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Yumi Saita
Hitotsubashi University
Chihiro Shimizu
Reitaku University and University of British Columbia
Tsutomu Watanabe
The University of Tokyo

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Yumi Saita* Chihiro Shimizu† Tsutomu Watanabe‡

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Abstract

In this paper, we empirically investigate how real estate prices are affected by aging. We run regional panel regressions for Japan and the United States. Our regression results show that, both in Japan and the U.S., real estate prices in a region are inversely correlated with the old age dependency ratio, i.e. the ratio of population aged 65+ to population aged 20-64, in that region, and positively correlated with the total number of population in that region. The demographic factor had a greater impact on real estate prices in Japan than in the U.S. Based on the regression result for Japan and the population forecast made by a government agency, we estimate the demographic impact on Japanese real estate prices over the next 30 years. We find that it will be -2.4 percent per year in 2012-2040 while it was -3.7 percent per year in 1976-2010, suggesting that aging will continue to have downward pressure on land prices over the next 30 years, although the demographic impact will be slightly smaller than it was in 1976-2010 as the old age dependency ratio will not increase as much as it did before.

JEL Classification Number: G12; J11
Keywords: aging; dependency ratio; declining population; real estate prices

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†Reitaku University and University of British Columbia
‡Graduate School of Economics, University of Tokyo. watanabe@e.u-tokyo.ac.jp.

1 Introduction

Aging in Japan are advancing faster than in other major developed nations, and this is expected to have substantial effects on the country's economic systems, including its social security system.[1] What kind of effect will the falling birthrate, aging society, and declining population have on the real estate market? Will the often mentioned real estate price asset meltdown really occur? The purpose of this paper is to address these questions by investigating how much demographic factors affected real estate prices in Japan and the U.S. To do so, we construct regional panel data covering over a quarter-century in Japan and the U.S., and then conduct regional panel data regressions to estimate the impact of demographic changes on real estate prices.

Looking back at fluctuations in Japan's real estate prices, if one excludes the temporary period of economic turmoil following the oil crisis in the mid-1970s, real estate prices continued to rise consistently from the end of World War II until the collapse of the bubble in the first half of the 1990s. In particular, the speed of growth increased at the start of the 1980s, gathered momentum in the latter half of the decade, reached a peak in 1991, and then abruptly entered a downward phase. At the start of the 2000s, real estate prices showed signs of bottoming out, then, in the middle of the decade, they entered a period of recovery which became known as the "mini-bubble". However, it entered a downward phase once again following the global financial crisis in 2008.

In terms of the factors underlying these fluctuations in real estate prices, it is to be expected that economic growth, monetary policy, banks' lending behaviors and so forth had a major effect, but the effect of population cannot be overlooked either. In our previous study (Shimizu and Watanabe 2010), we show that home ownership rates in Japan tend to rise significantly from age 35 through 45, and that the population in this age group creates new housing demand. In fact, the 1980s housing bubble overlapped with the period when the first wave of baby boomers entered this age group, creating the greatest housing demand since the war. When housing prices turned upward in the 2000s, significant housing demand was created by the second wave of baby boomers - the children of the first wave.

Research on the relationship between demographic changes and real estate prices has been started by Mankiw and Weil (1989), which argue that US housing demand would peak in the 1980s due to the baby boomer generation, making a prediction that housing prices

[1] See, for example, The Economist's report on Japan (The Economist, Special Report on Japan, November 20, 2010) which states that "Japan is aging faster than any country in history, with vast consequences for its economy."

will subsequently decline 47 percent in real terms by 2007.[2] For Japan, Ootake and Shintani (1996) estimate housing demand employing a housing demand index similar to that proposed by Mankiw and Weil (1989), showing that demographic changes have an effect on housing price fluctuations in the short term, where housing supply is not elastic to price changes, but that in the long term, demographic factors do not affect housing prices as housing supply increases in response to an increase in demand. A similar result is reported by Shimizu and Watanabe (2010) and Nagahata et al. (2004). In contrast, Nakamura and Saita (2007) shows that demographic changes are related to housing price fluctuations even in the long run.

