Aging, Inflation and Property Prices

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Abstract

How will the declining birthrate and aging of society affect the goods and services market and asset markets? When we estimated various models using panel data from 23 major developed nations, including leading Asian countries, we found that the young-age dependency ratio had a positive and statistically significant impact on both inflation and housing prices, while the old-age dependency ratio had a negative and statistically significant impact. In other words, this shows that as the number of children in society as a whole increases, it will drive up current housing prices due to the increased future expectations for the housing market, and it will drive greater consumption as well. On the other hand, the further aging of society will drive consumption down from its current level due to increases in social security costs and the like; moreover, since expectations for the future will also be lowered, commodity and housing prices will be driven down as well. This means that in nations where the birthrate is declining and society is aging, these trends will cause asset deflation (decline in housing assets) and promote deflation. This has many implications from a policy perspective. Going forward, the birthrate will continue to decline at the same time as society is aging in Japan, South Korea, and various Western countries. Even in countries such as China and Thailand where the population continues to grow, it is expected that there will be a sudden aging of society in future. In light of this, understanding what effect these trends will have on the economies of different countries will offer various useful clues with regard to economic policy.

Key Words: housing bubble; old-age dependency ratio; asset meltdown; immigration policy; social advancement of women

JEL Classification: E31 Price Level; Inflation; Deflation, R21 Housing Demand, R31 Housing Supply and Markets

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1 Introduction

Many economies in the world will soon be or already are aging rapidly. This aging of society does not happen suddenly but is manifesting slowly and steadily in many countries. In addition, even if countries implement policies to counter declining birthrates, it is to be expected that the situation will improve only slowly. These changes in the population makeup impact various markets, in a different way from economic shocks that bring about short-term economic fluctuation. The most notable impact that demographic changes such as the declining birthrate and aging of society have may be on the housing market—the most significant asset in household budgets. This is because population is a key factor determining housing supply and demand.

A representative study that concentrates on changes in housing demand based on democrathic factor and housing prices is Mankiew and Weil (1989)[9]. Focusing on birth rate, which leads to future housing demand, and housing demand by age group, the study projected future housing prices in the United States. In terms of the results, it predicted that over the 25-year period from the time of this study, U.S. housing prices would decrease by 47% in real terms. Since the projected impact on the housing market was extremely large, the results subsequently led to much controversy.

In 1991, a special issue of *Regional Science and Urban Economics* featuring critical essays on this study was published. Setting aside problems with the estimate, the criticism focused on: a) the fact that changes in housing demand have an effect on housing rents, but no direct effect on housing prices; b) the fact that housing supply is elastic in the long term, as shown in the stock flow model, so even if there is a change in housing demand, it will be adjusted by housing supply adjustments; c) the fact that since housing prices are fluctuating at the point when fluctuation in housing demand is predicted, the (short-term) housing demand for a given year alone will not affect housing prices[*1].

In Japan, Ootake and Shintani (1996)[12] and Shimizu and Watanabe (2010)[17] calculated housing demand with an index similar to that proposed by Mankiw and Weil (1989)[9] and conducted empirical analysis. The results suggested that although population factors have an effect on housing stocks, they do not have an effect on housing (residential land) prices[*2].

However, this series of studies only looked at the relationship of the estimated amount of housing supply and demand to housing prices; they were not able to explicitly address changes in population makeup, such as the aging of society. A series of studies, including Nishimura (2011)[10] and Nishimura and Takáts (2012)[11], have focused on the relationship between people's life cycles and housing demand in terms of long-term equilibrium spanning generations and analyzed the relationship between changes in population structure and the housing market.

If one considers that the life of a given individual can be broadly divided into two generations, individuals build up assets during their prime years, then upon entering their senior years, they use up and consume their savings (assets). During the asset formation period, housing assets may be considered a safe asset for people, since compared to savings and the like, they do not lose much value due to inflation. By owning housing, it may be possible to maintain value which will be eventually passed on to one's offspring (bequest motive), and it may also be possible to sell the house and allocate the profits to expenses in one's old age. This is why

[*1] See Hamilton (1991)[5] and Hendershott (1991)[6].

[*2] Engelhardt and Poterba (1991)[3] report that analysis using Canadian data did not obtain the same results as the analysis results presented by Mankiw et al.

new housing demand is generated by working-age individuals.

In an economy covered by these two generations, if life-spans continue to increase without the social welfare system being developed to accommodate it, working-age people will act to reduce their current consumption in preparation for post-retirement life. Therefore, the longer life-spans become, the more the consumption level of society as a whole will decrease. In addition, since the elderly population depends on the working-age population in various ways, an increase in the elderly population will end up making the economy as a whole less active.

Based on this kind of model, Takáts (2012)[23], Saita et al. (2013)[16] and Shimizu et al.(2015)[18] have developed empirical models concerning the relationship between population structure and the housing market. Takáts (2015)[23], Saita et al. (2013)[16] and Shimizu et al.(2015)[18] consider changes in the old-age dependency ratio — i.e., changes in the structure of two groups: the productive-age population (aged 20-64) and the elderly population (aged 65+) — as a factor explaining housing market fluctuations and explicitly incorporate this into their model. This model explains that if the productive-age population (working-age population) increases, asset demand (housing demand) will be driven up, while if the size of the elderly population increases in relation to the productive-age population, asset demand (housing demand) will be driven down.

Next, let us consider the effect on the goods and services market. Specifically, does the aging of society have a negative impact on commodity price levels, in the same manner as asset prices? Shirakawa (2011a)[19], (2011b)[20], and (2012)[21] conducted detailed analysis of the effect of the declining birthrate and aging of society on Japan's economy. In addition, Juselius and Takáts (2015)[7], building on research by Takáts (2015)[23], empirically clarified the effect of changes in the old-age dependency ratio on inflation. It may be anticipated that changes in population makeup, such as the declining birth rate and aging of society, will affect commodity prices via a more complex process than asset markets such as housing prices. For example, if the burden of social benefits such as pensions weighs more heavily on society as a whole due to the progressive aging of the population, consumption among the current working generation will decrease. If the elderly generation's marginal propensity to consume is smaller than that of the current working generation, the consumption level will drop for society as a whole, and, assuming fixed supply, deflation will grow worse. Meanwhile, in a society with many children, when expenditures specific to children (education costs, etc.) increase for society as whole, if there is a fall exceeding that increase in the consumption level among the current working generation or the elderly population, then deflation will grow worse. Alternatively, if consumption rises due to the increase in children, it should have the effect of driving commodity price levels up.

However, these hypotheses are based on assumptions that the adjustment of capacity and housing stock will not progress sufficiently. Forecast of changes in population numbers or population makeup have already been published with a certain degree of precision. However, while it is easy to adjust production capacity, housing supply/stock, etc., based on population forecasts, forecasting supply and demand for goods and services or housing stock based on changes in population makeup is extremely difficult. Our hypothesis here is that the existence of uncertainty has made it impossible to properly adjust production capacity and housing stock. In this sense, using an empirical model to clarify the impact that the declining birthrate and aging of society have on goods and services and housing prices is extremely significant.

In this research, our purpose is therefore to empirically clarify the impact that the declining birthrate and aging of society have on prices in the goods and services market (i.e., inflation) and asset markets—focusing in particular on the housing market, which accounts for the largest share of household finances.

Specifically, using global panel data from 23countries, including major developed nations such as Japan, the U.S., the U.K., and Germany, and Asian countries such as Indonesia, South Korea, and Hong Kong, we will analyze the effect of the young-age dependency ratio (the productive-age population (aged 15–64) and the young population (aged 0–14)) and old-age dependency ratio (the productive-age population (aged 15–64)) and the elderly population (aged 65+) have had on inflation and housing prices. In addition, we will simulate the impact that future demographic changes will have on inflation of general goods and service prices and housing prices in various countries.

2 Empirical Analysis

2.1 Data

The data used in this analysis (and the variable names in the regression output tables in parenthesis) are collected from various sources.

1. RPPI inflation (`rppi` and `pi_rppi`): The series "long-term series on nominal residential property prices" in BIS Residential Property Price database, obtained from the website of the Bank for International Settlements are used. The series has been constructed using data provided by various sources, including central banks, national statistical offices, research institutes, private companies and academic studies. The quarterly index are average for each year, and then log-differenced to obtain the inflation rate.
2. CPI and CPI inflation (`cpi` and `pi_cpi`): For most of the sample countries, the quarterly series "CPI, all items" obtained from IFS are used. For Germany, UK, and Korea, the quarterly CPI, all items series from OECD statistics are used. The quarterly series are converted to the annual series by taking simple averages. Then the CPI inflation is calculated by log-differencing.
3. Population data: Obtained from UN population database. Various population related variables are constructed as follows.
   (a) Shares of young, working, and old generations for country j (`n_young`, `n_working`, and `n_old`)

$$n_{jt}^{young} = 100 \times \frac{\sum_{k=1}^{3} p_{kjt}}{\sum_{k=1}^{17} p_{kjt}} \qquad n_{jt}^{working} = 100 \times \frac{\sum_{k=4}^{13} p_{kjt}}{\sum_{k=1}^{17} p_{kjt}} \qquad n_{jt}^{old} = 100 \times \frac{\sum_{k=14}^{17} p_{kjt}}{\sum_{k=1}^{17} p_{kjt}}$$

   where p_{kjt} is the poluations of age cohort k (for $k = 1, \ldots, 17; 0-4, 5-9, 10-14, 15-19, 20-24, 25-29, 30-34, 35-39, 40-44, 45-49, 50-54, 55-59, 60-64, 65-69, 70-74, 75-79$ and 80+) in total population for country j at year t. Notice that, in our definition, the "young" generation corresponds to the age $0-14$, the "working" generation is age $15-64$, and the "old" generation is age 65+.*3

   (b) Age dependency ratio for country j at year t (`depr`)

$$depr_{jt} = 100 \times \frac{n_{jt}^{young} + n_{jt}^{old}}{n_{jt}^{working}}$$

   (c) Age dependency ratios of young and old generations for country j at year t (`depr_y`

*3 By their definition, Juselius and Takáts (2015)[7] classify the age cohort "15-19" as "young" generation.

and depr_o)

$$depr^{y}_{jt} = 100 \times \frac{n^{young}_{jt}}{n^{working}_{jt}}, \qquad depr^{o}_{jt} = 100 \times \frac{n^{old}_{jt}}{n^{working}_{jt}}$$

Above three groups of variables are the core variables in our regression analysis. In addition, we have used the following variables.

