1.84)	(-2.24)	(-1.92)
YOUNG	-0.043***	-0.013	-0.169*	-0.004	-0.071***	-0.012
	(-5.08)	(-0.18)	(-1.89)	(-0.16)	(-3.16)	(-1.63)
lnGDPP	0.223***	0.567**	2.679	0.658*	0.161***	0.587**
	(4.051)	(2.57)	(1.24)	(1.93)	(4.0)	(2.68)
MS	0.0919**	0.004	0.67**	0.101	0.051	0.284**
	(2.013)	(0.09)	(2.55)	(0.89)	(0.18)	(2.38)
RATE	-0.007**	-0.005**	-0.007	0.005	-0.006	-0.003*
	(-2.29)	(-2.68)	(-0.32)	(0.62)	(-0.81)	(-1.97)
UN	-0.114***	-0.038*	-0.252***	-0.044*	-0.092***	-0.051
	(-4.27)	(-2.26)	(-3.34)	(-1.99)	(-5.23)	(-1.51)
Constant	7.264***	-0.612	32.36	-2.-83	8.162	-1.374
	(11.38)	(-0.14)	(1.41)	(-0.53)	(1.69)	(-0.46)
Observations	112	12	29	24	20	27
R-squared	0.7837	0.997	0.879	0.969	0.965	0.976

Panel B: Error Correction Model						
D(lnRHPI)	(1)	(2) CHN	(3) HKG	(4) KOR	(5) SGP	(6) THA
D(lnRHPI) (-1)		0.06	0.21	0.593***	0.198	0.287**
		(0.11)	(1.44)	(3.61)	(1.21)	(2.26)
D(OVER65)		-0.007*	-0.097*	-0.003*	-0.13**	-0.034**
		(-2.06)	(-2.32)	(-2.31)	(-3.00)	(-2.96)
ECM (-1)		-0.899	-0.313*	-0.572***	-0.949***	-1.081***
		(-0.56)	(-1.86)	(-4.18)	(-3.72)	(-6.03)
Observations		10	26	23	18	24
R-squared		0.4240	0.5336	0.7322	0.8230	0.6693

t-statistics in parentheses *** p<0.01, ** p<0.05, * p<0.1

Judging from the results of the robustness test, it is consistent with the regression results in Table 6-1. The impact of aging on housing prices is more significant. From the above analysis, no matter which indicator is used to measure population aging, the results are robust. Therefore, the following conclusion can be drawn: Population aging hurts the overall housing prices of those 5 Asian emerging markets. While controlling for other variables, the aggravated aging will lead to a drop in housing prices.

Chapter 7: Conclusions

From the perspective of the population structure, this article studies the impact of population aging on housing prices from both qualitative and quantitative aspects. We empirically study the effect of population aging on real house prices across 5 Asian emerging markets over the past 30 years. Specifically, we propose 4 hypotheses via theoretical models and empirically test whether those 5 economics with the most serious aging meet them. The conclusions are: Aging negatively affects house prices. The old dependency ratio significantly restrains the real house price index. The reasons are that the elderly population has low demand for housing; on the other hand, they will eventually choose to sell their houses or bequeath to the next generation, which increases the housing supply. So, population aging can affect the housing market from both the demand and the supply aspects. According to the United Nations' forecast (2009), starting from 2015, the old dependency ratio of Asia will rapidly rise. The ratio of Hong Kong, Korea and Singapore has already exceeded their youth dependency ratio so far, Thailand and China will occur in 2025 and 2030. By 2050 their old dependency ratios will all exceed 40%, and the highest even reach up to 73.2%, while the world level is only 26%. In the long run, this tendency and possible social issues such as multi-child in the future will cause difficulties in buying houses, the negative impact of aging may gradually deepen. The youth dependency ratio is also negatively correlated with housing prices but is not as strong as the old dependency ratio. The family will spend a lot of money on raising children, but children cannot create actual output value. A lot of family funds are occupied while the return is "long-term", which leads to a reduction in family investment and property purchasing power, so the decline in the youth dependency ratio will push up housing prices. At present, the youth dependency ratios of 5 Asian emerging markets are all in a declining channel, so the low birth rate is an important factor driving up housing prices. Besides population aging, other macro factors also affect house prices. In this paper, economic development and the increase in per capita income promote housing prices as residents have a higher income for housing consumption. In addition to basic demand, they also generate housing improvement demands which are less elastic and sensitive to prices, thus driving the rise of housing prices.