The debate on the impact of demographic changes on real estate prices has been recently restarted by Nishimura (2011) who argue that the Japanese real estate bubble in the late 1980s and its collapse in the early 1990s are closely related with demographic changes in Japan. Nishimura and Takáts (2012) presents a theoretical model to show that demographic changes are related to real estate prices and money demand. Takáts (2012) empirically test the relationship between demographic changes and housing prices using panel data for 21 countries, showing the presence of statistically significant correlation between the two. In this paper, we take Nishimura (2011) and Takáts (2012) as a starting point, but we focus on the relationship between demographic changes and real estate price fluctuations across regions in a country. We employ regional panel data for Japan and the U.S., covering a period that includes the Japanese 1980s land price bubble and the U.S. 2000s housing bubble, and examine the relationship between the two.

The rest of the paper is organized as follows. Section 2 explains our empirical method and the data employed. Section 3 provides estimation results. In Section 4, based on the regression result for Japan and the population forecast released by National Institute of Population and Social Security Research (IPSS), we estimate the demographic impact on Japanese real estate prices over the next 30 years. Section 5 concludes the paper.

[2] In 1991, a special issue of Regional Science and Urban Economics featuring critical essays on Mankiw and Weil (1989) was published. The following problems were pointed out: a) the fact that changes in housing demand have an effect on rental prices, not on selling prices; b) the fact that housing supply is elastic in the long term, so even if there is a change in housing demand, housing prices will not be affected due to the adjustment of housing supply; and c) the fact that since housing prices should respond immediately when an increase in housing demand is anticipated, the housing demand for a given year alone will not affect housing prices. The special issue also included analysis based on the same technique conducted by Engelhardt and Poterba (1991) that focused on Canada, with the reported results showing that no statistically significant relationship was observed with the estimated housing demand index and housing price fluctuations.

2 Empirical Method and Data

2.1 Empirical method

Housing is one of the largest assets for individuals, which is acquired throughout one's younger working years and consumed in one's older years. This is why age group-based demographics have an effect on new housing demand. Figure 1 shows household home ownership rates by age (i.e. the age of the household head). One can see that, in Japan, home ownership rates rise rapidly from age 35 through 44. In the U.S., on the other hand, home-ownership demand is already appearing at age 25. As a result, the period when the incidence of housing demand is most noticeable starts earlier than in Japan, from age 30 to 44. From 1980 onward, this trend has not changed much in either Japan or the U.S., and by the age of 60, home ownership rates reach 80 percent in both countries.

Takáts (2012) and Nishimura and Takáts (2012) construct a simple overlapping generation model, following Samuelson (1958) and Diamond (1965), in which young agents are assumed to purchase housing assets but old agents do not, so that housing demand depends on the number of total population as well as on the young-to-old ratio, yielding a relationship between demographic changes and housing prices. The regression equation implied by this model is as follows.[3]

$$\Delta \ln P_{it} = \alpha + \beta \Delta \ln \mathrm{GDPPC}_{it} + \gamma \Delta \ln \mathrm{OLDDEP}_{it} + \delta \Delta \ln \mathrm{TPOP}_{it} + \epsilon_{it} \qquad (1)$$

where P_{it} represents real housing price for region i in year t, GDPPC is per capita GDP, OLDDEP is the old age dependency ratio, which is defined by the ratio of population aged 65+ to the working population (i.e. population aged 20-64), and TPOP is total population. The disturbance term is represented by ϵ_{it}. We will use Eq. (1) as our baseline regression equation in our empirical exercises after adding some modifications, which will be explained later.

2.2 Data

We construct regional price data for Japan and the U.S. With regard to the U.S., we use the state-by-state housing price index published by the Office of Federal Housing Finance Agency (FHFA). This index, which has been published since 1975, is estimated with the traditional repeat sales method. We convert this index into dollar values by using the median of dollar transaction prices in 1975, which is published also by FHFA for each state.

[3] See Takáts (2012) for more details on the derivation of this equation.