4. Output gap (gap_hp): Output gaps are calculated by taking the ratio between a cyclical component and a trend component, both of which are obtained by applying the Hodrick-Prescott filter to the annual real GDP series, downloaded from IFS.[*4]
5. Growth rate of total population (dlnum_total): Using the date from UN population database, it is defined as $\Delta \log(p^{total}_{jt})$ where $p^{total}_{jt} = \sum_{k=1}^{17} p_{kjt}$.

2.2 Unit root tests

Before proceeding the regression analysis, we have applied a battery of unit root tests to our dataset. The Levin, Lin & Chu test (or LLC for short) is restrictive in a sense that it forces the coefficient of y_{it-1}, i.e., ρ, to be homogenous across countries i. Test by Im, Pesaran, and Shin and Fisher-type ADF, on the other hand, allow for a heterogenous coefficient of y_{it-1}.

Results of panel unit root test are summarized in Table 1. Top panel summaries the test results for the level data. For lcpi (log of CPI), lrppi (log of RPPI), depr, depr_y, depr_o, n_young, n_working, and n_old, all three tests reject the null hypothesis of unit root at 5% significance level at least.

The bottom panel reports the test results of the differenced data. Most importantly, the tests on the inflation rates of CPI and RPPI (dlcpi and dlrppi), the dependent variables in our regression models in the subsequent sections, reject the null hypothesis of unit root for all cases.

Though it is commonly assumed that error terms in panel data models are cross-sectionally independent, we observe many cases that they are indeed cross-sectionally dependent. It is now well-known that ignoring such a cross-sectional dependence in testing the panel unit root and the panel co-integration will bias the results. Thus the existence of cross-sectional dependence should be examined.

Table 2 reports the test results by Pesaran (2004)[13]. Pesaran (2004)[13] proposed a test statistic based on the average of the pairwise correlation coefficients which is asymptotically standard normal. The CD test always strongly rejects the null hypothesis of no cross-section dependence.

Therefore, as a final check, we employ the unit root tests in heterogeneous panels developed by Pesaran (2007)[14]. The right column of Table 1 reports the results. For the levels, unlike the previous three tests, Pesaran's test cannot reject the null of homogenous unit roots for lcpi and lrppi at 5% significance level. This results seems to be consistent with the idea that price index are non-stationary. However, for their inflations dlcpi and dlrppi, Pesaran test cannot reject the null hypothesis.

Overall, the panel data used in the regressions below are found to be not non-stationary. Given this observation, we model the relationship between two inflations and demographic variables in several different forms.

[*4] For our sample countries, except for CH, HK, MY, TH, and ZA, we have compared the calculated output gaps (by HP filter) and the ones obtained from the World Economic Outlook by IMF, and confirmed that the patterns of fluctuations are qualitatively similar.

Table 1 Panel data unit root tests

	Common Unit Root Tests	Individual Unit Root Tests		
		Without Cross-section Dependence (CD)		With CD
	Levin, Lin & Chu	IPS W-stat	ADF-Fisher χ^2	CIPS
null hypothesis	unit root	unit root	unit root	homogeneous non-stationary
alternative hypothesis	no unit root	some CS without UR	some CS without UR	otherwise
Series in Levels				
`lcpi`	−7.960***	−5.550***	142.391***	−2.552*
`lrppi`	−2.240**	−3.453***	79.257***	−2.111
`depr`	−5.006***	−3.775***	103.112***	−2.892***
`depr_y`	−11.907***	−9.526***	189.878***	−2.902***
`depr_o`	−3.012***	−3.975***	132.493***	−3.091***
`n_young`	−11.577***	−9.245***	186.811***	−3.556***
`n_working`	−5.764***	−4.767***	110.885***	−2.933***
`n_old`	−2.219**	−3.412***	100.079***	−3.128***
`ntilde1`	−4.376***	−2.963***	94.714***	−2.406
`ntilde2`	−2.111**	0.371	54.286*	−2.109
`ntilde3`	−0.742	2.728	46.885	−2.083
`ntilde4`	0.830	4.384	44.903	−1.884
`hp`	−8.433***	−9.454***	163.190***	−2.989***
`lrgdp2wpop`	−1.002	0.120	45.011	−1.916
`lnum_total`	0.948	−2.558***	107.365***	−2.765***
1st Differenced Series				
`Dlcpi`	−10.034***	−8.459***	160.200***	−3.229***
`Dlrppi`	−6.622***	−9.867***	178.767***	−3.45***
`Ddepr`	−0.913	0.974	39.883	−1.76
`Ddepr_y`	−5.233***	−3.419***	75.904***	−1.766
`Ddepr_o`	−1.033	−0.612	63.269**	−1.905
`Dn_young`	−4.245***	−3.392***	71.069***	−1.668
`Dn_working`	−1.013	0.756	39.467	−1.775
`Dn_old`	−1.635*	−1.202	67.949***	−1.883
`Dntilde1`	−1.815**	−2.571***	59.966**	−1.953
`Dntilde2`	−0.810	−1.148	53.193	−1.825
`Dntilde3`	0.162	0.441	44.018	−1.685
`Dntilde4`	0.300	0.948	41.426	−1.477
`Dhp`	−20.983***	−20.004***	398.684***	−4.702***
`Dlrgdp2wpop`	−15.048***	−14.659***	278.006***	−3.83***
`Dlnum_total`	−0.974	−2.494***	69.533***	−1.117

note) For all sample countries, except for Malaysia and Thailand, the sample period starts from 1981 and ends in 2015. For Malaysia and Thailand, the important variable, i.e., RPPI (resideicial property price index), is missing in the beginning of the period. Thus these two countries are eliminated from the sample when CIPS statistics are calculated since it requires a balanced panel data. For LLC, IPS, and Fisher-ADF, we use the unbalanced panel data. Number of asterisks indicates the level of significance: ***, **, and * for 1%, 5%, and 10%, respectively. For the level data, the test equations include individual intercepts and individual trends in order to control for both individual fixed effects and trends. For the first differenced data, only the individual intercepts are included. The optimal lag lengths for LLC, IPM, and Fisher type-ADF are selected by BIC, though the maximum lag length is restriced to be 3. For CIPS, the Portmanteau Q test for white noise is used.

Table 2 Tests of cross-sectional dependence

Variables	Pesaran CD test	p-value
lcpi	83.207	0.000
lrppi	67.960	0.000
depr	15.467	0.000
depr_y	66.025	0.000
depr_o	58.452	0.000
n_young	69.892	0.000
n_working	15.027	0.000
n_old	66.594	0.000
ntilde1	84.891	0.000
ntilde2	85.065	0.000
ntilde3	84.901	0.000
ntilde4	84.521	0.000
hp	34.340	0.000
lrgdp2wpop	83.587	0.000
lnum_total	79.352	0.000

2.3 Estimation results

2.3.1 Base models

The estimated results of our base models are reported in Table 3 for CPI inflation cases, and in Table 4 for RPPI inflation cases. Sample period starts from 1971 and ends in 2015. However, for some countries, the data at the beginning of the sample period are not available. Thus the dataset is unbalanced panel.

We start our examination from the cases of CPI inflation. Columns 1 and 2 of Table 3 corresponds to the specifications below.

$$\text{Model-1} \qquad \pi_{jt} = \mu + \mu_{j0} + \beta_1 depr_{jt} + \epsilon_{jt} \tag{1}$$

$$\text{Model-2} \qquad \pi_{jt} = \mu + \mu_{j0} + \lambda_t + \beta_1 depr_{jt} + \epsilon_{jt} \tag{2}$$

where μ is a constant term, μ_{j0} is the country-specific fixed effects with $\sum_{i=1}^{n} \mu_{j0} = 0$, and λ_t is the time effects with $\sum_{t=1}^{T} \lambda_t = 0$.

In these models, the CPI inflation is associated with the age dependency ratios. Both the dependent variable and the independent variables are not non-stationary from the unit root tests in the previous section.