However, considering that in the cross-country sample, there are large internal differences among regions and countries. They are limited by the development level, resource endowments, and even political and cultural differences, there will be some short-term or invisible factors that affect housing prices. These factors may even be possible to change the current situation of the housing market. But from a long-term perspective, the development of population aging will significantly influence the stable operation of the housing market, which deserves our attention.

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Appendices

Appendix A Two Period Overlapping Generation Model

We establish a two period OLG model according to the life-cycle hypothesis. This model has 3 basic assumptions: first, everyone survives for two periods, young and old age, the young at *t*, and the old at *t+1*; Young people earn income from work and save for consumption in old age, while the elderly have no income, and only rely on savings from his youth; Last, savings in the model are saved through benchmark assets. Benchmark assets are identical assets that can be divided. Therefore, the consumer utility function can be written as:

$$U=ln\ (C_t^Y)+\beta ln\ (C_{t-1}^O) \quad (1)$$

Where C^Y and C^O represent the consumption in youth and in old, β is discount factor and *t* is time.

The maximum utility function is limited by budget. The sum of the consumption in youth C^Y and the present value of the old-aged consumption C^O is almost equal to the income earned in young age, S_t. So, interest rate r_t is an endogenous variable which can describe the assets value as:

$$C_t^Y+\frac{C_{t+1}^O}{1+r_t} \leq S_t^Y \quad (2)$$

In the capital market, the divisible benchmark asset unit, *A*, is traded, the price is P_t and purchase volume by the young generation is Q_t. Therefore, the budget price curve is:

$$S_t^Y=C_t^Y+P_t*Q_t \quad (3)$$

Based on the assumptions above, the consumer behavior is completely consistent, the total expenditure is equal to the total consumption. In equilibrium, an individual's saving in youth is the total assets per young man ($A*P_t/N_t^Y$). The equation (3) can be transformed to:

$$S_t^Y=C_t^Y+P_t*\frac{A}{N_t^Y} \quad (4)$$

At *t+1* period, the elder sales his asset, and his consumption depends on sale proceeds and asset value, which is:

$$C_{t-1}^O=P_{t+1}*\frac{A}{N_t^Y}=(\frac{P_{t+1}}{Pt})*(\frac{P_t*A}{N_t^Y})=(1+r_t)*(\frac{P_t*A}{N_t^Y}) \quad (5)$$

The 1st derivative of the consumer utility is:

$$\frac{1}{C_t^Y}+\frac{\beta}{C_t^Y}\frac{dC_{t+1}^O}{dC_t^Y}=0 \quad (6)$$

Take (2) into equation (6):

$$C_{t+1}^{O}=\beta(1+r_t)\,C_t^{Y} \tag{7}$$

Take (7) into equation (2):

$$C_t^{Y}=\frac{S_t^{Y}}{1+\beta} \tag{8}$$

Take (8) into equation (4):

$$S_t^{Y}(1-\frac{1}{1+\beta})=\frac{P_t*A}{N_t^{Y}} \tag{9}$$

In the same way, the t+1 period can be written as:

$$S_{t+1}^{Y}(1-\frac{1}{1+\beta})=\frac{P_{t+1}*A}{N_{t+1}^{Y}} \tag{10}$$

Combine equation (9) and (10), we get:

$$\frac{S_{t+1}^{Y}}{S_t^{Y}}=(\frac{P_{t+1}}{P_t})(\frac{N_t^{Y}}{N_{t+1}^{Y}}) \tag{11}$$

To simply this model, we introduce two basic variables, d_t represents population change rate, that is the speed of the young generation at t grow up to old at *t+1*:

$$N_{t+1}^{Y}=(1+d_t)\,N_t^{Y} \tag{12}$$

And g_t is economic growth rate,

$$S_{t+1}^{Y}=(1+g_t)\,S_t^{Y} \tag{13}$$

Therefore, equation (11) can be transformed as:

$$\frac{P_{t+1}}{P_t}=(1+d_t)\,(1+g_t) \tag{14}$$

And this equation indicates that the higher proportion of the young population with healthier conditions, the greater the assets value.

Because of the assumption that everyone survives only two periods, a young man at the last period of *t-1* will be old at *t*. the old dependency ratio can be expressed as:

$$OLD_t=\frac{N_{t-1}^{Y}}{N_t^{Y}}=\frac{N_{t-1}^{Y}}{N_{t-1}^{Y}(1+d_{t-1})}=\frac{1}{1+d_{t-1}} \tag{15}$$

From the final equation, it's clear that the old dependency ratio is negatively related to assets value. Namely, a society's assets value is low if the support burden of the elder population is high.