For Japan, however, no region-by-region quality-adjusted housing price indexes covering the entire country exist. The only real estate price data available by region is the land price data published each year as of January 1st by the Ministry of Land, Infrastructure, Transport and Tourism, which have been used in many previous studies on the relationship between demographic changes and land prices, including Nagahata et al. (2004). However, as argued by Shimizu and Nishimura (2006) among others, this land price data is not reliable, since they are not transaction prices but appraisal prices, and some distortions are added by appraisers.

To minimize the distortion in land prices, we conduct quality adjustment using hedonic regression of the form

$$\ln p_{jt} = \sum_{k=0}^{K} \beta_k X_{jkt} + \sum_{s=0}^{\tau} \delta_s D_s + \nu_{jt}, \tag{2}$$

where p_{jt} represents the nominal land price for a property j in year t, X_{jkt} is the attributes associated with property j, D_s is a time dummy, and ν_{jt} is a disturbance term. Note that D_s is equal to 1 for $s = 1$ (i.e. D_1 represents the constant term), and that, for $s > 1$, D_s is equal to 1 if $s = t$ and zero otherwise. For the land attributes, we use area (m^2), building to land ratio, floor area ratio, distance to the nearest station, and time to the largest commercial center in the prefecture.[4] The regression results are summarized in Table 1.

[4]The prefectural center is defined as follows. For each prefecture, we generate a buffer from the highest price location and define the mesh center point with the highest office density as the prefectural center.

Table 1: Hedonic Regressions of Real Land Prices

Prefecture	Constant term	Acreage	Building to land ratio	Floor area ratio	Distance to nearest station	Distance to urban center	Adjusted R-squared	N. Obs
Hokkaido	9.882	-0.890	1.370	-0.070	-0.025	0.000	0.246	27,225
Aomori	10.021	-0.902	6.759	0.351	-0.024	-0.003	0.335	5,456
Iwate	10.069	-1.012	1.783	0.958	0.006	-0.010	0.505	3,528
Miyagi	10.588	-0.913	0.028	-0.359	-0.050	0.000	0.357	11,559
Akita	10.163	-1.022	-1.666	0.479	-0.060	-0.015	0.504	3,698
Yamagata	10.199	-1.124	4.141	0.112	-0.066	-0.010	0.512	3,507
Fukushima	10.453	-1.021	-2.237	0.275	-0.042	-0.008	0.463	9,364
Ibaraki	10.237	-0.829	0.647	0.587	-0.036	0.000	0.532	16,250
Tochigi	10.689	-1.177	-0.522	0.217	-0.052	-0.012	0.618	9,612
Gunma	10.442	-0.675	-0.450	0.056	-0.056	-0.013	0.639	7,941
Saitama	11.362	-0.582	0.057	0.589	-0.075	-0.029	0.754	31,476
Chiba	11.334	-0.870	1.676	0.049	-0.148	-0.015	0.573	30,689
Tokyo	11.192	0.742	3.870	1.920	-0.217	0.000	0.663	55,352
Kanagawa	11.130	0.088	-0.001	-0.710	-0.089	0.000	0.752	45,665
Niigata	10.733	-1.402	1.224	-0.206	-0.054	-0.007	0.462	8,230
Toyama	10.153	-0.567	0.863	0.406	-0.063	-0.018	0.533	4,355
Ishikawa	10.542	-1.178	0.655	0.162	-0.008	-0.011	0.514	4,320
Fukui	10.620	-0.493	-0.261	-1.033	-0.079	-0.010	0.551	2,338
Yamanashi	10.130	-0.919	1.588	0.515	-0.058	-0.006	0.723	3,118
Nagano	10.277	-0.924	-0.412	0.408	-0.028	-0.007	0.498	5,743
Gifu	10.445	-0.926	0.781	0.491	-0.030	-0.009	0.555	6,946
Shizuoka	10.374	-0.939	2.146	0.660	-0.036	0.000	0.643	14,365
Aichi	10.481	-0.084	1.416	-0.528	-0.070	0.000	0.597	37,281
Mie	10.075	-0.897	2.335	-0.157	-0.062	-0.004	0.619	9,116
Shiga	11.126	-1.507	1.516	-0.062	-0.074	-0.022	0.737	6,021
Kyoto	11.236	-0.061	3.512	0.176	-0.068	-0.027	0.814	13,996
Osaka	10.787	0.078	1.135	1.610	-0.115	0.000	0.625	38,451
Hyogo	11.046	-0.231	4.023	0.216	-0.175	0.000	0.421	28,558
Nara	11.108	-0.315	3.180	-0.970	-0.103	-0.032	0.790	9,297
Wakayama	10.749	-0.733	-0.126	0.115	0.016	-0.009	0.568	3,396
Tottori	10.783	-1.621	-0.214	-1.653	-0.086	-0.003	0.398	2,198
Shimane	10.011	-0.831	0.360	-0.200	-0.031	-0.005	0.359	2,491
Okayama	10.317	-1.843	1.654	0.703	-0.046	0.000	0.558	8,116
Hiroshima	10.859	-1.593	0.019	0.716	-0.051	0.000	0.343	13,452
Yamaguchi	10.011	-0.927	-0.160	0.432	-0.060	0.002	0.487	6,271
Tokushima	10.227	-0.011	-2.632	0.692	-0.030	-0.019	0.641	2,762
Kagawa	11.283	-1.311	0.138	0.633	-0.142	-0.021	0.640	3,216
Ehime	10.466	-1.162	1.147	0.696	-0.014	-0.009	0.576	4,881
Kochi	10.835	-1.453	-1.898	0.355	-0.002	-0.011	0.468	2,910
Fukuoka	9.830	0.005	1.683	0.301	-0.076	0.000	0.367	19,827
Saga	9.936	-1.334	1.825	0.102	-0.030	-0.015	0.469	2,256
Nagasaki	10.268	-0.573	-0.553	0.092	-0.040	-0.012	0.379	5,427
Kumamoto	9.888	-1.011	0.187	0.478	-0.030	-0.014	0.657	5,684
Oita	10.114	-0.493	-0.121	0.863	-0.044	-0.015	0.517	4,939
Miyazaki	10.293	-1.543	2.278	-0.311	-0.035	-0.010	0.583	4,833
Kagoshima	11.020	-2.285	-1.084	-0.848	-0.030	-0.002	0.368	5,398
Okinawa	10.728	-2.706	-2.026	1.020	0.156	-0.003	0.594	3,703