For Model-1, the estimated coefficient is 0.2662, with a standard error 0.0165, and it is statistically significant at 5% level. The value of the coefficient 0.2662 indicates that one percentage point increase in age dependency ratio rises the CPI inflation rate by 0.2662%.

Though Model-1 controls the unobservable cross-sectional heterogeneity by including the country-specific fixed effects, the period variation is not controlled yet. Thus, in Model-2, we added a set of period fixed effects to the model. This addition is important for the case of CPI inflations, since the CPIs for most of our sample countries are affected by the price of crude oil which is likely to generate a cross-sectional synchronization. By adding the period fixed effects, the R^2 has increased drastically to 0.729. However, the coefficient of age dependency ratio, 0.0098, is very small and no more significant.

Table 3 Demography and CPI inflation (Sample period: 1971-2015)

Model: Dep. Var:	1 PI_CPI	2 PI_CPI	3 PI_CPI	4 PI_CPI	5 PI_CPI	6 PI_CPI	7 PI_CPI	8 PI_CPI
C	−9.3468 0.8836**	4.2364 0.7295**	2.8208 1.0114**	5.2498 0.8051**	1.9612 1.7204	2.568 1.4202	−56.4073 15.1882**	8.4507 13.6439
DEPR	0.2662 0.0165**	0.0098 0.0137						
DEPR_Y			0.2331 0.0144**	0.0303 0.0153*				
DEPR_O			−0.3203 0.0350**	−0.0813 0.0340*				
N_YOUNG					45.393 1.6621**	10.4734 2.6242**		
N_WORKING					−2.9492 3.226	2.2187 2.5994		
N_OLD					−42.4438 3.5819**	−12.6921 3.7922**		
NTILDE1							0.9342 0.1168**	0.1597 0.1112
NTILDE2							−0.2693 0.0261**	−0.0662 0.0261*
NTILDE3							0.026 0.0022**	0.0075 0.0023**
NTILDE4							−0.0008 0.0001**	−0.0003 0.0001**
Fixed effects	cs	cs & period	cs	cs & period	cs	cs & period	cs	cs & period
Period	1971-2015	1971-2015	1971-2015	1971-2015	1971-2015	1971-2015	1971-2015	1971-2015
No of Obs:	1025	1025	1025	1025	1025	1025	1025	1025
R^2:	0.304	0.729	0.480	0.731	0.498	0.733	0.581	0.739
F-statistic:	19.038	38.410	38.445	38.270	41.406	38.664	53.261	38.624
AIC	5.457	4.600	5.168	4.593	5.132	4.586	4.955	4.568
BIC	5.572	4.927	5.288	4.925	5.252	4.918	5.085	4.909

In this paper, our interest focus on the asymmetric age affects between young generation and old generation. Thus we have extended our analysis by splitting the age dependency ratio into two categories. The estimation results are reported in columns 3 and 4.

$$\text{Model-3} \qquad \pi_{jt} = \mu + \mu_{j0} + \beta_1 depr^y_{jt} + \beta_2 depr^o_{jt} + \epsilon_{jt} \tag{3}$$

$$\text{Model-4} \qquad \pi_{jt} = \mu + \mu_{j0} + \lambda_t + \beta_1 depr^y_{jt} + \beta_2 depr^o_{jt} + \epsilon_{jt} \tag{4}$$

where Model-3 includes only the country-specific fixed effects, and Model-4 includes both the country and period fixed effects.

The asymmetric age effects are very clear. In Model-3, one percentage point increase of young generation's dependency ratio, depr_y, rises the CPI inflation by 0.23%. On the other hand, one percentage point increase of old generation's dependency ratio lowers the CPI inflation by 0.32%. Qualitatively similar tendency is observed for Model-4, though both the size and statistical significance of the coefficients become smaller.

In the next two models, the effect of population is modeled by including the share of three generations.

$$\text{Model-5} \qquad \pi_{jt} = \mu_{j0} + \beta_1 n_{jt}^{young} + \beta_2 n_{jt}^{working} + \beta_3 n_{jt}^{old} + \epsilon_{jt} \tag{5}$$

$$\text{Model-6} \qquad \pi_{jt} = \mu_{j0} + \lambda_t + \beta_1 n_{jt}^{young} + \beta_2 n_{jt}^{working} + \beta_3 n_{jt}^{old} + \epsilon_{jt} \tag{6}$$

Since the generation shares sums up to 100, i.e., $n_{jt}^{young} + n_{jt}^{working} + n_{jt}^{old} = 100$, following Stoker (1986)[22], Fair & Dominguez (1991)[4], we impose a restriction on the parameters $\beta_1 + \beta_2 + \beta_3 = 0$ at the time of estimation. Thus, for instance, Model-5 is written as:

$$\begin{aligned}
\pi_{jt} &= \mu_{j0} + \beta_1 n_{jt}^{young} + \beta_2 n_{jt}^{working} + \beta_3 n_{jt}^{old} + \epsilon_{jt} \\
&= \mu_{j0} + \beta_1 n_{jt}^{young} + \beta_2 n_{jt}^{working} + (-\beta_1 - \beta_2) n_{jt}^{old} + \epsilon_{jt} \\
&= \mu_{j0} + \beta_1 (n_{jt}^{young} - n_{jt}^{old}) + \beta_2 (n_{jt}^{working} - n_{jt}^{old}) + \epsilon_{jt}
\end{aligned}$$

In a similar fashion, a coefficient β_3 is estimated. Thus the results of columns 5 and 6 in Table 3 are estimated in two steps.

Again, we observed the asymmetric effect of age groups. In Model 5, one percentage point increase in the population share of young generation increases the CPI by 45.4%, and that of old generation decreases 42.4%. The qualitatively similar asymmetry is observed for Model 6.

Next, we investigate the age effects on the inflation by using the residential property price index (RPPI). The estimation results are reported in Table 4. In general, the findings resemble the ones from CPI inflation. However, two points are worth mentioning. First, the asymmetric age effects are larger, reflecting the wider variation of RPPI inflation rate.

Second, although the period fixed effects still exists, it is less apparent. One reason is that the RPPI inflation is less synchronized across countries. Unlike CPI inflation whose variation is likely to be affected by the fluctuation of crude oil prices, there may not be a clear common factor which generate a synchronizing movement. Reflecting this, the estimated coefficients between the cross-section fixed effect models and the cross-section and period fixed effect models are much similar than the cases of CPI inflation.

2.3.2 Polynomial model

The investigation of age cohort effects are pursued by modeling the population effect by a flexible polynomial function (See Fair and Dominguez, 1991[4]). Fair and Dominguez (1991)[4] estimate the effects of the changing U.S. age distribution on consumption, housing-investment, money demand, and labor-force-participation equations. Though technically possible, it is not wise to estimate the coefficients of 17 age cohorts, n_{kjt} for $k = 1, \ldots, 17$. proceeded for Model-5 and Model-6 due to the degree of freedom problems. Thus, Fair and Dominguez (1991)[4] estimated the relevant coefficients by imposing two restrictions. The first is that the age-group coefficients are summed to zero. The second restriction is that they lie on a p-th degree polynomial such that

$$\beta_{1k} = \sum_{p=0}^{P} \gamma_p k^p \tag{7}$$

This idea comes from Almon's (1965)[1] polynomial-distributed lag technique, which is often used to obtain a parsimonious modeling in time series literature.

Using this specification, a following general model

$$\pi_{jt} = \mu_{j0} + \sum_{k=1}^{17} \beta_{1k} n_{kjt} + \epsilon_{jt} \tag{8}$$

Table 4 Demography and RPPI inflation (Sample period: 1971-2015)

Model:	1	2	3	4	5	6	7	8
Dep. Var:	PI_RPPI	PI_RPPI	PI_RPPI	PI_RPPI	PI_RPPI	PI_RPPI	PI_RPPI	PI_RPPI
C	−11.2691	4.3315	2.0191	6.4353	6.7786	2.6792	−7.7455	−23.1874
	2.5213**	2.8805	2.873	2.9295*	4.7865	4.85	44.7131	45.8133
DEPR	0.3421	0.0419						
	0.0483**	0.0553						
DEPR_Y			0.3181	0.158				
			0.0466**	0.0646*				
DEPR_O			−0.3034	−0.2619				
			0.0878**	0.1046*				
N_YOUNG					52.5655	31.9198		
					4.6966**	9.1451**		
N_WORKING					−8.8635	2.1311		
					9.1837	9.2674		
N_OLD					−43.702	−34.0508		
					8.9993**	11.7632**		
NTILDE1							0.6013	0.5756
							0.3297	0.3586
NTILDE2							−0.1995	−0.161
							0.0723**	0.0827
NTILDE3							0.0204	0.0148
							0.0061**	0.0073*
NTILDE4							−0.0007	−0.0004
							0.0002**	0.0002*
Fixed effects	cs	cs & period	cs	cs & period	cs	cs & period	cs	cs & period
Period	1971-2015	1971-2015	1971-2015	1971-2015	1971-2015	1971-2015	1971-2015	1971-2015
No of Obs:	981	981	981	981	981	981	981	981
R^2:	0.108	0.296	0.173	0.305	0.175	0.305	0.186	0.308
F-statistic:	5.050	5.718	8.339	5.871	8.432	5.887	8.362	5.778
AIC	6.969	6.823	6.895	6.812	6.893	6.811	6.884	6.812
BIC	7.088	7.162	7.020	7.156	7.018	7.155	7.019	7.165

