NBP Narodowy Bank Polski

NBP Working Paper No. 288

Population aging and housing prices: who are we calling old?

Ye Jin Heo

NBP Working Paper No. 288

Population aging and housing prices: who are we calling old?

Ye Jin Heo

Economic Research Department
Warsaw 2018

Ye Jin Heo – Graduate Institute of International and Development Studies;
yejin.heo@graduateinstitute.ch

The views expressed herein are those of the author and not necessarily those of Narodowy Bank Polski.

Published by:
Narodowy Bank Polski
Education & Publishing Department
ul. Świętokrzyska 11/21
00-919 Warszawa, Poland
www.nbp.pl

ISSN 2084-624X

© Copyright Narodowy Bank Polski 2018

Contents

Abstract

This paper empirically studies through which channel - between short expected remaining life and withdrawal from the labor market - population aging affects real house price more and how the effect can vary if old-age population is defined alternatively in a way to reflect different aspects of aging, using a panel data of OECD countries. It finds that the main driver of a negative relationship between aging and real house price comes from the later stage of life and not immediately after the age of 65 or retirement. It also shows that the effective retirement age matters more in explaining the relationship between aging and real house price than the age 65, since the share of retired population has a nonlinear effect on real house price, while the standard old-age population aged over 65 does not. When I project future real house price, the standard old-age population only predicts a further decrease in real house price as aging continues, whereas the retired population captures a positive marginal effect and leaves room for policy intervention.

Keywords: Aging, house prices, demographics

JEL Classification Codes: J11, G12, R21

1 Introduction

This paper empirically studies the relationship between real house price and population aging in 22 OECD countries. OECD countries are aging fast, and its potential negative economic effect has been much discussed in both academic and policy forums, such as in Greenspan (2003), Bloom et al. (2011), Liu and Spiegel (2011) and Yoon et al. (2014). However, there has been little discussion about whether people aged 65 or above, the most commonly used definition of old-age population, is the most suitable one for the analysis of potential economic effect of population aging, given ever-increasing life expectancy. This paper introduces alternatively defined old-age population based on different aspects of population aging and compares how their effect on real house price differs from each other.

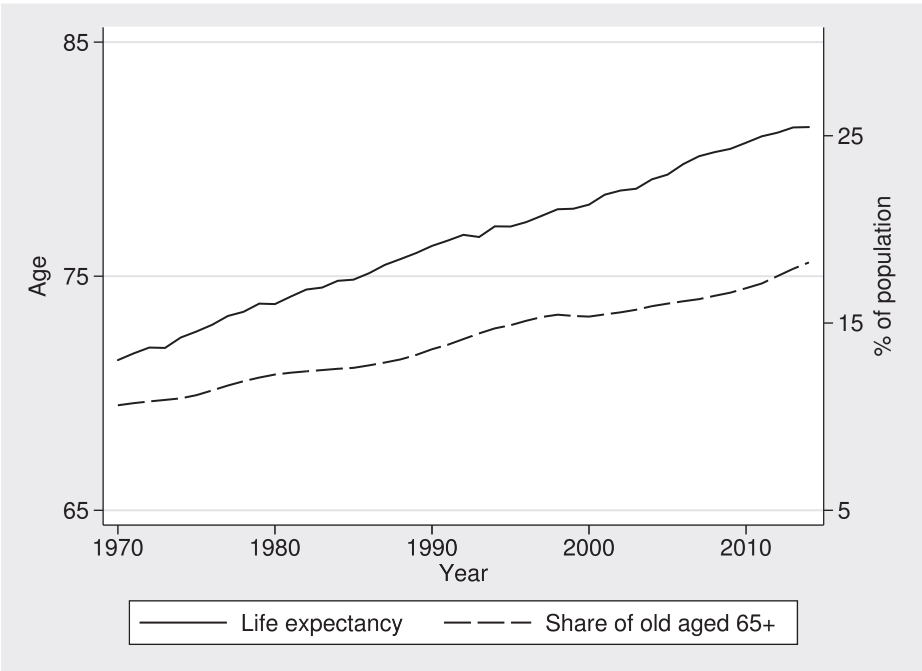


Figure 1: Median life expectancy and the share of old

Figure 1 shows how life expectancy (unit on the left axis) and the share of people aged 65 or above (unit on the right axis) had evolved between 1970 and 2014 in 22 OECD countries. Life expectancy, and therefore, the share of people aged 65 or above has been consistently increasing over time; in the beginning of the sample period, the median life expectancy is 71.4 years and the median share of standard old-age people is 10.6%, but it increased to 81.3 years and 18.2%, respectively, in 2014, which confirms that population is aging in OECD countries. However, this definition of old gives little information on how age-specific behavior within this group may have changed as life expectancy increases.

I investigate how real house price is associated with population aging by focusing on the hypothesis that two different aspects of aging - a distance to life expectancy and labor force participation - may affect housing demand of older population, which consequently also may affect real house price. Thus, this paper introduces two alternatively defined old-age population based on a distance to life expectancy and the effective retirement age.[1] Since life expectancy and the effective retirement age change over time and across countries, unlike the standard fixed age 65, the alternatively defined old-age population only includes either people whose expected remaining life is short or people who are effectively withdrawn from labor force in each year. It can be useful to define old in a country- and time-specific way since today's old people are likely to behave differently from old who lived 40 years ago, even if they are the same age, as their expected life horizon is much longer now than their counterparts.

To be specific, I first regress real house price on the share of standard old-age population as a benchmark, and then I regress real house price on the share of old defined by a distance to life expectancy and the effective retirement age, respectively. By doing so, this paper answers the following two questions: First, how does increase in the share of standard old-age population affect real house price in a panel setting? Second, how does the effect of old-age population change if old is redefined in a way to reflect different aspects of aging, namely expected remaining life and retirement?

Old-age population can negatively affect house prices through the lack of housing demand. It is likely that older people already own their home, therefore demand is weaker for them to buy a new house compared to the working-age population. Also, they may sell off a house and move to a smaller one or change to a rented house after retirement to finance consumption for the rest of their lives, if they bought a house as investment. This negative relationship between population aging and house price has been much discussed in previous studies. However, if life expectancy increases fast enough so that their expected remaining life is still relatively long even if they are retired, then older people may

[1] The effective retirement age is the average age of all persons withdrawing from the labor force in a given period, calculated by the OECD. It is explained more in detail in Section 2, where the alternative definitions of old-age population is discussed.

postpone selling their houses or even buy a house. This thought experiment suggests that the effect of old-age population on real house price may differ, depending on whether old is defined by expected remaining life or by labor force participation.

This study has three main findings. First, it provides empirical evidence that increase in the share of elderly population is negatively related to real house price: 1 percent point increase in the share of elderly population is associated with between 4% to 6% decrease in real house price, subject to the definition of old-age population. It shows that the magnitude of negative effect is largest when old is defined as people whose expected remaining life is ten years or below, which seems to suggest that the negative effect of aging on real house price is driven by the expected remaining years of life rather than retirement. Finally, it finds that explaining the relationship between aging and real house price by distinguishing adult population between "effectively" retired and those not makes more economic sense, than using the arbitrary age 65 to define old-age population: a nonlinear effect of aging on real house price is detected only when old is defined as effectively retired population.

The rest of the paper is organized as follows. Section 2 reviews the relevant literature, and Section 3 describes data and alternative definitions of old-age population. Section 4 presents the empirical strategy, results and interpretations. Section 5 estimates future real house prices in selected countries and discusses the result, and Section 6 concludes the paper.

2 Literature Review

Since the relationship between aging and the savings behavior was pioneered by Modigliani and Brumberg (1954), studies on the effect of demographic changes have been based on the life-cycle theory of savings. Although the life-cycle hypothesis predicts that agents dissave when they are old, the hypothesis is not always strongly supported by empirical evidence, especially when microeconomic data is employed (see Poterba (1994), Deaton and Paxson (1997), Hildebrand (2001), Battistin et al. (2009), Nardi et al. (2015)). In the literature of demographic effect on asset market, so-called "demographic doomsday" scenario, which predicts a large adverse effect of the aging population on the asset market, has been the subject of debates generating two opposite views in the literature: those who agree with the non-negligible negative demographic effect (for example, Mankiw and Weil (1989), Yoo (1994), Takats (2010), and Liu and Spiegel (2011)) and those who believe that demographic change is likely to bring only a limited effect, if any (for example, Poterba (2001), Abel (2003), and Davis and Li (2003)). Although the "asset-market meltdown" prediction by Mankiw and Weil (1989) in the 1990s is proved wrong, demographic effect on asset market is still a topic that has mixed views in the literature.

This study contributes to several strands of the literature. The current literature on the effect of population aging on house price has three limitations. First, commonly used measures of aging in the literature are not sufficient to examine potentially changing implications of population aging over time. By fixing the threshold age as 65, regardless of the speed of aging in each country, it explores little about heterogeneity among elderly people who are aged more than 65. Second, given the amount of studies on determinants of real house price, there is relatively less empirical work that exclusively studies the role of population aging. Third, many empirical papers look at population aging in a single-country setting, which does not incorporate possible consequences of aging that might already be happening in other fast-aging countries. This paper attempts to address each of these three points.

First of all, it introduces three different measures of old-age population. A number of papers study the relationship between demographic changes and macroeconomic variables, but most of them focus on certain "age" groups to capture population aging. For instance, Yoo (1994), Davis and Li (2003), Goyal (2004), Poterba (2004), and Brooks (2006) use the size of detailed adult age groups (i.e., population aged 25-34, 35-44, ..., 65+) or 5-year age groups (i.e. population aged 0-4, 5-9, ..., 65+), while Nishimura and

Takats (2012) uses the size of working-age population (i.e. population aged 20-64) and Bakshi and Chen (1994) uses the average age of total population. On the other hand, the old-dependency ratio, the share of old-age relative to the working-age population, is another commonly adopted measure of population aging in the literature (Ang and Maddaloni (2005), Krueger and Ludwig (2007), and Takats (2010) among others). Finally, and less frequently, the age of head of household is used in studies with survey data (Bergantino (1998) and Andrews and Sánchez (2011)). Many papers adopt multiple measures of aging, yet in most cases 65 is fixed as a threshold age that distinguishes old-age people from the rest of the adult population. This paper contributes to the literature by introducing a distance to life expectancy as well as the effective retirement age as an alternative threshold age that defines old-age population.

Second, this paper finds a significant role of old-age population, specifically the retired population, on real house price, given the conventional determinants of house price. Recent empirical studies on the determinants of house prices such as Égert and Mihaljek (2007), Rae and van den Noord (2006), Hirata et al. (2013) commonly find that real income, real interest rates, credit growth, demographics, and supply-side factors are important drivers of real house price. However, they do not explicitly consider population aging as a driver of real house price. On the other hand, using detailed adult age groups, Fortin and Leclerc (2000) shows that the population aged between 25 and 54 played an important role in real housing price in Canada and predicts that the negative effect of aging, measured by the size of population aged 65 or above, will stay limited in the future, given continuing growth in real income. Similarly, Chen et al. (2012) forecasts real house price in Scotland using six adult age-bands (i.e. population aged 25-34, ..., 65-74, 75+), and concludes that demographic change is not an important determinant of house price. Takáts (2012) is a recent empirical works on aging and house prices in a global context. Using the old-dependency ratio, it finds that population aging will negatively affect real house prices in OECD countries, although the asset price meltdown is unlikely to happen. Consistent with existing studies, this paper predicts a considerable decrease in real house price in OECD countries associated with increasing share of population aged 65 or above. However, it also shows that real house price does not necessarily decrease significantly, if old is defined as effectively retired people.

Lastly, this paper considers a high degree of heterogeneity in population aging among OECD countries by including Japan and Korea, who are the fastest-aging countries in the world, in the sample. A number of empirical papers study the effect of aging in a single country, while only a few papers conduct an international analysis. Andrews and Sánchez (2011) examines the relationship between population aging and homeownership in OECD countries, but they do not include Japan whose population aging is faster than any other country. In this paper, I use a country-specific threshold age to define old-age population so that the analysis can deal with cross-sectional heterogeneity caused by a different pace of population aging.

3 Data and Measurement

3.1 Data Sources

I build a panel dataset of 22 advanced OECD countries - Australia, Austria, Belgium, Canada, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Japan, Korea, Netherlands, New Zealand, Norway, Portugal, Spain, Sweden, Switzerland, United Kingdom, United States - for the periods between 1970 and 2014. The main variables can be grouped into four categories: house prices, demographics, employment, and other standard macroeconomic variables.