is transformed as

$$\pi_{jt} = \mu_{j0} + \sum_{p=1}^{P} \gamma_p \tilde{n}_{pjt} + \epsilon_{jt}$$

where

$$\tilde{n}_{pjt} = \sum_{k=1}^{K} \left(k^p n_{kjt} - \frac{k^p}{K} \right)$$

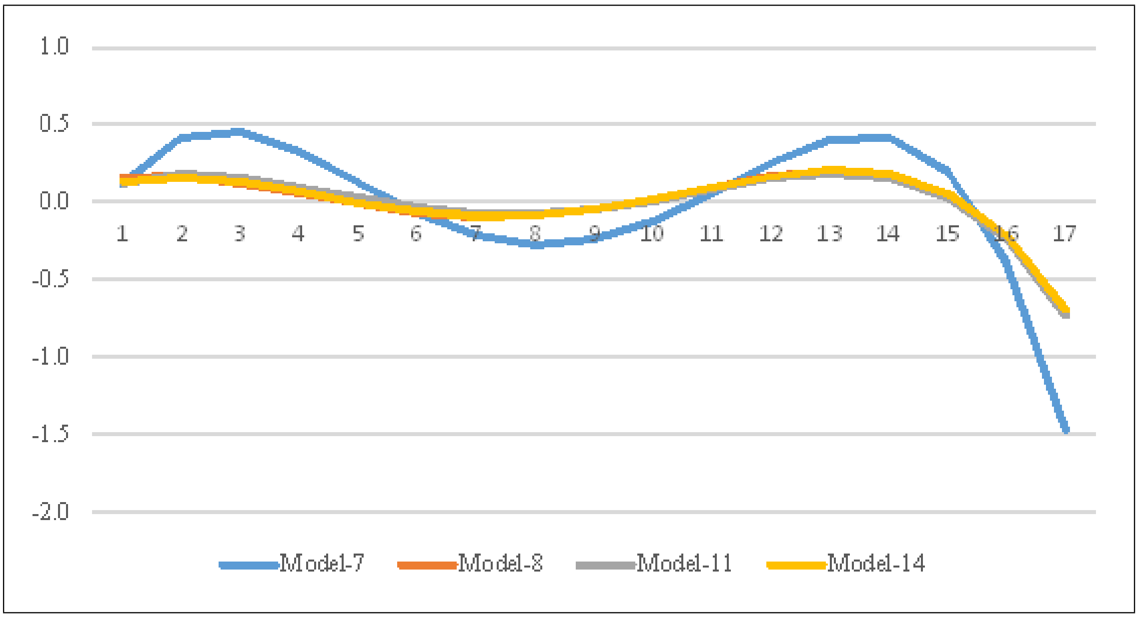
with P parameters to be estimated. Following Juselius and Takáts (2014)[7], we set $P = 4$.

Thus, Model-7 and Model-8, which approximate the the effect of cohort by a polynomial function, are

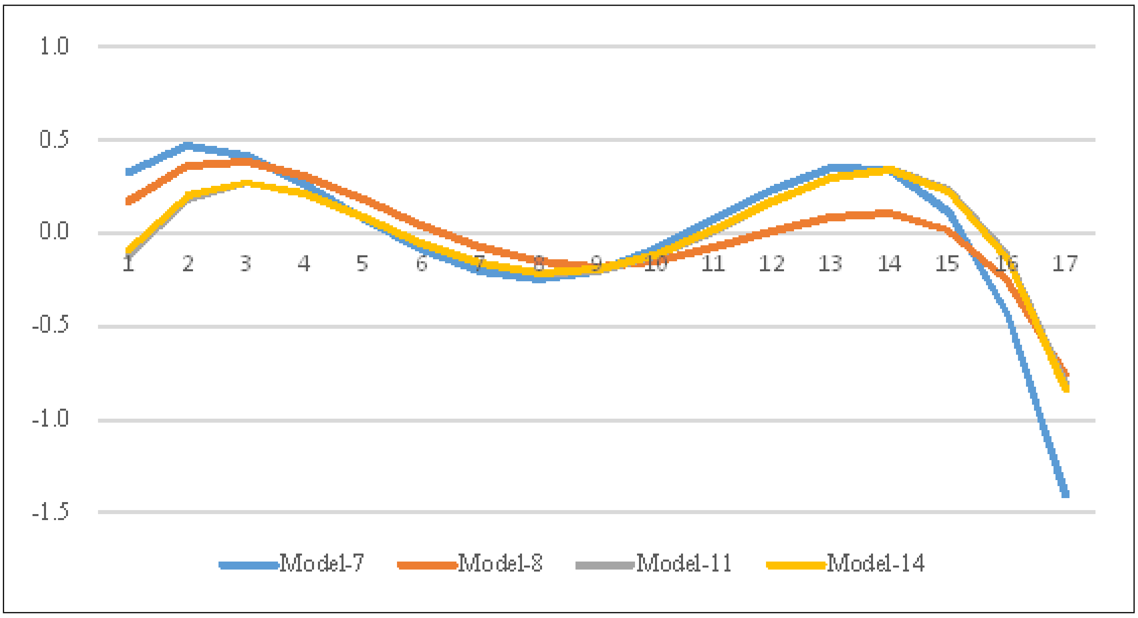
$$\text{Model-7} \qquad \pi_{jt} = \mu + \mu_{j0} + \sum_{p=1}^{4} \gamma_p \tilde{n}_{pjt} + \epsilon_{jt} \tag{9}$$

$$\text{Model-8} \qquad \pi_{jt} = \mu + \mu_{j0} + \lambda_t + \sum_{p=1}^{4} \gamma_p \tilde{n}_{pjt} + \epsilon_{jt} \tag{10}$$

Estimated coefficients $\hat{\gamma}_1, \hat{\gamma}_2, \hat{\gamma}_3$, and $\hat{\gamma}_4$ are reported in columns 7 and 8 of Table 3 for CPI inflation cases, and Table 4 for RPPI inflation cases. Also, the polynomial coefficients (with control variables) are reported in Models 11 and 14 in Table 5. Figure 1 plots the calculated $\hat{\beta}_1, \ldots, \hat{\beta}_{17}$ from $\hat{\gamma}$s of these four models. Shapes of curvature originated from the 4-th degree polynomial approximation. Thus the behavior of the both edges should be interpreted with caution. Roughly speaking, if we take the averages of $\hat{\beta}$s for three generation groups, the reported tendency, i.e., the effects of young generation is positive and highest, followed by the working populations, and that of old generation is negative, is again confirmed.



(a) CPI



(b) RPPI

Figure 1 Age cohort effects on CPI and RPPI inflations

2.4 Differences from the work by Juselius and Takáts (2014)

Although the work by Juselius and Takáts (2014)[7] are similar, there are important distinctions between our work and theirs.

- The sample period are different. Most of the regression models in Juselius and Takáts (2014) are estimated by using the data from 1955 to 2010. The end of sample period in our study is extended from 2010 to 2015. Thus includes the after turmoil period of the Global Financial Crisis. On the other hand, our main dataset starts from 1971.
- The sample countries are slightly different. In Juselius and Takáts (2014), the number of sample countries is 22. In our dataset, 23 countries are included of which 19 countries are the same. In Juselius and Takáts (2014), Austria, Greece, and Portugal are included, but they are not included in our dataset. On the other hand, Hong Kong, Malaysia, Thailand, and South Africa are included in our sample, but not in their dataset. On average, our dataset includes more Asian countries than the European countries.
- On the model specification, our benchmark specification includes both country-specific and period fixed effects. In Juselius and Takáts (2014), after estimating a series of models, they have selected the model with coutry-fixed effects with 1974 and 1980 year dummies. We formally tested the exclusion of period fixed effects except for years 1974 and 1980, but the test rejected the exclusion restriction. Thus we decided to use the cross-section and period fixed effects as a benchmark specification.
- In this paper, we are interested in the asymmetric age effects on the CPI and the RPPI inflations. Although the flexibility of polynomial models (Models 7-8) are preferable, we use the simpler specifications (Models 3-6) for at least two reasons. First, the degree of polynomial function affects the shape of curvature, especially at the both edges. Second, in our current definition, the highest age cohort is 80 years old and above, thus the aging country will have a big mass of population in this category. We anticipate that this aggregation might underestimate the ago cohort effects at the right edge.
- A set of control variables are different. Effects of monetary and fiscal policy on inflations are investigated in Juselius and Takáts (2014). In this paper, we concentrate our attention to the demographic effect to the inflations. In order to control other possible effects, other than the policy effects, we included the output gaps, and the growth rate of total population. The results with these variables are reported in Table 5, and discussed in the next section. Examination of policy effects on the inflations will be our future research topic.
- Juselius and Takáts (2014) are interested in the demographic effects on the CPI inflation only. Thus in their model, the asset price enters as an independent variable. On the other hand, we are interested in the demographic effects on the good and services (i.e., CPI inflation) as well as the asset (i.e., RPPI inflation).

Table 5 Demography and inflations (with control variables; Sample period: 1971-2015)

Models	9	10	11	12	13	14	9	10	11	12	13	14
Dep. Var:	PI_CPI						PI_RPPI					
C	5.2909	2.539	6.6987	5.2741	2.541	−2.0385	7.0215	2.1938	−30.3602	6.8922	1.7594	−68.5691
	0.7873**	1.3881	13.3306	0.7881**	1.4146	15.4633	2.7343*	4.5251	42.7483	2.7397*	4.5542	48.2007
DEPR_Y	0.029			0.0234			0.1337			0.1113		
	0.015			0.0181			0.0603*			0.0666		
DEPR_O	−0.0811			−0.0757			−0.2519			−0.2289		
	0.0333*			0.0347*			0.0976*			0.1019*		
N_YOUNG		0.105			0.1052			0.2921			0.2568	
		0.0256**			0.0302**			0.0854**			0.0948**	
N_WORKING		0.0227			0.0227			0.0345			0.0402	
		0.0254			0.0258			0.0865			0.0867	
N_OLD		−0.1277			−0.1278			−0.3266			−0.297	
		0.0371**			0.0388**			0.1098**			0.1151*	
NTILDE1			0.1728			0.2293			0.5895			0.8381
			0.1087			0.1199			0.3346			0.3645*
NTILDE2			−0.0688			−0.0809			−0.1595			−0.2129
			0.0255**			0.0277**			0.0771*			0.0831*
NTILDE3			0.0077			0.0088			0.0146			0.0191
			0.0023**			0.0024**			0.0068*			0.0073**
NTILDE4			−0.0003			−0.0003			−0.0004			−0.0006
			0.0001**			0.0001**			0.0002*			0.0002**
HP	0.2159	0.217	0.2174	0.2144	0.217	0.2141	1.1745	1.176	1.1741	1.1645	1.165	1.151
	0.0323**	0.0321**	0.0318**	0.0324**	0.0323**	0.0319**	0.1007**	0.1006**	0.1005**	0.1015**	0.1014**	0.1013**
DLNUM_TOTAL				0.1284	−0.0017	0.2757				0.546	0.5699	1.2529
				0.2327	0.2243	0.2474				0.6859	0.6662	0.7331
Fixed effects	cs & period	cs & period	cs & period	cs & period	cs & period	cs & period	cs & period	cs & period	cs & period	cs & period	cs & period	cs & period
Period	1971-2015	1971-2015	1971-2015	1971-2015	1971-2015	1971-2015	1971-2015	1971-2015	1971-2015	1971-2015	1971-2015	1971-2015
No. of Obs:	1025	1025	1025	1025	1025	1025	981	981	981	981	981	981
R^2:	0.743	0.746	0.751	0.743	0.746	0.752	0.395	0.396	0.398	0.395	0.396	0.400
F-statistic:	40.091	40.543	40.564	39.494	39.922	40.028	8.617	8.647	8.465	8.500	8.531	8.406

2.5 Robustness check

In order to examine if our findings on the asymmetric age affects are robust, we have extended our analysis in two dimensions.

First, two variables are added to the model. They are: 1) output gaps, and 2) growth rates of total population. Results are reported in Table 5. For all the cases, we have included both the country fixed effects and the period fixed effects. Again, we observe the qualitatively similar age asymmetric effects.

As a second robustness check, we have re-estimated the models with a longer sample period. Unfortunately, the RPPI series are available only from 1971. Thus we have investigated this for CPI cases only. Results are reported in Table 6. For all the cases, we have included both the country fixed effects and the period fixed effects. Notice that the estimated models do not include the control variables due to non-availability. We still observe the statistically significant asymmetric age effects.

Table 6 Demography and CPI inflation (sample period: 1956-2015)

Models Dep. Var:	15 PI_CPI	16	17	18	19	20	21	22
C	−1.9011 0.6925**	4.032 0.6102**	5.1861 0.9137**	5.592 0.6538**	0.2921 1.5925	0.3333 1.1873	−181.3589 12.7994 **	−17.0231 12.3802
DEPR	0.1168 0.0124**	0.0094 0.011						
DEPR_Y			0.088 0.0121**	0.0482 0.0126**				
DEPR_O			−0.2188 0.0321**	−0.1586 0.0297**				
N_YOUNG					22.1083 1.4116**	16.5432 2.3156**		
N_WORKING					3.0642 2.9744	4.2383 2.1321*		
N_OLD					−25.1725 3.3205**	−20.7814 3.2742**		
NTILDE1							1.7002 0.1061**	0.4136 0.1026**
NTILDE2							−0.3898 0.0249**	−0.1239 0.0244**
NTILDE3							0.0321 0.0022**	0.0122 0.0022**
NTILDE4							−0.0009 0.0001**	−0.0004 0.0001**
Fixed effects	cs	cs & period	cs	cs & period	cs	cs & period	cs	cs & period
Period	1956-2015	1956-2015	1956-2015	1956-2015	1956-2015	1956-2015	1956-2015	1956-2015
No of Obs:	1311	1311	1311	1311	1311	1311	1311	1311
R^2:	0.176	0.661	0.250	0.671	0.261	0.675	0.430	0.685
F-statistic:	11.962	29.186	17.840	30.127	18.878	30.668	37.228	31.304
AIC	5.532	4.734	5.439	4.706	5.425	4.694	5.168	4.666
BIC	5.626	5.062	5.538	5.038	5.524	5.026	5.275	5.005

3 Simulation

3.1 Prediction for Population Structure

In this section, we use the model 7 (Table 4) to predict inflation rate and real property prices in 23 countries each five years until 2050, a quarter century from the present. We calculate the rate of change in the real property price and inflation for each country for each five years and add them up to get the level estimate of the real property price and inflation, assuming (a) no bubble and bust effects, and (b) constant income per capita of working age population ($\Delta \ln Y_{it} = 0$). In addition, we use in this calculation the estimated rate of change in the total population, nyoung, noworking and nold, which are derived from detailed estimates of each country's population and its components by United Nations, 'World Population Prospects' (Medium Fertility Estimates).

In this sense, we are not predicting the future here; rather, we are simulating the impact that changes in population factors alone will have on inflation rates and housing prices in various countries in future.

Before considering the simulation results, let us first look at changes over time in the young generation (Age 0-14 / Total Population), working generation (Age 15-64 / Total Population), and old generation (Age 65+ / Total Population) in various countries.

In 1950, the young generation represented an extremely high proportion of the population in Asian countries; for example, it was 35% in Japan, 30% in Hong Kong, and over 40% in South Korea, Malaysia, and Thailand. The young generation goes on to become the working generation. As a result, we can see that in 2015, the working generation accounted for around 60% to 70% of the population in most countries, providing a strong labor force that drives high economic growth.

The old generation, meanwhile, in 1950 represented 10% or more of the population in only a few Western countries, such as Belgium, France, and Sweden, while in 2015, it exceeds 20% only in a few countries, including Germany, Finland, Italy, and Japan.

Next, let us consider future demographics in different countries. As of 2015, the young generation had fallen below 15% in Switzerland, Spain, Italy, Hong Kong, Japan, and South Korea. The countries with the lowest proportions are Hong Kong (12%) and Japan (13%). In other countries, the figure is forecast to fall below 15% in future: from 2040 in Canada, from 2035 in Switzerland, and from 2030 in Thailand.

As Mankiw and Weil (1989)[9] have pointed out, this ongoing decline in birthrates means that macro-economic demand will decline in future, particularly housing demand.

Turning next to the old generation, we find that in Japan, where the aging of society is advancing the fastest, the proportion was 26% in 2015. As this society ages even further, the level will exceed 30% in 2030. Hong Kong, Italy, and South Korea will then surpass 30% in 2040. This ongoing decline in the birthrate coupled with the progressive aging of society means that the proportion of working generation to population will shrink in the long term.

The working generation proportion remained high and stable from 1950 to 2015, in the range of 60% to 75%. On the macro level, this provided a strong labor force, which may be considered to have driven global economic growth. However, in Japan, where the birthrate continues to decline and society continues to age, the working age percentage will fall below 60% in 2020, followed by other countries at various times: Finland in 2025, then Germany, France, Italy, and Holland in 2030. From 2035 onward, it will drop below 60% in most countries.

These macro-level trends show that while the young-age dependency ratio will drop from

2035 onward, the old-age dependency ratio will rise at a rate far exceeding the rate of that drop, so the proportion of the population that is productive will decrease.