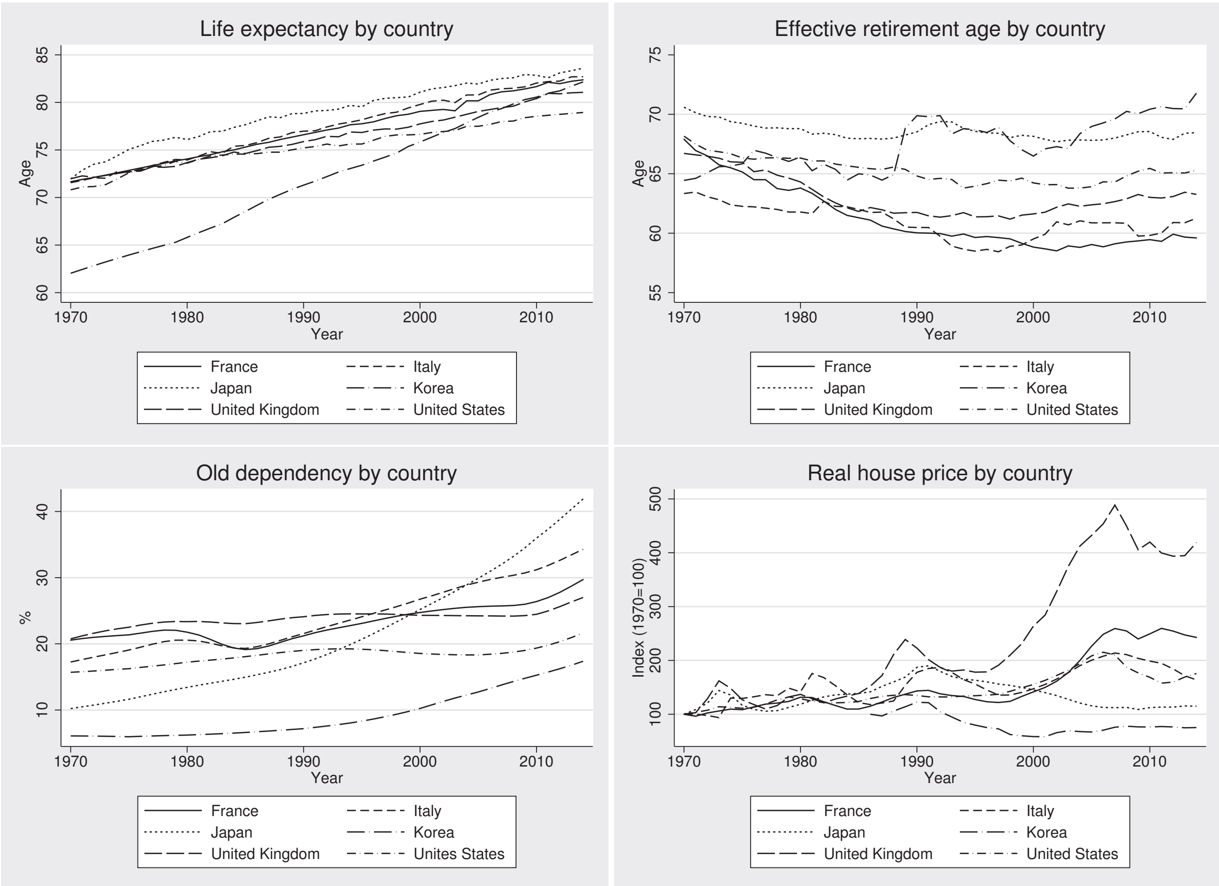
Housing market data is from the OECD House Prices Indicators, in which I use nominal house price index and real house price index. Life expectancy at birth, fertility rate, population density and the old-dependency ratio are from the World Bank World Development Indicators (WDI). Population by single year of age for European countries is obtained from Eurostat, which provides population data from age 0 to over 100. For non-European countries, I interpolate population of 5-year age group from the UN Population Division to calculate the single year of age population, following Beer's methodology introduced in NCHS (1999).[2]

To account for the effect of retirement on housing demand, I use the average effective retirement age from the OECD Ageing and Employment Policies. The conventional macroeconomic determinants of house prices such as GDP per capita, 10-year government bond rate, current account balance, and construction cost are obtained from various sources including the WDI, the International Financial Statistics, the Jordà-Schularick-Taylor dataset, the OECD, and national statistics departments. Nominal values are all transformed into real terms using the Consumer Price Index (2010 = 100) from the OECD.

Figure 2 shows the development of demographic factors as well as real house prices between 1970 and 2014 in 22 OECD countries in the sample. A high level of heterogeneity is present across countries, especially in old-age dependency ratio, the average effective retirement age, and real house price. The obvious and commonly observed trend in the figure is that the old dependency ratio as well as life expectancy have been increasing over time. The evolution of the effective retirement age and real house price apparently varies wildly across regions: Japan and Korea have a higher effective retirement age with

[2]In order to minimize any artificial changes in the size of population, I do not combine population data of a country from different sources. Detailed steps of the interpolation are described in appendix.

Figure 2: Demographic changes and real house price in selected OECD countries



relatively lower real house price than other countries, while European countries have a lower effective retirement age with a boom in real house price in a recent decade.

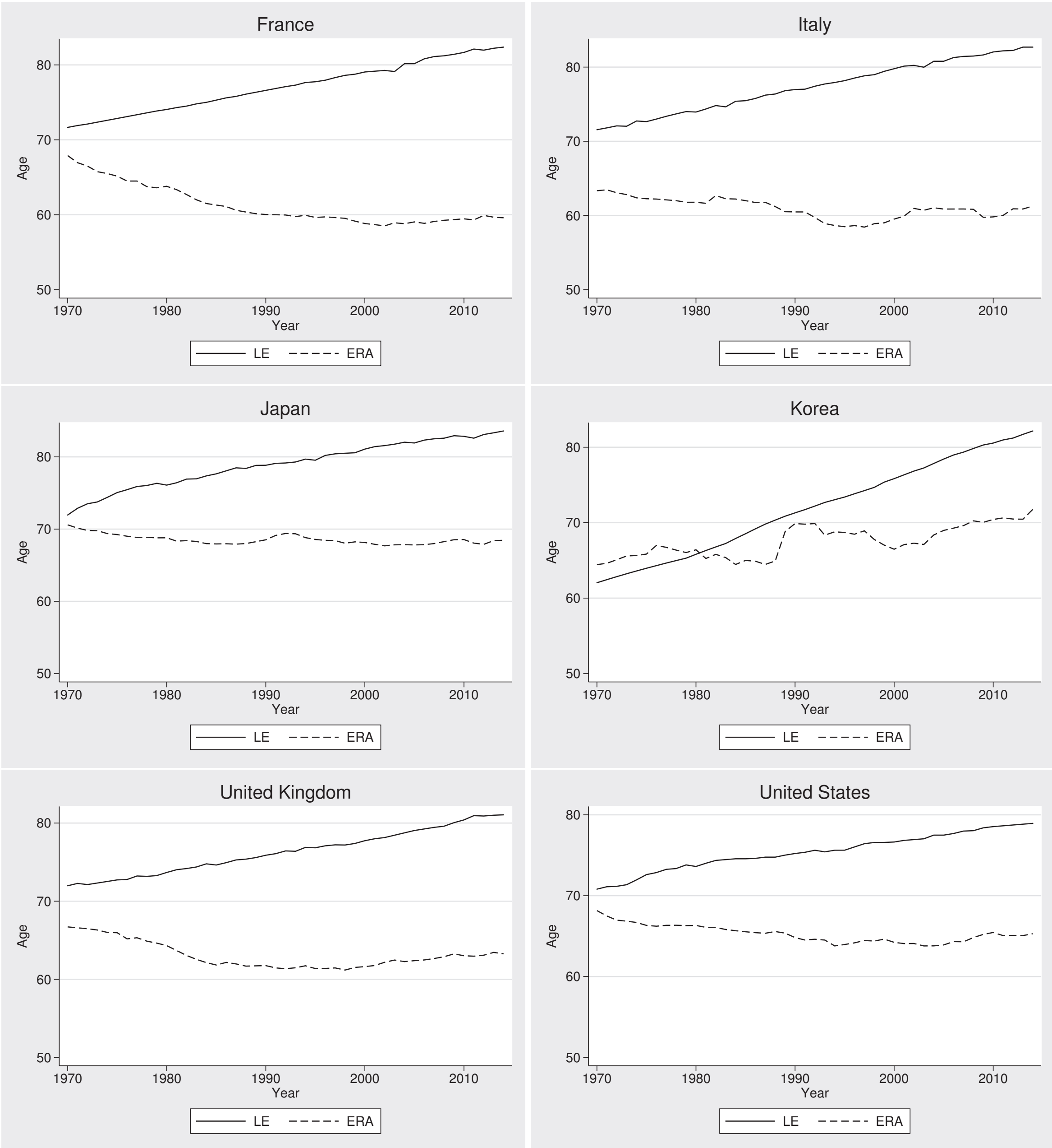
3.2 Measures of Population Aging

In the literature, population aging is often measured by an increase in the share of old-age population out of either total population or the working-age population, in which the threshold age to distinguish old from the rest of adult population is typically fixed as 65. Therefore, the standard measures essentially capture the accumulated stock of elderly people who are aged over 65. Although these measures are useful to account for changes in longevity, they do not allow a possibility that increased life horizon may generate different consumption behaviors within the group aged over 65.

Figure 3 shows that there has been an increasing gap between retirement age and life expectancy in all OECD countries. In most countries, the effective retirement age has little increased over time, if not decreased. Therefore, unlike in the 1970s, retirement now does not mean reaching life expectancy in a few years; rather, there is a substantive size of retired population who still has relatively long expected remaining life. Given these observations, I redefine old in two ways; first, old-age population is considered as people who have a short distance to life expectancy, and second, old-age population is the adult population who is withdrawn from the labor force. By comparing these two measures along with the benchmark measure, I try to identify which of two channels of population aging - short expected remaining life or withdrawal from the labor market - matters more to real house prices.

I start with the standard representation of three age groups, young, middle, and old, and later I introduce a finer representation of old-age groups, which specify subgroups of elderly population. The general form of the standard age groups is as follows:

Figure 3: Life expectancy at birth and the effective retirement age in selected countries



$$Y^{0-19}(\%) = \left(\frac{\sum_{i=0}^{19} age_i}{\text{Total population}} \right) \times 100 \tag{1}$$

$$M^{20-(\delta-1)}(\%) = \left(\frac{\sum_{i=20}^{(\delta-1)} age_i}{\text{Total population}} \right) \times 100$$

$$O^{\delta+}(\%) = \left(\frac{\sum_{i=\delta}^{\infty} age_i}{\text{Total population}} \right) \times 100$$

in which age_i is the number of people whose age is i, and δ is a threshold age that separates old-age population from the rest of adult population. In the benchmark case δ is 65. Young age group (Y^{0-19}), the share of population aged between 0 and 19, is the only group that is not affected by a threshold age.

In the first alternative definition of old, δ is life expectancy minus ten. This measure of aging investigates whether a distance to life expectancy plays a significant role in housing demand by older population. By exclusively capturing the size of people who have maximum ten years of expected remaining life in any country and year, it tries to account for the fact that the behavior of people aged over 65 in different time periods may not be necessarily the same when their expected life horizon differs. For instance, life expectancy in Korea was 67.9 in 1984, but it surged to 82.15 in 2014, therefore, 65 years old Korean today has much longer life horizon than the one would have 30 years ago, which suggests that his or her consumption behavior is also likely to have changed during the past three decades.

δ in the second alternative definition is the effective retirement age, which is the sum of each year of age 40 and over, weighted by the proportion of all withdrawals from the labor force occurring at that year of age.[3] The effective retirement age is different from the official retirement age in the sense that it captures when the labor force participation actually ceases on average by the older adult population. Depending on various social and economic factors, such as wealth, health, education, social security and pension scheme,

[3] A detailed explanation on the method for calculating the effective retirement age is available at http://www.oecd.org/els/emp/39371923.pdf

the effective retirement age can be lower or higher than the official retirement age, and it also can change every year. Thus, the second definition of old focuses on to what extent labor force participation that already accounts for economic and social factors affects housing demand by older population.