Table 7-a Population cohort ratio: Age 0-14 / Total Population

		Ratio Age 0-14														
		1950	1960	1970	1980	1990	2000	2010	2015	2020	2025	2030	2035	2040	2045	2050
Australia	AUS	26.60%	30.18%	29.04%	25.26%	22.03%	20.84%	19.01%	18.70%	19.25%	19.06%	18.60%	17.82%	17.29%	17.11%	17.16%
Belgium	BEL	20.92%	23.88%	23.58%	20.01%	18.05%	17.56%	16.78%	16.94%	17.30%	17.02%	16.53%	16.07%	15.88%	15.97%	16.16%
Canada	CAN	29.68%	33.73%	30.13%	22.76%	20.70%	19.17%	16.47%	15.97%	16.23%	15.98%	15.61%	15.14%	14.83%	14.76%	14.94%
Switzerland	CHE	23.51%	24.15%	23.73%	20.00%	17.03%	17.44%	15.05%	14.78%	15.01%	15.27%	15.29%	14.95%	14.61%	14.45%	14.59%
Germany	DEU	23.24%	21.44%	23.33%	18.62%	15.93%	15.38%	13.52%	12.89%	12.85%	13.09%	13.18%	12.94%	12.57%	12.36%	12.44%
Denmark	DNK	26.30%	25.20%	23.28%	20.82%	17.02%	18.47%	17.96%	16.88%	16.29%	15.98%	16.50%	16.84%	16.75%	16.38%	16.06%
Spain	ESP	26.49%	27.36%	28.12%	25.92%	20.00%	14.77%	14.60%	14.88%	14.24%	12.97%	12.19%	11.81%	11.94%	12.36%	12.70%
Finland	FIN	29.76%	30.40%	24.62%	20.31%	19.32%	18.15%	16.51%	16.34%	16.48%	16.20%	15.85%	15.57%	15.40%	15.43%	15.55%
France	FRA	22.65%	26.27%	24.75%	22.10%	19.86%	18.79%	18.46%	18.48%	17.98%	17.48%	17.11%	16.94%	16.94%	16.94%	16.82%
United Kingdom	GBR	22.45%	23.15%	24.16%	21.02%	18.97%	19.05%	17.70%	17.77%	18.27%	17.99%	17.47%	16.88%	16.49%	16.46%	16.60%
Hong Kong (China)	HKG	30.35%	40.89%	37.07%	25.40%	21.49%	17.20%	12.06%	11.96%	13.12%	14.23%	13.53%	12.60%	11.78%	11.51%	12.05%
Ireland	IRL	28.62%	30.92%	30.74%	30.41%	27.52%	21.38%	20.72%	21.78%	21.11%	19.21%	17.47%	16.81%	17.06%	17.54%	17.61%
Italy	ITA	26.70%	25.06%	24.65%	21.96%	16.47%	14.34%	14.02%	13.71%	13.23%	12.67%	12.50%	12.53%	12.72%	12.91%	13.02%
Japan	JPN	35.38%	30.16%	24.12%	23.56%	18.31%	14.62%	13.29%	12.86%	12.60%	12.40%	12.22%	12.14%	12.18%	12.30%	12.43%
Republic of Korea	KOR	42.49%	40.91%	42.13%	33.92%	25.63%	20.96%	16.24%	13.99%	13.41%	13.27%	13.21%	13.00%	12.52%	11.85%	11.44%
Netherlands	NLD	29.20%	30.06%	27.44%	22.51%	18.14%	18.47%	17.37%	16.52%	15.77%	15.57%	15.65%	15.67%	15.54%	15.31%	15.14%
Norway	NOR	24.24%	25.92%	24.49%	22.18%	18.95%	20.01%	18.80%	17.97%	18.14%	18.01%	17.84%	17.43%	17.06%	16.85%	16.83%
New Zealand	NZL	29.09%	32.88%	31.76%	27.19%	23.25%	22.75%	20.51%	20.21%	19.65%	18.84%	18.14%	17.71%	17.30%	16.94%	16.66%
Sweden	SWE	23.32%	22.44%	20.85%	19.59%	17.93%	18.43%	16.51%	17.28%	18.01%	18.03%	17.79%	17.31%	17.01%	17.11%	17.41%
United States of America	USA	26.99%	30.80%	28.20%	22.70%	21.60%	21.26%	19.75%	18.95%	18.58%	18.26%	18.21%	17.98%	17.72%	17.54%	17.46%
South Africa	ZAF	38.58%	40.94%	42.07%	41.55%	38.94%	34.87%	30.94%	29.24%	28.35%	26.77%	25.40%	24.09%	23.08%	22.22%	21.35%
Malaysia	MYS	40.90%	45.50%	44.79%	38.99%	37.10%	33.32%	27.29%	24.50%	22.90%	22.48%	21.64%	20.39%	18.97%	17.72%	16.87%
Thailand	THA	42.13%	42.73%	43.99%	39.44%	30.21%	23.98%	19.20%	17.71%	16.36%	15.08%	13.97%	13.33%	13.03%	12.84%	12.69%

Table 7-b Population cohort ratio: Age 15-64 / Total Population

		Ratio Age 15-64														
		1950	1960	1970	1980	1990	2000	2010	2015	2020	2025	2030	2035	2040	2045	2050
Australia	AUS	65.23%	61.22%	62.73%	65.13%	66.87%	66.81%	67.50%	66.26%	64.43%	63.09%	62.01%	61.90%	61.38%	61.28%	60.35%
Belgium	BEL	68.06%	64.13%	63.02%	65.54%	66.89%	65.52%	66.04%	64.83%	63.39%	61.95%	60.42%	59.24%	58.42%	57.76%	57.14%
Canada	CAN	62.65%	58.60%	61.89%	67.84%	68.07%	68.28%	69.37%	67.89%	65.49%	63.09%	60.92%	60.21%	59.89%	59.50%	58.70%
Switzerland	CHE	67.05%	65.67%	65.03%	66.18%	68.40%	67.26%	68.04%	67.18%	65.82%	63.76%	61.26%	59.25%	58.45%	57.98%	57.02%
Germany	DEU	67.07%	67.05%	63.02%	65.71%	69.20%	68.41%	65.87%	65.87%	64.41%	61.92%	58.80%	56.27%	56.10%	56.02%	55.22%
Denmark	DNK	64.68%	64.19%	64.42%	64.74%	67.35%	66.66%	65.38%	64.16%	63.57%	62.70%	60.91%	59.09%	58.66%	58.83%	59.60%
Spain	ESP	66.28%	64.46%	62.28%	63.04%	66.65%	68.59%	68.24%	66.33%	65.44%	64.31%	62.08%	59.41%	56.01%	52.79%	51.51%
Finland	FIN	63.60%	62.29%	66.22%	67.72%	67.30%	66.93%	66.36%	63.18%	61.00%	59.70%	58.73%	58.19%	58.86%	58.50%	57.97%
France	FRA	65.95%	62.15%	62.42%	63.98%	66.12%	65.11%	64.52%	62.40%	61.17%	60.16%	59.00%	57.98%	57.04%	56.93%	56.85%
United Kingdom	GBR	66.71%	65.10%	62.81%	64.03%	65.30%	65.12%	66.13%	64.47%	63.28%	62.46%	61.12%	60.07%	59.69%	59.41%	58.67%
Hong Kong (China)	HKG	67.15%	56.29%	59.01%	68.73%	69.82%	71.79%	75.03%	72.98%	68.68%	63.51%	60.19%	58.22%	56.72%	55.18%	53.44%
Ireland	IRL	60.41%	57.96%	58.23%	58.98%	61.43%	68.07%	68.14%	65.08%	63.93%	64.17%	63.90%	62.93%	60.53%	58.07%	56.60%
Italy	ITA	65.21%	65.45%	64.26%	64.73%	68.72%	67.58%	65.54%	63.88%	62.76%	61.41%	58.88%	56.06%	53.50%	52.17%	51.91%
Japan	JPN	59.68%	64.11%	68.85%	67.39%	69.74%	68.20%	63.77%	60.80%	58.94%	58.17%	57.35%	55.96%	53.61%	52.16%	51.25%
Republic of Korea	KOR	54.64%	55.35%	54.55%	62.22%	69.39%	71.70%	72.67%	72.88%	70.83%	67.03%	63.08%	59.56%	56.65%	54.87%	53.42%
Netherlands	NLD	63.11%	61.01%	62.45%	66.08%	69.16%	67.96%	67.08%	65.25%	63.91%	61.91%	59.45%	57.37%	56.68%	57.04%	57.39%
Norway	NOR	66.19%	63.03%	62.65%	63.12%	64.77%	64.82%	66.19%	65.70%	64.55%	63.27%	62.13%	60.94%	60.12%	59.98%	59.51%
New Zealand	NZL	61.95%	58.47%	59.76%	63.06%	65.67%	65.49%	66.49%	64.93%	63.64%	62.34%	60.66%	59.64%	58.80%	59.11%	59.23%
Sweden	SWE	66.50%	65.82%	65.49%	64.12%	64.28%	64.30%	65.29%	62.77%	61.30%	60.51%	60.01%	59.21%	59.20%	59.16%	58.77%
United States of America	USA	64.74%	60.05%	62.06%	65.94%	65.88%	66.42%	67.23%	66.26%	64.71%	62.86%	61.11%	60.60%	60.42%	60.64%	60.31%
South Africa	ZAF	57.83%	55.19%	54.49%	55.35%	57.87%	61.15%	64.01%	65.73%	66.18%	67.03%	67.52%	68.11%	68.57%	68.87%	68.45%
Malaysia	MYS	54.05%	51.07%	51.94%	57.43%	59.29%	62.84%	67.85%	69.64%	70.09%	69.09%	68.42%	68.24%	68.26%	67.99%	66.33%
Thailand	THA	54.62%	53.95%	52.51%	56.82%	65.27%	69.46%	71.91%	71.82%	70.67%	68.80%	66.58%	63.83%	61.13%	58.80%	57.23%