Figure 4: The share of old-age populations in selected countries

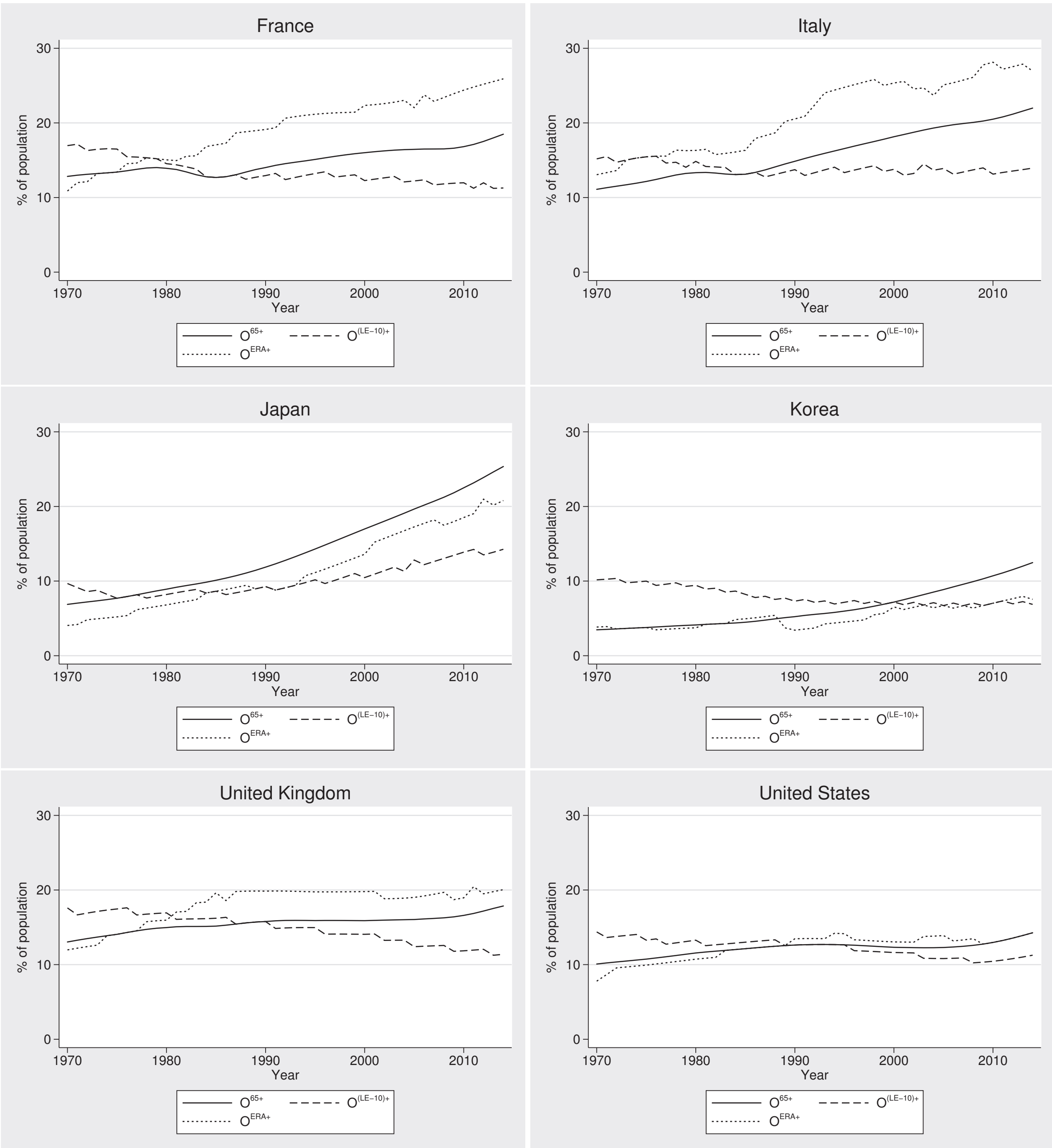


Figure 4 presents the share of three different elderly groups in selected countries in the sample. The solid line represents the share of people aged 65 or above, the benchmark case, while the dashed line and the dotted line represent people who have maximum ten years of expected remaining life and people who are effectively out of the labor market, respectively. Overall, the solid line and the dotted line move closely to each other; the share of population aged 65 or above has significantly increased over time and so does the share of retired population. However, in most countries except Japan and Korea, the share of retired population is larger than that of the standard old-age population, which indicates that people withdraw from the labor market before they reach age 65.

To study a finer effect of population aging, I further introduce two subgroups of elderly population - relatively less old (O_-) and very old (O_+), by setting a second threshold age δ' which ranges between the first threshold age and life expectancy. δ' is not applied to the standard old-age population, however, because in some observations life expectancy is lower than age 65. For the alternative cases, δ' is life expectancy minus five, and the mean between the effective retirement age and life expectancy, respectively. The general expressions of O_- and O_+ are as follows:

$$O_-^{\delta-(\delta'-1)}(\%) = \left(\frac{\sum_{i=\delta}^{(\delta'-1)} age_i}{\text{Total population}} \right) \times 100 \tag{2}$$

$$O_+^{\delta'+}(\%) = \left(\frac{\sum_{i=\delta'}^{\infty} age_i}{\text{Total population}} \right) \times 100$$

in which δ' is defined such that

$$\delta' = \text{life expectancy} - 5 \tag{3}$$

when δ is life expectancy minus ten, and

$$\delta' = \frac{\delta + \text{life expectancy}}{2} \tag{4}$$

when δ is the effective retirement age.

Table 1 provides summary statistics of the main variables based on the observations in the regressions described in Section 4. From the original dataset that covers 45 years of 22 countries, I use five-year interval data as population census is typically conducted in five-year interval. Also, I use a balanced-sample for each regression to compare the effect of the alternatively defined old-age populations, therefore any observations lacking life expectancy and/or the effective retirement age are excluded from the regressions, which results in 125 observations. On average, the share of elderly population defined by life expectancy (δ = LE-10) is about 2.5% lower than the share of elderly defined in a standard way (δ = 65), while the share of elderly defined by the effective retirement age (δ = ERA) is 2.5% higher than that. The effectively retired population is the most heterogenous group across countries; the maximum share of retired population is 27.7%, whereas the minimum is 5.2% of total population. In both alternative measures of old, the share of very old people (O_+) is at least 3% larger than that of relatively less old people (O_-). It can be partially explained by the fact that I include people outlive the life expectancy in O_+.

Table 1: Summary statistics

Variable	Mean	Std. Dev.	Min.	Max.	N
Real house price index (log)	4.31	0.35	3.23	5.01	125
Real GDP per capita (log)	10.44	0.39	9.00	11.39	172
Real construction cost (log)	4.53	0.10	4.15	4.72	125
Current account balance (%)	0.19	4.32	-12.36	13.86	125
Population density (log)	4.12	1.45	0.90	6.24	125
O (δ = 65) (%)	14.88	2.88	7.69	22.21	125
O (δ = LE-10) (%)	12.43	2.43	7.01	17.30	125
O- (δ' = LE-5)	4.13	0.72	2.67	5.98	125
O+ (δ' = LE-5)	8.30	1.83	3.95	11.77	125
O (δ = ERA) (%)	17.26	4.73	5.22	27.72	125
O- (δ' = (ERA+LE)/2)	7.02	2.57	1.04	13.30	125
O+ (δ' = (ERA+LE)/2)	10.23	2.50	3.89	14.99	125

4 Empirical Analysis

4.1 Empirical Strategy

The main econometric method employed in this study is a panel two-way fixed effect model, which removes country- and year-specific unobserved characteristics to account for possible omitted variable bias.[4] To examine the potential channels through which population aging affects real house price, I repeat the analysis using three alternatively defined old-age populations one by one.[5] The general expression of the regression model has the following form:

$$RHP_{it} = \beta_0 + \beta_1 M_{it}^{20-(\delta-1)} + \beta_2 O_{it}^{\delta+} + \gamma \mathbf{X_{it}} + \phi_\mathbf{i} + \eta_\mathbf{t} + \varepsilon_\mathbf{it} \tag{5}$$

in which RHP_{it} represents the the log of real house price index, and M_{it} and O_{it} are middle and old-age populations, respectively, expressed as a share of total population (%). As discussed in the previous section, three values - 65, life expectancy minus ten, and the effective retirement age - are assigned to δ. β_1 captures the effect of middle-age group (aged from 20 to δ-1) on real house prices and the expected sign is positive since the working-age population has demand for housing, whereas β_2 represents that of the old-age population (aged from δ and over) and the expected sign is negative. By changing the value of δ, I compare the sign and magnitude of β_1 an β_2 in each regression result. $\mathbf{X_{it}}$ is a set of standard explanatory variables for real house price that have been documented in the literature. It includes the following variables:

- Real GDP per capita: As a consumption good, demand for housing is supposed to increase as income per person increases. It also captures the effect of business cycle fluctuations on house price. The expected sign of a coefficient is positive.

- Real cost of construction for residential buildings: The cost covers labor, transport, and material costs, and it accounts for the supply side of housing market. Since

[4] I do not pursue first-difference model as a baseline estimation since the demographic variables are very slow-moving, which can leave little variation if they were first-differenced. Nevertheless, results from the first-difference model are reported in Section 4.3.3 as a robustness check.

[5] Although it would be nice if the effect of different channels of aging can be simultaneously compared in the same regression, given that the number of observation is small (125) and the model employs the fixed effects as well, I only keep essential explanatory variables in the regression to avoid biased results.

it is hard to de-trend real house price, which has been consistently increasing in some countries, including the construction cost in the regression aims to capture slow technological growth which has contributed to increasing house price. The expected sign of a coefficient is positive.

- Population density: People per square kilometer of land area is included. It captures both a change in total population and the land availability. The share of urban population as well as population growth are also used for robustness checks. The expected sign of a coefficient is positive.
- Current account as a share of GDP: Existing studies such as Ferrero (2015) and Adam et al. (2012) show that current account deficit is a fundamental that is closely related to a house price boom. The expected sign of a coefficient is negative.

Additionally, I include country fixed effect (ϕ_i) and year fixed effect (η_t) to account for country- and year-specific unobserved characteristics.

As a second step, two subgroups of the old-age population - relatively less old population (O_{-it}) and very old population (O_{+it}) - are included in the regression model:

$$RHP_{it} = \beta_0 + \beta_1 M_{it}^{20-(\delta-1)} + \beta_2 O_{-it}^{\delta-(\delta'-1)} + \beta_3 O_{+it}^{\delta'+} + \gamma \mathbf{X_{it}} + \phi_\mathbf{i} + \eta_\mathbf{t} + \varepsilon_\mathbf{it} \quad (6)$$

in which δ is the same threshold age as those in equation (5), and δ' is the second threshold age described in equations (3) and (4). Although the sign of β_2 and β_3 are both expected to be negative, possibly different magnitude of the coefficients can suggest which stage of old - immediately after entering the old group or at the end of expected life - affects more their demand of housing.

Lastly, given that the speed of aging varies among the OECD countries, I test whether there is any nonlinear effect of aging on real house prices by including the quadratic term of the old-age population:

$$RHP_{it} = \beta_0 + \beta_1 M_{it}^{20-(\delta-1)} + \beta_2 O_{it}^{\delta+} + \beta_3 {O^{\delta+}}_{it}^{2} + \gamma \mathbf{X_{it}} + \phi_\mathbf{i} + \eta_\mathbf{t} + \varepsilon_\mathbf{it} \quad (7)$$

$$RHP_{it} = \beta_0 + \beta_1 M_{it}^{20-(\delta-1)} + \beta_2 O_{-\,it}^{\,\delta-(\delta'-1)} + \beta_3 O_{+\,it}^{\,\delta'+} + \beta_4 {O_{-}^{\delta-(\delta'-1)}}^2_{it} + \beta_5 {O_{+}^{\delta'+}}^2_{it} + \gamma \mathbf{X_{it}} + \phi_\mathbf{i} + \eta_\mathbf{t} + \varepsilon_\mathbf{it} \quad (8)$$

These specifications investigate how the marginal effect of the old-age population on real house prices changes when the share of old becomes larger than a certain threshold. If the sign of β_2 and β_3 are different from each other in equation (7), it means the size of old group has a nonlinear effect on house prices. This nonlinearity test will be also done on the sub-groups of old-age population as presented in equation (8).

4.2 Results

Before turning to the main regression analysis, I start by running the regression model in Takats (2010), which examines the relationship between the standard old dependency ratio and real house price in OECD countries, considering real GDP per capita and total population. For a comparison purpose, I use log-differenced variables in five-year interval data with year fixed effects as in Takats (2010).

Results are presented in Table 2 in which δ is the threshold age used in each regression.[6] Column (1) uses the old dependency ratio defined in a standard way, and all the explanatory variables show the expected sign with the coefficients significant at 1 percent level, which is comparable and consistent with Takats (2010). When the old dependency ratio is defined by the ratio between effectively retired population and the working age population in column (3), although it still shows a significantly negative coefficient, the magnitude of the coefficient is much smaller than in column (1).[7] However, the coefficient for the old dependency ratio in column (2) is not statistically different from zero. Given that the regression is based on the first-differenced variables, the reason could be that the share of population who has maximum ten years of expected life generally has not changed much over time in sample countries, as shown in Figure 3, therefore the differ-

[6] This study covers a longer period than in Takats (2010), but ends up with a smaller number of observation since it focuses on the observations that have information both on life expectancy and the average effective retirement age, which is not always available for some countries.

[7] The working age population here is the population aged between 20 and the effective retirement age minus one.

Table 2: Regression model in Takats (2010)

	(1)	(2)	(3)
	δ = 65	δ = LE-10	δ = ERA
Real GDP per capita	1.185***	1.177***	1.081***
	(0.219)	(0.228)	(0.226)
Total population	1.267*	1.952***	1.660**
	(0.658)	(0.699)	(0.657)
Old-age dependency	-0.958***	0.188	-0.332**
	(0.273)	(0.239)	(0.136)
Constant	-0.0501	-0.119**	-0.0534
	(0.0544)	(0.0531)	(0.0594)
Observations	154	154	154
Number of countries	22	22	22
R^2	0.524	0.535	0.522

Standard errors in parentheses.
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Notes: LE stands for life expectancy, and ERA stands for the effective retirement age.

enced variable may contain little explanatory power, which ends up with the insignificant coefficient. Nonetheless, the comparison between column (1) and (3) suggests that the definition of old age population matters in estimating the negative relationship between demographic change and real house prices.

Now, I turn to the main regression models of this paper, equations (5)-(8). Unlike the regression model in Takats (2010), this regression model uses variables in level in five-year interval data and includes both country and year fixed effects, instead of first-differencing. Since real house price is expressed in logarithm, the coefficient for the age variables is interpreted as % change of real house price by 1 percent point increase in the age group variables.

Table 3 shows that the non-demographic explanatory variables overall show the expected sign, and among them real GDP per capita and current account are significant in all specifications. In panel A, in which the result of linear regression model reported, the coefficient for old-age population is negative in all columns. Therefore, a higher share of elderly population is associated with lower real house price no matter how the elderly population is defined. There can be three possible explanations on this; firstly, as elderly owners approach to life expectancy, housing supply naturally increases because real estates go back to a market, secondly, elderly people no longer purchase a house because it

Table 3: Effect of population aging on real house prices

	(1)	(2)	(3)	(4)	(5)
	δ = 65	δ = LE-10		δ = ERA	
Panel A. Linear effect			δ' = LE-5		δ' = (ERA+LE)/2
Real GDP per capita	1.272***	1.454***	1.456***	1.359***	1.356***
	(0.267)	(0.308)	(0.312)	(0.294)	(0.242)
Real construction cost	0.436*	0.416**	0.424**	0.599**	0.377
	(0.214)	(0.190)	(0.194)	(0.220)	(0.240)
Current account	-0.0161*	-0.0182**	-0.0181**	-0.0197*	-0.0219**
	(0.00794)	(0.00793)	(0.00793)	(0.00989)	(0.00909)
Population density	-0.0976	0.271	0.278	0.257	-0.0334
	(0.697)	(0.693)	(0.696)	(0.673)	(0.694)
M	0.0401*	0.0177	0.0171	-0.00383	0.00459
	(0.0229)	(0.0218)	(0.0229)	(0.0253)	(0.0241)
O	-0.0430***	-0.0571**		-0.0246	
	(0.0138)	(0.0210)		(0.0252)	
O-			-0.0454		0.00600
			(0.0322)		(0.0213)
O+			-0.0625**		-0.0625*
			(0.0274)		(0.0354)
Constant	-12.17***	-13.75***	-13.81***	-12.90***	-11.01***
	(3.151)	(3.434)	(3.404)	(3.571)	(3.527)
Observations	125	125	125	125	125
Number of countries	22	22	22	22	22
R^2	0.830	0.816	0.816	0.789	0.801
Panel B. Nonlinear effect					
O	0.00159	-0.0309		-0.111***	
	(0.0702)	(0.129)		(0.0382)	
O^2	-0.00155	-0.00103		0.00257**	
	(0.00242)	(0.00435)		(0.000966)	
O-			0.187		-0.0461
			(0.228)		(0.0452)
O+			-0.0440		-0.167**
			(0.140)		(0.0743)
$O\text{-}^2$			-0.0277		0.00365
			(0.0285)		(0.00284)
$O+^2$			-0.000950		0.00545
			(0.00691)		(0.00319)
Constant	-10.53***	-14.04***	-14.97***	-16.38***	-13.88***
	(3.421)	(3.309)	(3.228)	(3.792)	(3.732)
Observations	125	125	125	125	125
Number of countries	22	22	22	22	22
R^2	0.831	0.816	0.817	0.813	0.820

Robust standard errors, clustered at country-level, are in parentheses.
$^{*}\ p < 0.1$, $^{**}\ p < 0.05$, $^{***}\ p < 0.01$

is likely that they already own their house, and finally, elderly people may sell their house and change to a rented one (or a smaller one) after retirement to finance their consumption. Another finding in Table 3 is that the magnitude of the coefficient for the old defined by a distance to life expectancy is significantly larger that that of the ones by the standard threshold age 65 and the effective retirement age. When I use a finer definition of old-age population by introducing second threshold ages in columns (3) and (5), the older elderly population (O_+) shows a significantly negative coefficient. Thus, these results overall suggest that the negative relationship between the share of old and real house price is more driven by a distance to life expectancy rather than retirement per se. Meanwhile, the middle age group, who traditionally is considered as home buyers who positively affect house prices, does not turn out to significantly affect real house price in any columns.

Panel B of Table 3 tests the existence of nonlinear relationship between old-age population and real house prices. Interestingly, nonlinearity is only detected in column (4), in which the old is defined as people completely withdraw from labor force; therefore, as the share of retired people increases, there is a net positive effect on real house prices. The result reflects the fact that retired population is the most heterogenous group in the sample; people retire relatively early in European countries, while that is the opposite in East Asian countries. Increase in the share of retired population can mean two things; 1) either a certain cohort whose absolute size is large starts to retire (i.e. retirement of the baby boom generation), or 2) the duration of life after retirement is increased due to extended life span and/or early retirement. One of the possible interpretations of the nonlinear effect is that if the share of retired population becomes large enough, either they simply do not sell their houses as they still have many years to live or they even have demand for houses for various purposes. The marginal effect of retired population on real house price, keeping all the other explanatory variables constant, is visualized in Figure 5; real house price continues to decrease until the effectively retired population reaches around 23% of total population, and then it starts to increase again.

Overall, the results suggest that increase in the share of elderly population is negatively associated with real house prices, and the negative relationship is more determined by a distance to life expectancy rather than retirement. Thus, being retired itself brings a smaller and smaller negative effect on real house price, given ever increasing life expectancy. Furthermore, it finds the evidence that there is a positive pressure on real house price as the share of retired population reaches a certain threshold. Therefore, the results imply that effectively retired population matters more to explain real house price than

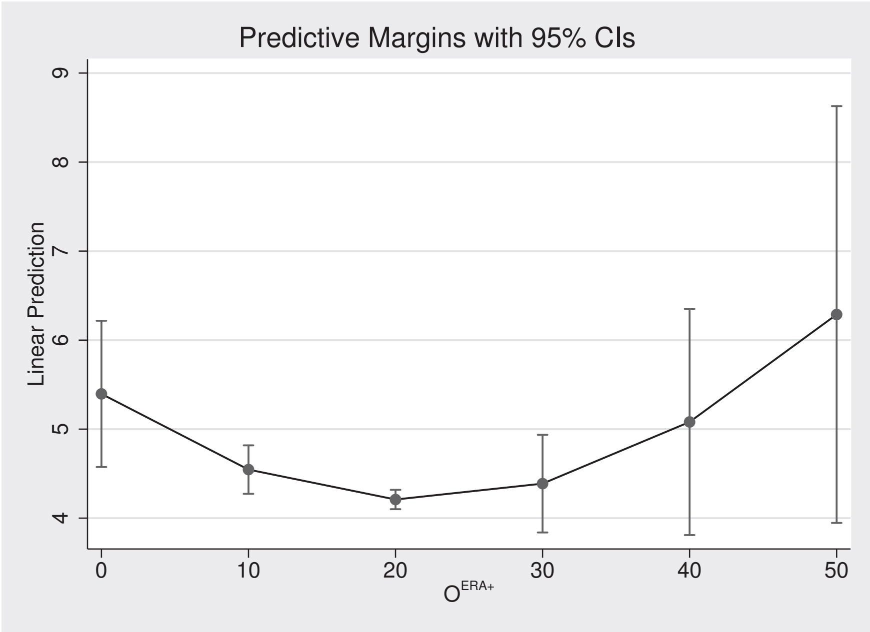


Figure 5: Marginal effect of retired population on real house price

population simply aged over 65.

4.3 Robustness Checks

In this section, I conduct a series of checks to confirm the robustness of the different magnitude of the negative effect of population aging on housing prices, depending on the definition of old.

4.3.1 Robustness to alternative population measures

I first examine whether the results survive when alternative population measures are used. An increase in total population triggers housing demand, thus leads to an increase in real house prices. To the extent that change in total population is considered, real house price will be affected, regardless of aging. Instead of population density used in the main analysis, I alternatively use the share of urban population and total population for robustness check. In both specifications, old-age population defined by a distance to life expectancy explains the largest part of a decrease in real house prices in the linear model, and the share of retired population shows evidence of the nonlinear effect on real house price.

Table 4: Robustness check: alternative population variables

Panel A. Linear effect	(1) δ = 65	(2) δ = LE-10	(3) δ = ERA	(4) δ = 65	(5) δ = LE-10	(6) δ = ERA
Real GDP per capita	1.337***	1.572***	1.556***	1.262***	1.436***	1.344***
	(0.250)	(0.284)	(0.320)	(0.269)	(0.314)	(0.294)
Real construction cost	0.365	0.282	0.392	0.449*	0.428**	0.620**
	(0.259)	(0.233)	(0.265)	(0.218)	(0.190)	(0.226)
Current account	-0.0146	-0.0185*	-0.0188*	-0.0157*	-0.0179**	-0.0190*
	(0.00967)	(0.00927)	(0.0105)	(0.00819)	(0.00811)	(0.0101)
Urban population	-0.0118	-0.0133	-0.0211			
	(0.0150)	(0.0139)	(0.0183)			
Total population				-0.0342	0.354	0.381
				(0.690)	(0.690)	(0.645)
M	0.0341	0.00999	-0.0119	0.0403*	0.0181	-0.00356
	(0.0239)	(0.0239)	(0.0254)	(0.0231)	(0.0220)	(0.0252)
O	-0.0401**	-0.0557***	-0.0258	-0.0422***	-0.0560**	-0.0230
	(0.0182)	(0.0186)	(0.0232)	(0.0145)	(0.0209)	(0.0249)
Constant	-11.72***	-11.88***	-10.92**	-11.97	-18.54*	-18.26*
	(3.074)	(3.555)	(3.979)	(10.43)	(10.36)	(9.668)
Observations	125	125	125	125	125	125
Number of countries	22	22	22	22	22	22
R^2	0.833	0.819	0.800	0.830	0.816	0.789

Panel B. Nonlinear effect						
O	-0.0140	-0.0539	-0.0942**	-0.00236	-0.0203	-0.110***
	(0.0469)	(0.117)	(0.0406)	(0.0717)	(0.133)	(0.0367)
O^2	-0.000851	-0.0000727	0.00186*	-0.00139	-0.00140	0.00258**
	(0.00171)	(0.00408)	(0.000956)	(0.00249)	(0.00451)	(0.000935)
Constant	-11.26***	-11.89***	-12.33***	-7.789	-19.73*	-27.48**
	(3.280)	(3.646)	(3.824)	(13.26)	(10.09)	(10.97)
Standard explanatory variables	Yes	Yes	Yes	Yes	Yes	Yes
Observations	125	125	125	125	125	125
Number of countries	22	22	22	22	22	22
R^2	0.834	0.819	0.811	0.830	0.816	0.814

Robust standard errors, clustered at country-level, are in parentheses.

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

4.3.2 Robustness to old-age dependency ratio

Since the old-dependency ratio is one of the most frequently used measures of population aging in academic literature as well as in policy discussions, here I use the old-dependency ratio, instead of the share of middle and old age groups. Similar to the main analysis, the working-age population is defined as the population ages between 15 and δ - 1. Consistent with the baseline results, the negative relationship seems to be driven by elderly people who have relatively shorter expected remaining life, and the nonlinear effect of old-age population is only significant when the threshold age for old is the effective retirement age.

Table 5: Robustness check: old-age dependency ratio

	(1)	(2)	(3)	(4)	(5)
Panel A. Linear effect	δ = 65	δ = LE-10	δ = LE-5	δ = ERA	δ = (ERA+LE)/2
Real GDP per capita	1.408***	1.517***	1.501***	1.318***	1.343***
	(0.323)	(0.366)	(0.378)	(0.356)	(0.327)
Real construction cost	0.365	0.408*	0.500**	0.711**	0.401
	(0.249)	(0.230)	(0.214)	(0.290)	(0.271)
Current account	-0.0207**	-0.0185**	-0.0179**	-0.0170*	-0.0214**
	(0.00797)	(0.00812)	(0.00859)	(0.00960)	(0.00930)
Population density	-0.180	0.319	0.376	0.461	0.0546
	(0.756)	(0.791)	(0.772)	(0.761)	(0.746)
Old-age dependency	-0.0316***	-0.0332***	-0.0518**	-0.00742	-0.0399*
	(0.00768)	(0.00982)	(0.0188)	(0.00611)	(0.0200)
Constant	-10.47***	-13.51***	-14.12***	-14.15***	-11.09***
	(2.878)	(3.144)	(3.320)	(3.503)	(3.703)
Observations	125	125	125	125	125
Number of countries	22	22	22	22	22
R^2	0.823	0.815	0.812	0.784	0.799
Panel B. Nonlinear effect					
Old-age dependency	-0.0202	-0.0406	-0.0419	-0.0554**	-0.149***
	(0.0400)	(0.0642)	(0.110)	(0.0213)	(0.0524)
Old-age dependency^2	-0.000237	0.000163	-0.000388	0.000698**	0.00383**
	(0.000822)	(0.00125)	(0.00373)	(0.000284)	(0.00162)
Constant	-9.771**	-13.24***	-14.33***	-15.63***	-12.59***
	(3.454)	(3.173)	(3.254)	(3.786)	(4.128)
Standard explanatory variables	Yes	Yes	Yes	Yes	Yes
Observations	125	125	125	125	125
Number of countries	22	22	22	22	22
R^2	0.823	0.815	0.812	0.812	0.817

Robust standard errors, clustered at country-level, are in parentheses.
$^* p < 0.1$, $^{**} p < 0.05$, $^{***} p < 0.01$

4.3.3 Robustness to first-difference model

To account for possible nonstationarity of the variables such as real house price, real GDP per capita, and population, I repeat the estimation using first-difference model with year fixed effect in five-year interval data. It is worth emphasizing that population is a very slow moving variable, therefore first-differenced old age variables are likely to lose explanatory power especially when the old is defined as a group with ten years of expected remaining life, since there will be only a little change in the share of this group unless life expectancy and/or fertility rate change dramatically. The results are overall consistent with the baseline results. Old-age populations are both represented as a share of total population (col(1)-(3)) as well as old-dependency ratio (col(4)-(6)) in Table 6. Although old-age population based on life expectancy shows no significant effect, the retired population shows evidence of the nonlinear effect on real house price.