Table 7-c Population cohort ratio: Age 65- / Total Population

		Ratio Age 65-														
		1950	1960	1970	1980	1990	2000	2010	2015	2020	2025	2030	2035	2040	2045	2050
Australia	AUS	8.17%	8.60%	8.23%	9.62%	11.10%	12.35%	13.50%	15.04%	16.32%	17.84%	19.40%	20.28%	21.33%	21.61%	22.49%
Belgium	BEL	11.01%	11.99%	13.40%	14.45%	15.06%	16.92%	17.18%	18.22%	19.31%	21.03%	23.04%	24.68%	25.70%	26.26%	26.70%
Canada	CAN	7.67%	7.67%	7.98%	9.39%	11.23%	12.55%	14.15%	16.14%	18.28%	20.93%	23.47%	24.65%	25.28%	25.74%	26.36%
Switzerland	CHE	9.44%	10.18%	11.24%	13.81%	14.57%	15.30%	16.91%	18.04%	19.17%	20.97%	23.45%	25.80%	26.94%	27.57%	28.39%
Germany	DEU	9.69%	11.51%	13.64%	15.68%	14.87%	16.20%	20.60%	21.24%	22.74%	24.98%	28.02%	30.79%	31.33%	31.61%	32.34%
Denmark	DNK	9.03%	10.61%	12.30%	14.44%	15.63%	14.87%	16.66%	18.96%	20.14%	21.32%	22.59%	24.07%	24.60%	24.78%	24.35%
Spain	ESP	7.23%	8.18%	9.60%	11.04%	13.35%	16.64%	17.16%	18.79%	20.32%	22.72%	25.73%	28.78%	32.04%	34.85%	35.79%
Finland	FIN	6.63%	7.31%	9.16%	11.98%	13.39%	14.92%	17.13%	20.48%	22.52%	24.11%	25.42%	26.23%	25.74%	26.07%	26.48%
France	FRA	11.40%	11.59%	12.83%	13.92%	14.02%	16.10%	17.02%	19.12%	20.85%	22.36%	23.89%	25.08%	26.01%	26.13%	26.33%
United Kingdom	GBR	10.83%	11.75%	13.04%	14.95%	15.73%	15.83%	16.18%	17.76%	18.45%	19.55%	21.41%	23.05%	23.83%	24.13%	24.73%
Hong Kong (China)	HKG	2.50%	2.82%	3.92%	5.87%	8.70%	11.01%	12.91%	15.06%	18.19%	22.27%	26.28%	29.19%	31.51%	33.30%	34.52%
Ireland	IRL	10.97%	11.12%	11.03%	10.61%	11.05%	10.55%	11.14%	13.14%	14.96%	16.62%	18.63%	20.26%	22.41%	24.38%	25.79%
Italy	ITA	8.09%	9.50%	11.09%	13.31%	14.81%	18.08%	20.44%	22.41%	24.01%	25.93%	28.63%	31.40%	33.78%	34.92%	35.07%
Japan	JPN	4.95%	5.73%	7.03%	9.05%	11.95%	17.18%	22.94%	26.34%	28.45%	29.43%	30.43%	31.90%	34.21%	35.54%	36.31%
Republic of Korea	KOR	2.87%	3.74%	3.32%	3.86%	4.98%	7.34%	11.09%	13.13%	15.75%	19.70%	23.71%	27.43%	30.83%	33.28%	35.15%
Netherlands	NLD	7.69%	8.93%	10.11%	11.41%	12.70%	13.57%	15.55%	18.23%	20.31%	22.52%	24.91%	26.96%	27.78%	27.65%	27.47%
Norway	NOR	9.57%	11.05%	12.87%	14.69%	16.29%	15.17%	15.01%	16.33%	17.31%	18.72%	20.03%	21.63%	22.81%	23.17%	23.67%
New Zealand	NZL	8.96%	8.64%	8.48%	9.75%	11.08%	11.76%	13.00%	14.86%	16.71%	18.82%	21.20%	22.65%	23.90%	23.94%	24.12%
Sweden	SWE	10.19%	11.75%	13.66%	16.29%	17.78%	17.26%	18.20%	19.94%	20.69%	21.46%	22.20%	23.47%	23.79%	23.73%	23.81%
United States of America	USA	8.26%	9.15%	9.74%	11.36%	12.52%	12.32%	13.01%	14.79%	16.71%	18.88%	20.68%	21.41%	21.86%	21.82%	22.24%
South Africa	ZAF	3.58%	3.87%	3.45%	3.10%	3.19%	3.98%	5.05%	5.03%	5.47%	6.20%	7.08%	7.80%	8.35%	8.91%	10.19%
Malaysia	MYS	5.06%	3.43%	3.27%	3.58%	3.61%	3.84%	4.86%	5.86%	7.01%	8.43%	9.94%	11.38%	12.76%	14.29%	16.80%
Thailand	THA	3.25%	3.31%	3.50%	3.75%	4.52%	6.57%	8.90%	10.47%	12.97%	16.12%	19.45%	22.83%	25.84%	28.36%	30.07%

3.2 Simulation Results

What kind of effect will these demographic changes have on future inflation rates and housing prices? Here, using Model 7 constructed in Chapter 2, we have simulated changes in commodity prices and housing prices according to the changes in the proportion of the total population that is age 0-14, age 15-64, and age 65+, as shown in Tables 7a-c.

The simulation results are shown in Tables 8a and b and Figures 2 and 3. These show future estimate values, taking 2015 as 100. First, commodity price levels (CPI) will decline continuously in Japan, reaching 83 in 2030, 68 in 2040, and around 50 in 2050, which can be understood as the effect of deflation. Other countries where there is likewise a strong possibility of deflation include Germany, Spain, Hong Kong, and Italy. The results suggest that Italy will face deflation from 2025 onward, Germany from 2030 onward, Spain from 2035 onward, and Hong Kong from 2040 onward.

A more serious impact will be felt in the housing market. Most countries, with the exception of South Africa and Malaysia, will face asset deflation in this market. Looking at the rates of decline suggests that values may be expected to drop at such a rate so as to be described as an asset meltdown. The results show that by 2050, housing prices in Japan will drop to one-quarter of their 2015 level; in Germany, Spain, Hong Kong, Italy, and South Korea, they will drop to one-third of their 2015 level; and in Canada, Switzerland, Denmark, Spain, Finland, France, and even Thailand, they will drop to half of their 2015 level.

Table 8-a Prediction of Inflation rate

		CPI						
		2020	2025	2030	2035	2040	2045	2050
Australia	AUS	111.603	122.510	132.062	140.542	147.574	154.376	160.063
Belgium	BEL	107.237	112.816	115.960	116.906	116.508	115.474	114.032
Canada	CAN	107.830	113.002	115.125	115.592	115.118	114.058	112.370
Switzerland	CHE	106.235	110.902	112.834	111.837	109.339	106.114	102.166
Germany	DEU	101.322	100.389	96.370	89.729	82.928	76.328	69.741
Denmark	DNK	105.813	110.432	114.028	116.117	117.545	118.557	119.934
Spain	ESP	104.596	106.058	103.812	98.210	89.804	79.846	70.397
Finland	FIN	103.324	104.863	104.797	103.701	103.066	102.098	100.757
France	FRA	105.884	110.094	112.471	113.387	113.203	112.877	112.250
United Kingdom	GBR	108.689	116.636	122.485	126.087	128.516	130.560	131.892
Hong Kong (China)	HKG	106.363	109.013	106.776	100.964	92.770	83.518	74.411
Ireland	IRL	114.148	126.985	137.236	145.389	150.798	153.577	154.183
Italy	ITA	100.161	98.058	93.227	86.073	77.551	69.084	61.479
Japan	JPN	95.296	89.794	83.643	76.675	68.585	60.515	52.984
Republic of Korea	KOR	109.223	114.452	114.981	110.972	103.073	92.964	82.024
Netherlands	NLD	105.365	108.397	108.805	106.899	104.052	101.315	98.762
Norway	NOR	109.905	118.980	126.968	133.009	137.383	141.234	144.428
New Zealand	NZL	111.372	120.907	127.651	132.483	135.455	138.192	140.540
Sweden	SWE	106.069	111.624	116.432	119.581	122.234	125.076	128.067
United States of America	USA	110.809	119.899	127.312	134.010	140.237	146.679	152.702
South Africa	ZAF	129.859	166.208	209.559	260.759	321.172	391.808	469.965
Malaysia	MYS	124.731	153.080	184.333	217.495	251.383	284.395	312.325
Thailand	THA	113.941	124.963	131.713	133.627	131.168	125.264	117.392