Table 6: Robustness check: first-difference model

	(1)	(2)	(3)	(4)	(5)	(6)
	Share of old age population			Old dependency ratio		
Panel A. Linear effect	δ = 65	δ = LE-10	δ = ERA	δ = 65	δ = LE-10	δ = ERA
Δ Real GDP per capita	1.093***	1.137***	1.091***	1.159***	1.060***	1.031***
	(0.252)	(0.275)	(0.306)	(0.250)	(0.279)	(0.295)
Δ Real construction cost	0.724***	0.847***	0.799***	0.722***	0.874***	0.792***
	(0.261)	(0.263)	(0.260)	(0.256)	(0.261)	(0.266)
Δ Current account	-0.0156**	-0.0162**	-0.0173**	-0.0148**	-0.0149**	-0.0169**
	(0.00644)	(0.00686)	(0.00679)	(0.00625)	(0.00689)	(0.00693)
Δ Population density	1.107**	1.590***	1.351***	1.290***	1.788***	1.460***
	(0.470)	(0.521)	(0.491)	(0.498)	(0.571)	(0.530)
Δ M	0.00655	-0.0205	-0.0132			
	(0.0286)	(0.0218)	(0.0248)			
Δ O	-0.0424***	-0.0121	-0.0239			
	(0.0150)	(0.0287)	(0.0194)			
Δ Old-age dependency				-0.593***	0.106	-0.213
				(0.186)	(0.252)	(0.160)
Constant	-0.0854	-0.110	-0.0933	-0.0944	-0.134*	-0.0958
	(0.0744)	(0.0791)	(0.0831)	(0.0704)	(0.0805)	(0.0868)
Observations	103	103	103	103	103	103
Number of countries	22	22	22	22	22	22
R^2	0.664	0.672	0.669	0.660	0.668	0.661
Panel B. Nonlinear effect						
Δ O	0.00465	-0.00747	-0.0411**			
	(0.0311)	(0.0327)	(0.0192)			
Δ O^2	-0.0251**	0.00859	0.00879***			
	(0.0121)	(0.0161)	(0.00308)			
Δ Old-age dependency				0.0520	0.0537	-0.344***
				(0.305)	(0.286)	(0.129)
Δ Old-age dependency^2				-5.719***	-0.270	1.170*
				(1.758)	(1.288)	(0.678)
Constant	-0.0990	-0.112	-0.111	-0.104	-0.134*	-0.114
	(0.0774)	(0.0799)	(0.0801)	(0.0704)	(0.0788)	(0.0848)
Standard explanatory variables	Yes	Yes	Yes	Yes	Yes	Yes
Observations	103	103	103	103	103	103
Number of countries	22	22	22	22	22	22
R^2	0.667	0.675	0.682	0.672	0.666	0.671

Robust standard errors, clustered at country-level, are in parentheses.
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

5 Projection under Forward-Looking Scenario

In this section, I investigate the responses of real house price to future demographic changes based on the regression results. Before I calculate anything, I first check goodness of fit of the regression models that give significant results in Table 3. The relationship between the log of real house price index (x axis) and the fitted value (y axis) are plotted in Figure 6 for the whole sample period. From the left, the linear benchmark model (δ = 65, panel A column (1) in Table 3), the linear life expectancy model (δ = LE-10, panel A column (2) in Table 3), and the nonlinear effective retirement age model (δ = ERA, panel B column (4) Table 3) are presented, respectively. Overall, the models seem to fit the data well.

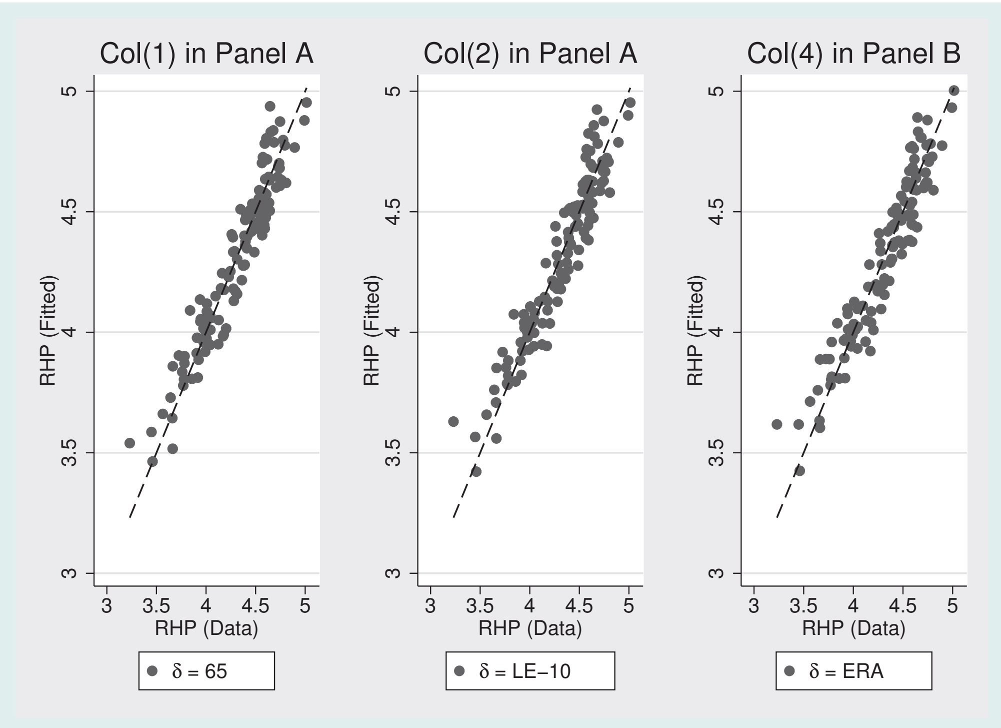


Figure 6: Goodness of fit of the regression models in Table 3

5.1 Population Projection

In the next step, I project the share of three alternatively defined old-age population for the future period following the same way described in equation (1). Firstly, I obtain population projections for single year of age. All European countries in the sample along with the U.S. and Korea are those whose single year of age data is readily available, at furthest, until 2080.[8] Countries whose detailed population projection is not available are excluded from the prediction.

To calculate the future share of old-age population based on expected remaining life, I use the country-specific life expectancy projections suggested by Kontis et al. (2017) and linearly interpolate and extrapolate the projections until 2055. In the case of the effective retirement age, however, there are no projections available. During the sample period between 1970 and 2014, the effective retirement age has changed every year, and it has not always moved hand in hand with life expectancy. Thus, I make two assumptions and project the share of effectively retired population under each scenario: 1) the effective retirement age is fixed at the level of 2014, and 2) the effective retirement age increases over time according to the past change in life expectancy. For the second assumption, I calculate the average change in life expectancy of each country for the period 1974-2014: the country who has the highest mean change in life expectancy is Korea (average 2.26 years of increase), and with the lowest years of average increase is Denmark (average 0.84 year of increase), while the overall mean is 1.13 years per five-year.

Figure 7 shows the share of population aged 65 or above (O^{65+}), population with ten years of expected life ($O^{(LE-10)+}$), and effectively retired population (O^{ERA+}) in selected countries. First of all, the share of population aged 65 or above, the solid line, is predicted to increase consistently until around 2050 in all selected countries when it reaches well above 30$\%$ of total population in fast-aging countries such as Italy and Korea. Meanwhile, in European countries the share of effectively retired population is predicted to be always higher than the share of the standard old-age population, if the retirement age is assumed to be fixed at the current level. This is due to people's early exit from the labor market in Europe. In the case of the U.S., the share of standard old-age population and retired population are projected to be almost the same since the effective retirement age in the U.S. in 2014 is 65.29. In Korea, the situation is the opposite to that of European countries, which means that people exit the labor market much late. If I assume that the effective retirement age keeps increasing by 1.13 years in every five-year, however, the share of retired population is projected to increase only limitedly over time in all countries. Finally, the share of people who have maximum ten years of expected remaining life is projected

[8] European population projections are taken from the Eurostat, and the other two countries' data are obtained from national statistics.

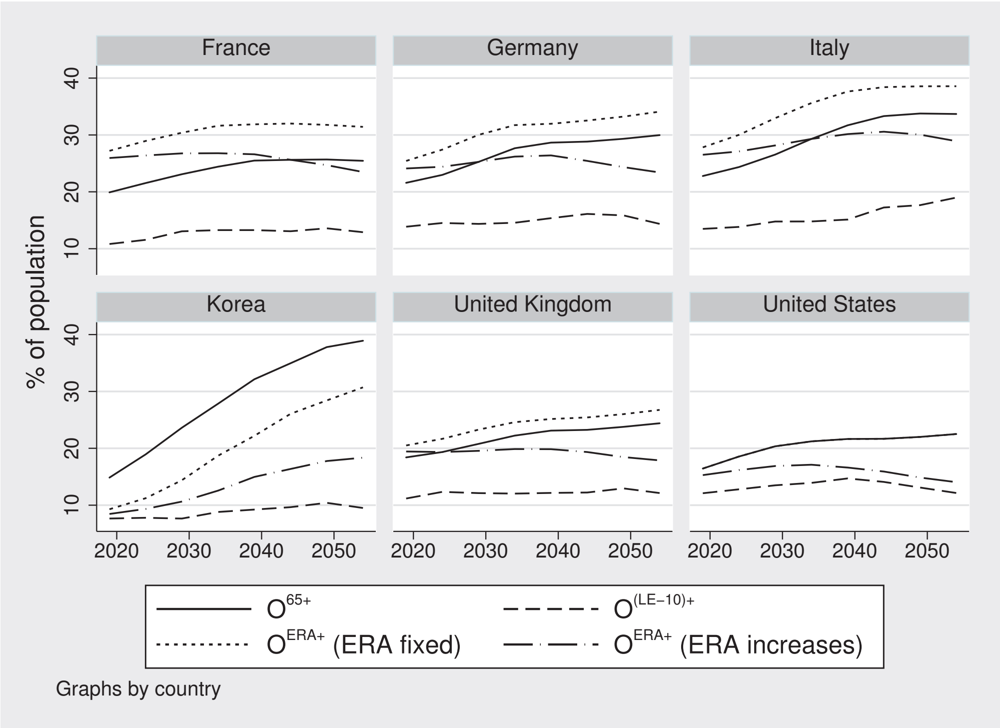


Figure 7: Old-age population projections in selected countries

to either stay at the current level or slightly increase, except in Italy.

5.2 Real House Price Prediction

Since the prediction focuses on the effect of future demographic changes on real house price, the values of non-demographic explanatory variables are set to the value of its last observation, mostly the observation in 2014, except real GDP per capita and population density, which I can safely assume a continuing change over time. I assume the growth rate of real GDP per capita to be each country's own average growth rate during the past ten years, and recalculate population density based on each country's population projection. Then, I predict real house price in selected countries using the three regression models and their corresponding coefficients that I checked the goodness of fit in Figure 6.

In Figure 8, the solid line is real house price predicted by the benchmark regression model (using O^{65+}), while the dashed line and the dotted line are by the life expectancy model (using $O^{(LE-10)+}$) and the effective retirement age model (using O^{ERA+}), respectively. As the size of standard old-age population increases, real house price is predicted to immediately decrease from the level of 2019 in all countries, although the extent to which it drops varies across countries. However, when I focus on the alternatively defined old-age population, the regression models predict future real house price to be significantly higher than the one predicted by the benchmark model in all selected countries. Since the retired population in Figure 8 is calculated under the assumption that the effective retirement age is fixed at the level of 2014, the projections suggest that accumulating size of retired population will put an upward pressure on real house price, therefore house prices will significantly increase over time. Finally, when old is defined by a distance to life expectancy, the dashed line, real house price is still projected to increase but not as much as in the case where the old is defined as retired population. Note that the projected level of real house price varies a lot across countries since the predictions are allowed to be affected not only by demographic factors but also by each country's past real GDP per capita growth.

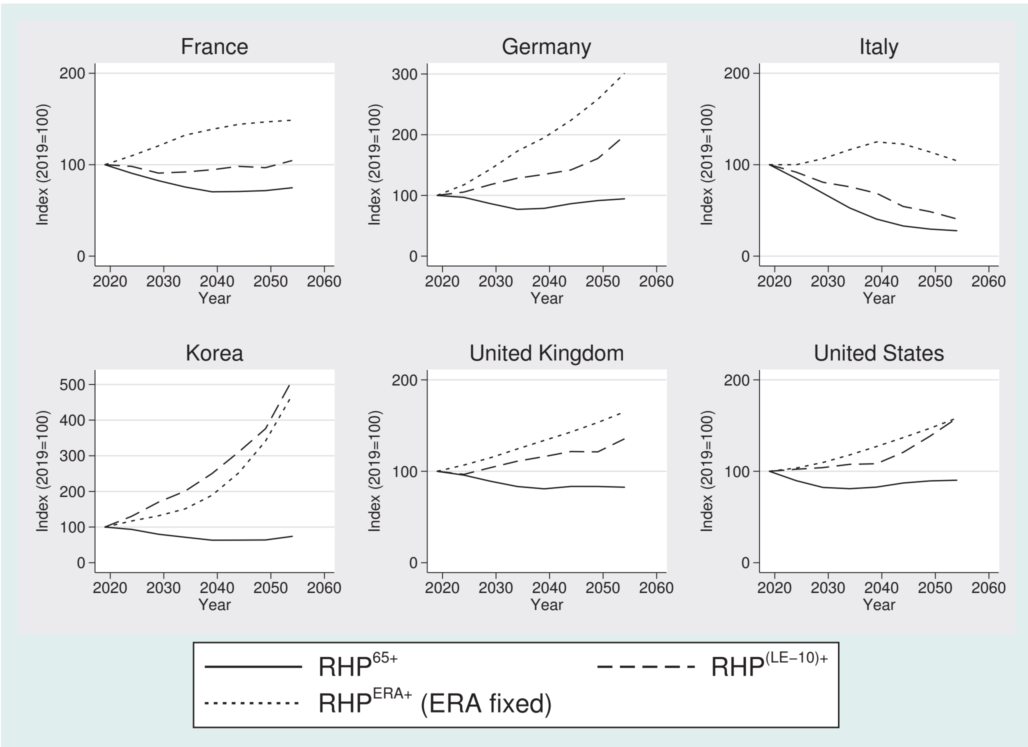


Figure 8: Real house price projections in selected countries

Figure 9 shows how the change in the effective retirement age is likely to affect real house price. In all selected European countries, the fixed effective retirement age, the

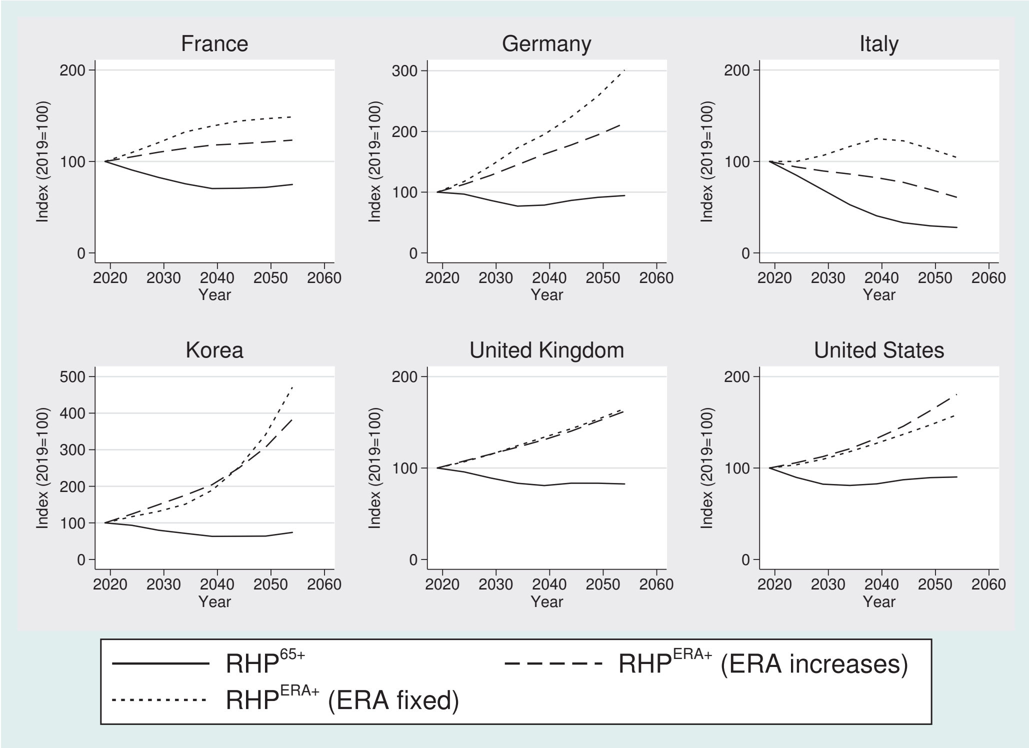


Figure 9: Real house price projections in selected countries: different assumptions on ERA

dotted line, predicts a higher real house price than the one predicted by the increasing effective retirement age, the dashed line. Since people currently retire early in Europe, raising the effective retirement age means that a large size of retired population who brings a positive effect on real house price will be reduced or limited over time, which results in lower real house prices. In the U.K and the U.S, however, raising effective retirement age rather predicts a slightly higher increase in real house price than fixed effective retirement age possibly because 1) the share of retired population in these countries is not big enough in the first place as in other European countries to bring a positive marginal effect on real house price, and 2) the decreased share of retired population by raising effective retirement age reduces the overall negative effect of aging on real house price.

Korea looks exceptional in these figures in the sense that real house price is predicted to increase considerably in the future in any models. As Figure 7 shows, Korea is one of the most fast-aging countries in the world, and therefore there is a considerable negative pressure on real house price. However, as mentioned above, the projection assumes that real GDP per capita will keep grow at the rate of growth of each country's own past, which is high enough to cancel out the negative effect of aging in the case of Korea.[9]

Main findings in this section are as follows. Firstly, under the standard definition of old, population aging undoubtedly predicts a decrease in real house price. Once old is defined alternatively, however, increase in the share of old-age group does not necessarily bring a significant drop in real house price. Rather, future real house price can increase, depending on how life expectancy and the effective retirement age change over time. Therefore, a key take-away from this exercise would be that the standard old-age population does not detect a nonlinear effect of old-age population on real house price and only predicts a further decrease in real house price as aging continues, whereas the effectively retired population does capture a nonlinear effect and leaves room for policy intervention. In the meantime, although a change in the effective retirement age can be a useful policy tool to affect housing market, the effect seems to be highly country-specific even among the advanced OECD countries as the speed of aging matters a lot. In European countries, where people currently withdraw from labor market relatively early, raising effective retirement age may help avoid an overheated housing market. However, countries such as

[9]Indeed, when I assume the same real GDP per capita growth in all sample countries, real house price in Korea is estimated to decrease significantly under any regression models. In a similar way, the projections of Italy keep decreasing since the growth rate of real GDP per capita is assumed to be negative according to its past 10 years of average.

the U.K. and the U.S. whose speed of aging is slow and the gap between the effective retirement age and the official retirement age is small, longer working lives may not result in any significant change in real house prices. Last but not least, the negative effect of aging can be mitigated as long as other macroeconomic variables such as real GDP per capita keep performing well in the future.

6 Conclusion

This paper empirically studies the effect of population aging on real house prices across 22 OECD countries over the past 40 years. Specifically, it addresses through which channel, between short expected remaining life and withdrawal from the labor market, population aging affects real house price more and how the effect can vary if the old-age population is defined alternatively in a way to reflect different aspects of aging. I first estimate the relationship between the share of population aged over 65 and real house price, given other standard determinants of real house price. Then, I repeat the regression model using the two alternatively defined old-age populations: 1) the population whose distance to life expectancy is maximum ten years and 2) the population who effectively withdrew from the labor force.

By introducing the alternative definitions of old-age population, this paper shows that the housing demand of people who are traditionally considered old seems to change over time as expected life horizon increases. Although the old-age population is negatively associated with real house price no matter how they are defined, the magnitude of the negative effect is the largest when the old is defined by a distance to life expectancy, which suggests that the main driver of a negative relationship between aging and real house price comes from the later stage of life and not immediately after the age of 65 or retirement. It also shows that the effective retirement age matters more in explaining the effect of aging on real house price than the age 65, since the share of effectively retired population has a nonlinear effect on real house price. Relatedly, future real house price may not decrease significantly as aging continues. In all sample countries, future real house prices based on the regression models are predicted to drop when aging is defined as increasing share of standard old-age population. However, as soon as old is defined as retired population, real house prices are predicted to increase considerably. Finally, the projection exercise suggests that the effect of raising effective retirement age will be heterogenous among OECD countries since the current level of effective retirement as well as the speed of aging varies wildly across countries.

References

Abel, A. B. (2003). The Effects of a Baby Boom on Stock Prices and Capital Accumulation in the Presence of Social Security. *Econometrica 71*(2), 551–578.

Adam, K., P. Kuang, and A. Marcet (2012). House Price Booms and the Current Account. *NBER Macroeconomics Annual 26*(1), 77–122.

Andrews, D. and A. C. Sánchez (2011). The Evolution of ownership Rates in Selected OECD Countries: Demographic and Public Policy Influences. *OECD Journal: Economic Studies 2011*(1), 1–37.

Ang, A. and A. Maddaloni (2005). Do Demographic Changes Affect Risk Premiums? Evidence from International Data. *The Journal of Business 78*(1), 341–380.

Bakshi, G. S. and Z. Chen (1994). Baby Boom, Population Aging, and Capital Markets. *The Journal of Business 67*(2), 165–202.

Battistin, E., A. Brugiavini, E. Rettore, and G. Weber (2009). The Retirement Consumption Puzzle: Evidence from a Regression Discontinuity Approach. *American Economic Review 99*(5), 2209–26.

Bergantino, S. M. (1998). Life cycle investment behavior, demographics and asset prices. Ph.d. thesis, Massachusetts Institute of Technology.

Bloom, D. E., D. Canning, and G. Fink (2011). Implications of Population Aging for Economic Growth. NBER Working Papers 16705, National Bureau of Economic Research, Inc.

Brooks, R. (2006, July). Demographic Change and Asset Prices. In C. Kent, A. Park, and D. Rees (Eds.), *Demography and Financial Markets*, RBA Annual Conference Volume. Reserve Bank of Australia.

Chen, Y., K. Gibb, C. Leishman, and R. Wright (2012). The Impact of Population Ageing on House Prices: A Micro-simulation Approach. *Scottish Journal of Political Economy 59*(5), 523–542.

Davis, E. P. and C. Li (2003). Demographics And Financial Asset Prices In The Major Industrial Economies. Public Policy Discussion Papers 03-07, Economics and Finance Section, School of Social Sciences, Brunel University.

Deaton, A. and C. Paxson (1997). The effects of economic and population growth on national saving and inequality. *Demography 34*(1), 97–114.

Ferrero, A. (2015). House Price Booms, Current Account Deficits, and Low Interest Rates. *Journal of Money, Credit and Banking 47*(S1), 261–293.

Fortin, M. and A. Leclerc (2000). Demographic Changes and Real Housing Prices in Canada. Cahiers de recherche 00-06, Departement d'Economique de l'École de gestion à l'Université de Sherbrooke.

Goyal, A. (2004). Demographics, Stock Market Flows, and Stock Returns. *Journal of Financial and Quantitative Analysis 39*(01), 115–142.

Greenspan, A. (2003). Aging global population: testimony before the Special Committee on Aging, U.S. Senate, February 27, 2003. Speech 21, Board of Governors of the Federal Reserve System (U.S.).

Hildebrand, V. (2001). Wealth Accumulation of US Households: What do we learn from the SIPP data? IRISS Working Paper Series 2001-01, IRISS at CEPS/INSTEAD.

Hirata, H., M. A. Kose, C. Otrok, and M. E. Terrones (2013). Global House Price Fluctuations: Synchronization and Determinants. *NBER International Seminar on Macroeconomics 9*(1), 119–166.

Kontis, V., J. E. Bennett, C. D. Mathers, G. Li, K. Foreman, and M. Ezzati (2017). Future life expectancy in 35 industrialised countries: projections with a Bayesian model ensemble. *Lancet 389*, 1323–1335.

Krueger, D. and A. Ludwig (2007). On the consequences of demographic change for rates of returns to capital, and the distribution of wealth and welfare. *Journal of Monetary Economics 54*(1), 49–87.