Table 8-b Prediction of Residential Property Prices

		RPPI						
		2020	2025	2030	2035	2040	2045	2050
Australia	AUS	97.754	94.436	89.901	84.446	78.370	72.471	66.659
Belgium	BEL	94.073	87.257	79.483	71.292	63.395	56.209	49.786
Canada	CAN	93.738	86.136	77.540	68.938	60.844	53.500	46.928
Switzerland	CHE	92.101	84.021	75.410	66.409	57.837	50.085	43.191
Germany	DEU	88.066	76.576	65.289	54.500	45.169	37.284	30.649
Denmark	DNK	92.650	84.908	77.551	70.363	63.562	57.146	51.363
Spain	ESP	90.721	79.998	68.604	57.415	47.062	37.999	30.589
Finland	FIN	91.363	82.366	73.356	64.800	57.338	50.638	44.649
France	FRA	93.733	86.551	78.832	71.118	63.762	57.120	51.041
United Kingdom	GBR	95.496	90.284	83.895	76.669	69.443	62.753	56.557
Hong Kong (China)	HKG	91.023	81.499	70.554	59.344	48.737	39.438	31.818
Ireland	IRL	100.389	97.910	92.666	86.217	79.268	72.264	65.310
Italy	ITA	87.640	75.407	63.603	52.665	42.990	34.884	28.309
Japan	JPN	84.533	70.849	58.875	48.399	39.182	31.472	25.177
Republic of Korea	KOR	92.770	83.719	73.501	62.809	52.202	42.387	33.844
Netherlands	NLD	92.081	83.390	74.375	65.443	57.193	49.917	43.550
Norway	NOR	96.097	91.379	86.000	79.770	73.145	66.776	60.746
New Zealand	NZL	97.883	93.754	87.806	81.110	74.010	67.277	60.918
Sweden	SWE	93.854	87.658	81.274	74.380	67.727	61.750	56.439
United States of America	USA	96.881	92.246	86.750	81.007	75.231	69.760	64.459
South Africa	ZAF	114.236	127.994	140.797	152.293	162.590	171.565	178.078
Malaysia	MYS	107.503	114.064	118.909	121.361	121.112	118.237	112.619
Thailand	THA	97.204	91.420	83.195	73.564	63.557	53.887	45.096

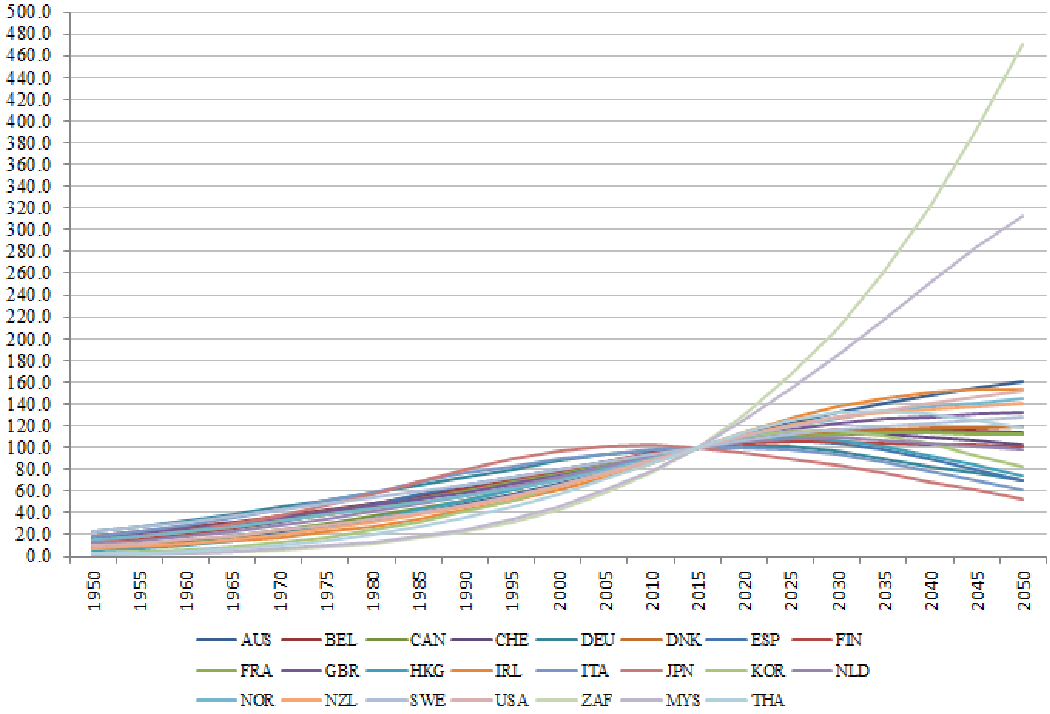


Figure 2 Changes and prediction of Inflation rate: 2015=100

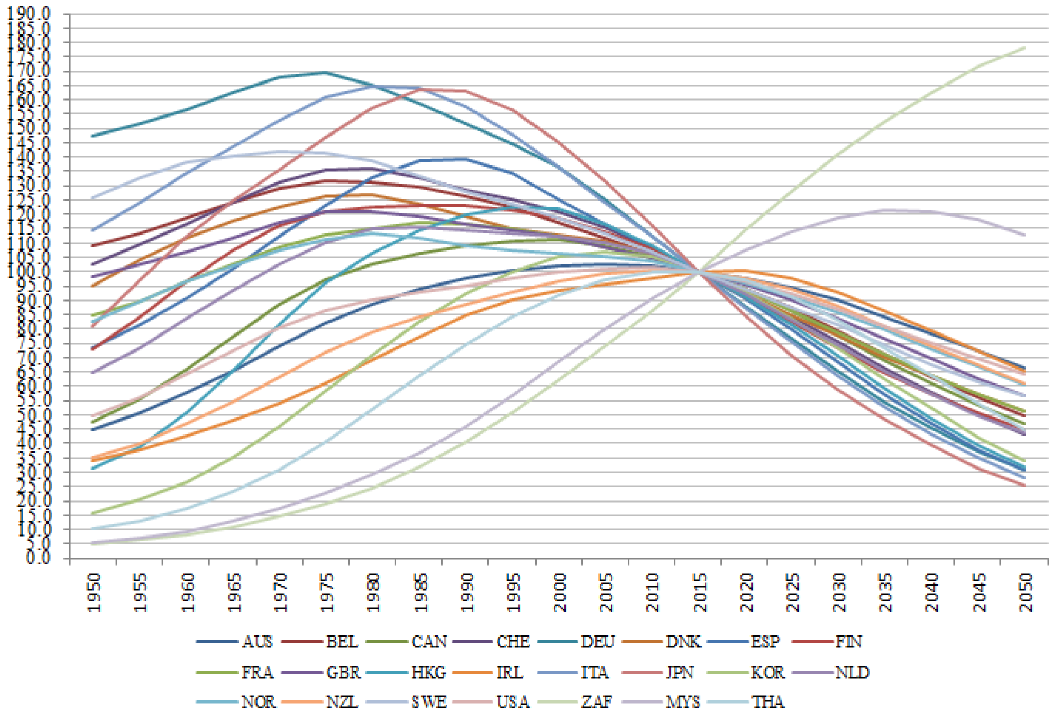


Figure 3 Changes and prediction of Residential Property Prices: 2015=100

4 Conclusion

In this paper, we have constructed a set of empirical models and simulated the impact of declining birthrate and aging of society on the goods and services market and asset markets using panel data from 23 major advanced nations, including leading Asian countries. The major findings of this paper are:

- The estimated impact of the young-age dependency ratio was positive and statistically significant for both inflation and housing prices. Therefore, a drop in the birth rate is a factor leading to both a decline in housing assets, which account for the largest share of assets, and deflation.
- We estimated that the impact of the old-age dependency ratio was negative and statistically significant for both inflation and housing prices. Therefore, the aging of society will cause not only asset deflation (i.e., a decline in housing assets) but deflation as well.
- When we examined the impact on inflation and housing asset prices by population group using a polynomial model, we found that increases in the ratio had a positive effect for the 15- to 20-year-old population. The impact then decreased for subsequent age groups, before increasing again starting with the population aged 35 to 40, who are typically married and have a family by that point. After that, the impact decreases suddenly at the age of 70. This is consistent with the previous two findings.
- In addition, we constructed a model using the GDPgap as an economic factor. The estimate results showed that increases in the GDP gap have a positive, statistically significant impact on inflation and housing prices and that the impacts of the young-age dependency ratio and old-age dependency ratio were the same as the findings above. Considered together, the results with the polynomial model and the results with the model that incorporates economic factors demonstrate the robustness of our findings.

How, then, should these results be interpreted? The fact that the aging of society will continue to promote deflation is easy to understand. Since the ongoing aging of society will increase the ratio of the population who are dependent on society (through increased social security, etc.), it will have the effect of causing the economic activity of society as a whole to stagnate and decrease consumption, including spending on housing services. Moreover, in societies where the old-age dependency ratio is expected to increase further in future, expected returns will also decrease, which will serve to drive asset prices down even more.

What should we think about the relationship between the progress of a declining birthrate and deflation? The fact that increases in the young-age dependency ratio have a positive, statistically significant effect on housing assets is easily understood, since an increase in the number of children may be expected to increase future housing demand. However, increases in this ratio could have either a negative or positive impact, depending on how the effect is interpreted. For example, when the number of children increases, the burden of current and future education costs may be expected to rise, and if this causes consumption to be reduced, it should have a negative effect. This is similar to the finding that increases in the elderly population have a negative effect via an increased dependence on society (increased social security, etc.). However, in this research, it became clear that the effect on commodity prices is positive and statistically significant. The reason for this may be that increases in the number of children also have the effect of driving up household consumption.

Finally, when we estimated housing prices and inflation rates in various countries through 2050, using the figures estimated with our models and U.N. population forecast data.

In many major developed nations, there will a sharp decline in birthrates and sudden aging of society in future. These two trends may be expected to cause asset deflation while also driving down inflation rates.

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