Liu, Z. and M. M. Spiegel (2011). Boomer retirement: headwinds for U.S. equity markets? *FRBSF Economic Letter* (aug22).

Mankiw, N. G. and D. N. Weil (1989). The baby boom, the baby bust, and the housing market. *Regional Science and Urban Economics 19*(2), 235–258.

Modigliani, F. and R. Brumberg (1954). Utility analysis and the consumption function: An interpretation of cross-section data. In K. Kurihara (Ed.), *Post-Keynesian Economics*. New Brunswick, NJ: Rutgers University Press.

Nardi, M. D., E. French, and J. B. Jones (2015). Savings After Retirement: A Survey. NBER Working Papers 21268, National Bureau of Economic Research, Inc.

NCHS (1999). Method for Constructing Complete Annual U.S. Life Tables. Vital and Health Statistics Series2 No.129, National Center for Health Statistics.

Nishimura, K. and E. Takats (2012). Ageing, property prices and money demand. BIS Working Papers 385, Bank for International Settlements.

Poterba, J. M. (1994). *International Comparisons of Household Saving*. NBER Books. National Bureau of Economic Research, Inc.

Poterba, J. M. (2001). Demographic Structure And Asset Returns. *The Review of Economics and Statistics 83*(4), 565–584.

Poterba, J. M. (2004). The impact of population aging on financial markets. *Proceedings - Economic Policy Symposium - Jackson Hole* (Aug), 163–216.

Rae, D. and P. van den Noord (2006). Ireland's Housing Boom: What has Driven it and Have Prices Overshot? OECD Economics Department Working Papers 492, OECD Publishing.

Takats, E. (2010). Ageing and asset prices. BIS Working Papers 318, Bank for International Settlements.

Takáts, E. (2012). Aging and house prices. *Journal of Housing Economics 21*(2), 131–141.

Yoo, P. S. (1994). Age dependent portfolio selection. Working Papers 1994-003, Federal Reserve Bank of St. Louis.

Yoon, J.-W., J. Kim, and J. Lee (2014). Impact of Demographic Changes on Inflation and the Macroeconomy. IMF Working Papers 14/210, International Monetary Fund.

Égert, B. and D. Mihaljek (2007). Determinants of House Prices in Central and Eastern Europe. *Comparative Economic Studies 49*(3), 367–388.

Appendix A Data

I construct a panel data by combining several datasets from different sources. Basically, there are two types of data I use in this study - data for the period 1970-2014 to run the main regression models and data for the period 2014-2055 to project future real house price.

First, I use house price dataset from the OECD that includes real house price, nominal house price, price to rent ratio, price to income ratio for all 22 OECD countries in the sample. For population data, I use the population of five-year age group by gender from the UN Population Division. Total population used in this study is the sum of male and female populations. Other demographic variables, which include life expectancy, old-age dependency ratio, population density, urban population, population growth, are obtained from the WDI of the World Bank. The effective retirement age is calculated by the OECD by gender, and I use the average of male and female effective retirement age in the regression. I mainly use current account balance data from the WDI, and use the IMF's International Financial Statistics and the Jordà-Schularick-Taylor Macrohistory dataset to complement the missing observations. Construction cost is combined from the various sources. Cost of construction index for residential buildings is obtained from national sources for the following countries: France from the Institut national de la statistique et des etudes economiques, U.K. from the Department for Business, Innovation and Skills, U.S. from the Census Bureau, Korea from the Korean Statistical Information Service (KOSIS), Finland from the Statistics Finland, Australia from the Australian Bureau of Statistics, New Zealand from the Stats NZ, and Japan from the Statistics Bureau. For the rest of the sample countries, I use cost of construction index of residential buildings from the OECD and construction cost index of new residential buildings from the Eurostat.

The single-year of age population projections for the U.S. and Korea are obtained from the Census Bureau and the KOSIS, respectively. Otherwise, I use the Eurostat data for 15 European countries, except Switzerland. Life expectancy projections are taken from Kontis et al. (2017), which estimates life expectancy in 2030 for all countries in my sample. I linearly interpolate and extrapolate life expectancy until 2055.

Appendix B Interpolation of population data

I interpolate population data of five-year age group using Beer's formula. Beer's formula used in this study has the following general expression:

$$P_{x+k} = C_{k,x-10}\ {}_5P_{x-10} + C_{k,x-5}\ {}_5P_{x-5} + C_{k,x}\ {}_5P_x + C_{k,x+5}\ {}_5P_{x+5} + C_{k,x+10}\ {}_5P_{x+10}$$

in which P_{x+k} is the population aged $x+k$ (k = 0,1,2,3,4), ${}_5P_x$ is the total population aged x to $x+5$, and $C_{k,x}$ is Beer's interpolation coefficient. To obtain the size of single-year aged between 0-4 and 5-9, I use the following formulas:

$$P_{0+k} = C_{k,0}\ {}_5P_0 + C_{k,5}\ {}_5P_5 + C_{k,10}\ {}_5P_{10} + C_{k,15}\ {}_5P_{15} + C_{k,20}\ {}_5P_{20}$$

$$P_{5+k} = C_{k,0}\ {}_5P_0 + C_{k,5}\ {}_5P_5 + C_{k,10}\ {}_5P_{10} + C_{k,15}\ {}_5P_{15} + C_{k,20}\ {}_5P_{20}$$

Values for $C_{k,x}$ are taken from Table A in NCHS (1999).

Figure 10 compares the share of population aged 65 in New Zealand and the U.S. from the national statistics and from the interpolation. I use interpolated data to construct the share of different age populations for countries whose single-year of age population is not readily available.

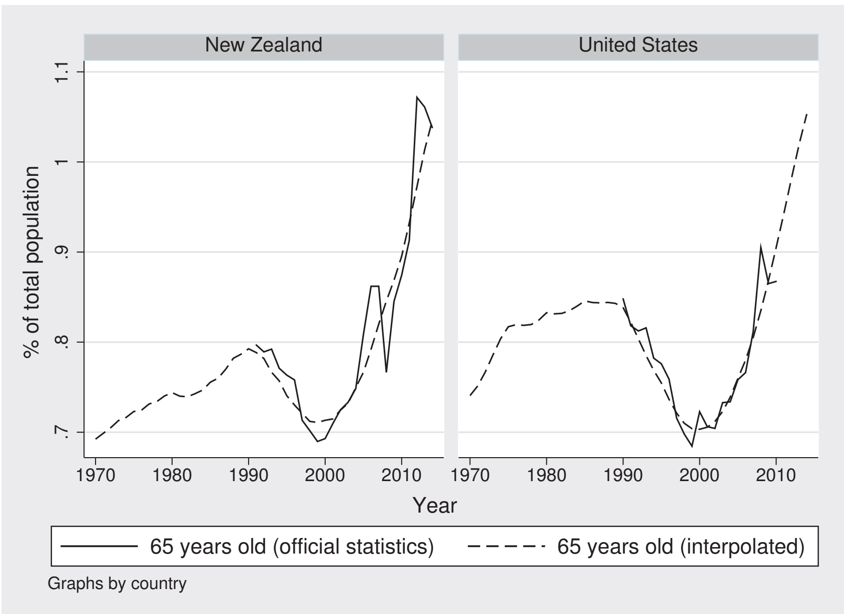


Figure 10: Comparison between the official statistics and the interpolated series

Appendix C Comparison between male and female

Since in many countries life expectancy as well as the effective retirement age of male and female population are considerably differ from each other, I further investigate if gender differences exist in the effect of population aging on real house prices in Table 6. I run the same regression models as before but by separating male and female; the old-age population in panel B and C is the share of male elderly out of total male population and the share of female elderly out of total female population, respectively, calculated based on the gender-specific life expectancy and effective retirement age. The main difference between panel B and C can be found in columns (2) and (3), in which the old age population is defined by a distance to life expectancy. The effect of female population aging explains decrease in real house price more than aging of male population does; 1 percent point increase in female population who has maximum ten years of expected remaining life is associated with 6.6 percent decrease in real house price, whereas the same amount increase in male elderly population is associated with 4.7 percent decrease in real house price. The result does not seem to support the belief that male homeownership is generally higher than female, thus aging of male population is likely to bring a larger negative effect on real house price than female. Rather, it suggests that since female life expectancy is obviously longer than male, even if there may be a gender gap in homeownership rate, housing demand of the old is still more affected by a distance to life expectancy rather than their gender. However, there is no significant difference between the effect of male and female aging, when aging is measured by an increase in the share of retired population.

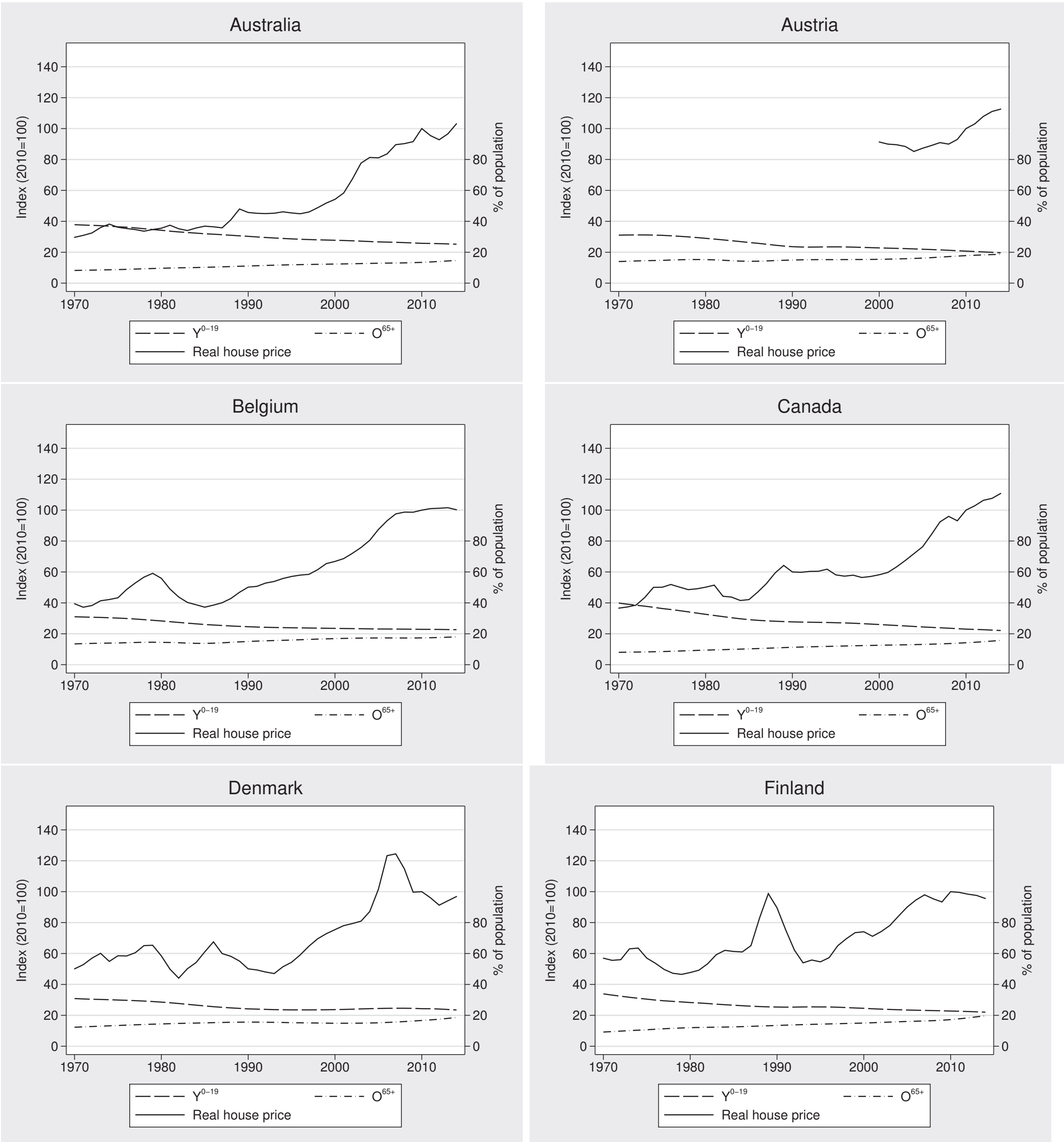
Table 7: Comparison between male and female populations

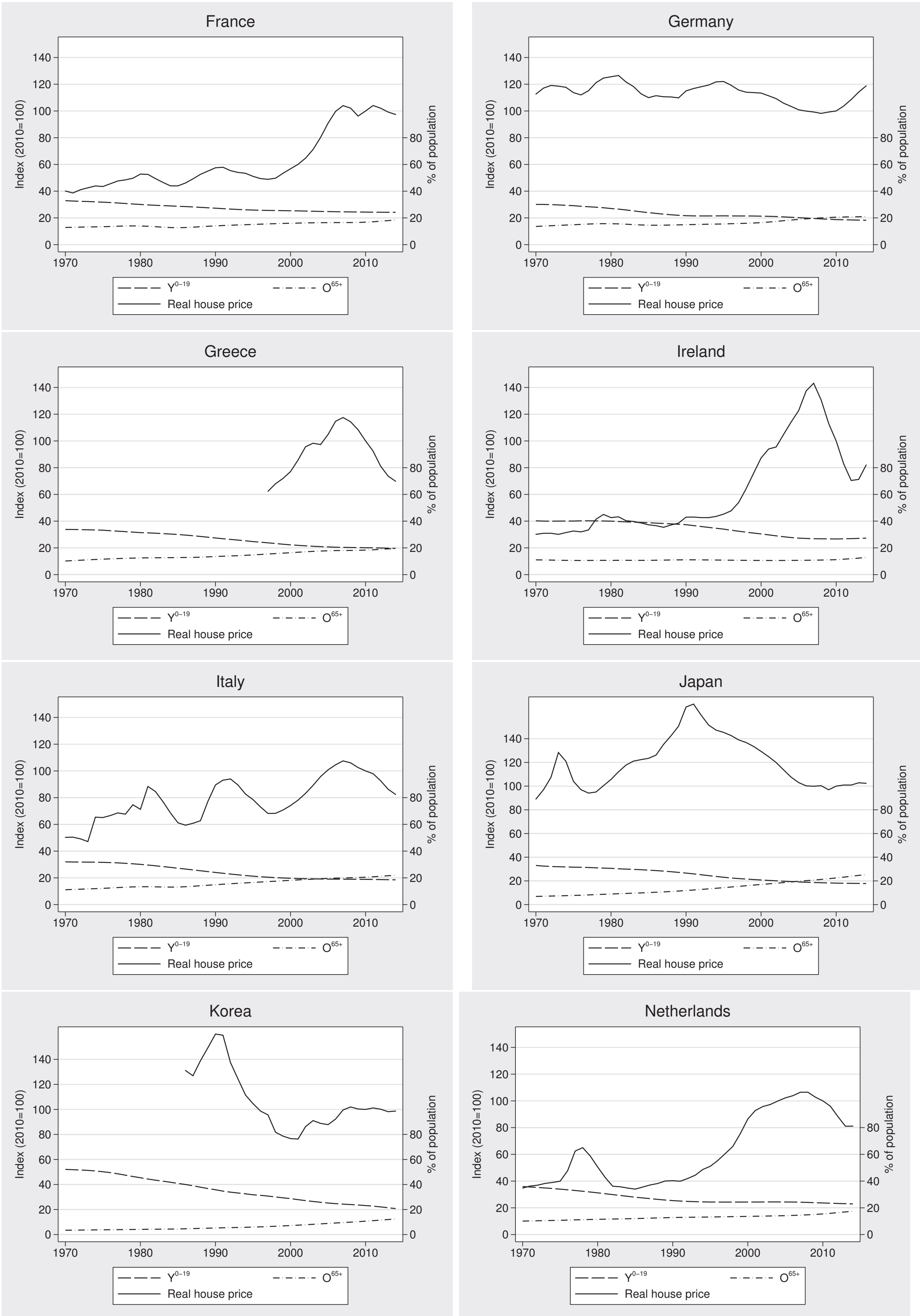
	(1)	(2)	(3)	(4)	(5)
	δ = 65	δ = LE-10		δ = ERA	
Panel A. Total			δ' = LE-5		δ' = (ERA+LE)/2
M	0.0329	0.00867	0.00720	-0.0157	-0.00767
	(0.0270)	(0.0252)	(0.0268)	(0.0264)	(0.0260)
O	-0.0432***	-0.0544***		-0.0289	
	(0.0147)	(0.0185)		(0.0228)	
O-			-0.0375		-0.00549
			(0.0252)		(0.0244)
O+			-0.0616**		-0.0569*
			(0.0264)		(0.0301)
R^2	0.834	0.825	0.825	0.809	0.816
Panel B. Male					
M (m)	0.0139	0.0104	0.00955	-0.0259	-0.0141
	(0.0269)	(0.0243)	(0.0252)	(0.0231)	(0.0271)
O (m)	-0.0516**	-0.0478**		-0.0194	
	(0.0188)	(0.0181)		(0.0244)	
O- (m)			-0.0288		0.00499
			(0.0348)		(0.0355)
O+ (m)			-0.0560**		-0.0445**
			(0.0219)		(0.0194)
R^2	0.826	0.825	0.825	0.809	0.816
Panel C. Female					
M (f)	0.0432	0.00896	0.00763	-0.00135	0.00508
	(0.0261)	(0.0232)	(0.0255)	(0.0257)	(0.0253)
O (f)	-0.0308**	-0.0668***		-0.0340	
	(0.0136)	(0.0198)		(0.0208)	
O- (f)			-0.0558*		-0.0146
			(0.0304)		(0.0220)
O+ (f)			-0.0721**		-0.0494*
			(0.0295)		(0.0277)
R^2	0.838	0.836	0.836	0.822	0.825
Standard explanatory variables	Yes	Yes	Yes	Yes	Yes
Observations	122	122	122	122	122
Number of countries	22	22	22	22	22

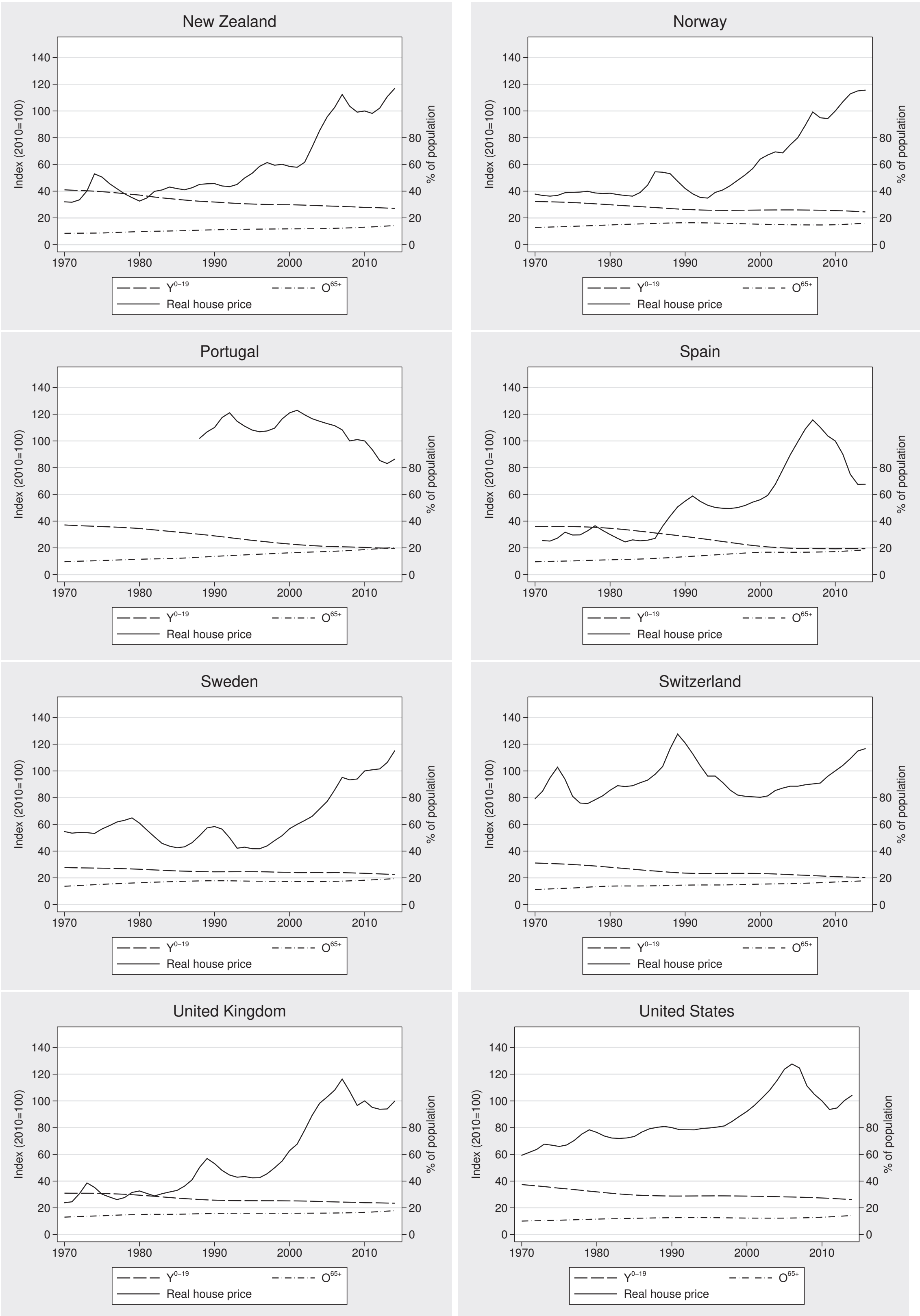
Robust standard errors, clustered at country-level, are in parentheses.
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Appendix D Additional figures

D.1 Real house price and the share of old: 1970-2014

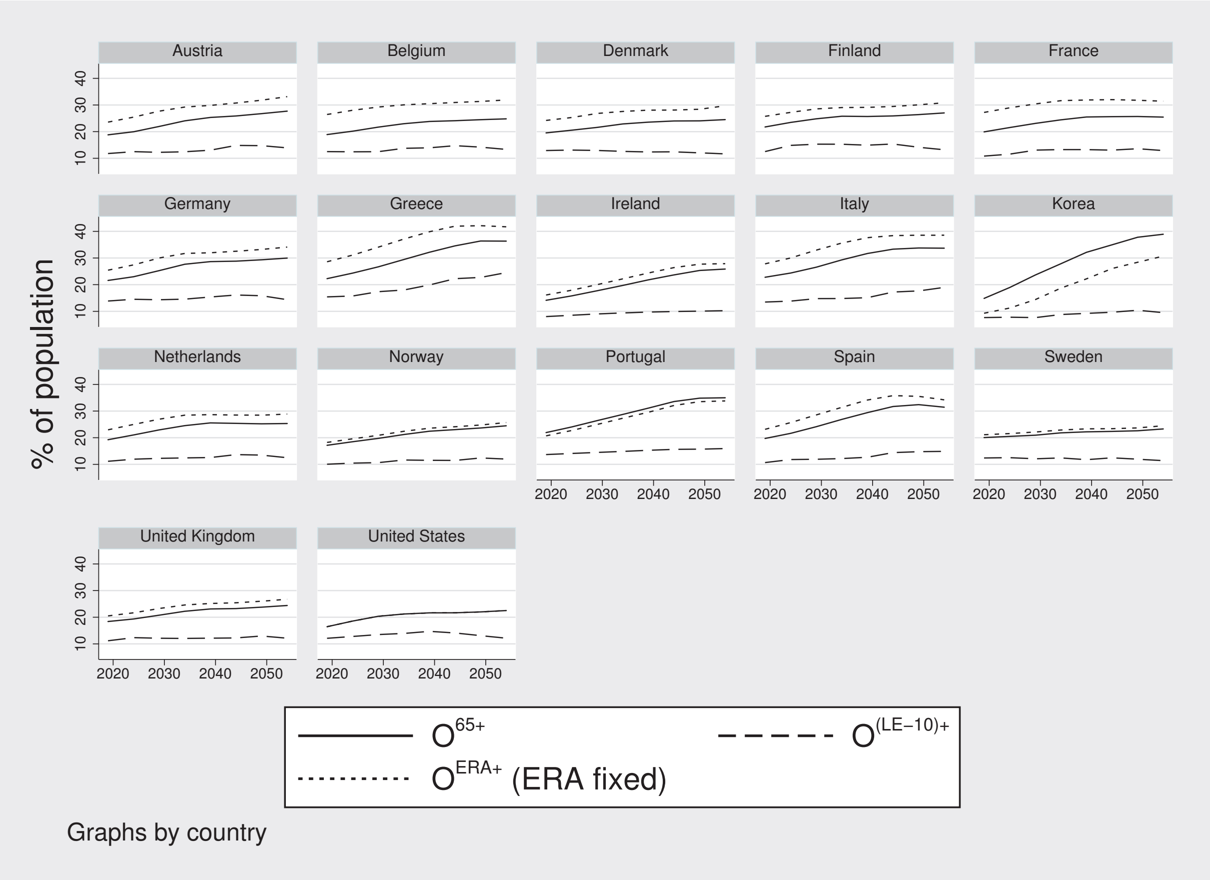



France
Germany
Greece
Ireland
Italy
Japan
Korea
Netherlands
Index (2010=100)
% of population
Y0–19
O65+
Real house price


New Zealand
Norway
Portugal
Spain
Sweden
Switzerland
United Kingdom
United States
Index (2010=100)
% of population
0
20
40
60
80
100
120
140
1970
1980
1990
2000
2010
Y0–19
O65+
Real house price

D.2 Share of different old-age populations: 1970-2014

D.3 Projections of different old-age populations: 2019-2055



www.nbp.pl