Note: Dependent variable is the log of real land price in each prefecture. The indicated acreage, building-to-land ratio, floor area ratio, distance to nearest station, and distance to major urban center coefficient estimates are multiplied by 1,000.

Table 2: Sources of Employed Data

	Prefectural panel data for Japan	State panel data for U.S.
Sample period	1976 to 2010	1975 to 2011
Real estate prices	Ministry of Land, Infrastructure, Transport and Tourism, "Official land prices". We use land prices only for residential use, which are quality adjusted by hedonic regression.	Housing price data from Federal Housing Finance Agency ("All-transactions Indexes" and "Summary statistics for house prices")
Per capita GDP	Cabinet Office, "Prefectural economic accounts"	Bureau of Economic Analysis, "GDP by state"
Interest rate	Bank of Japan, "Average contractual interest rate on bank loans"	Federal Reserve Board, "Contract rate on 30-year, fixed-rate conventional home mortgage commitments"
Consumer price	Statistics Bureau of Japan, "Consumer price index" by prefecture	Bureau of Labor Statistics, "CPI for all items" by state
New housing supply	Ministry of Land, Infrastructure, Transport and Tourism, new housing starts in "Statistical survey of construction starts"	U.S. Census, New privately-owned housing units authorized by building permits in "Building permits survey"
Population by age group	Ministry of Internal Affairs and Communications, "National Census". For years in which the census is not available, we use estimates by National Institute of Population and Social Security Research.	U.S. Census, population by age and state in "State population estimates"

Quality adjusted land prices are given by

$$\ln \hat{p}_{jt} = \sum_{k=1}^{K} \hat{\beta}_k X_{jk} + \hat{\delta}_1 + \hat{\delta}_t; \qquad \ln \hat{p}_{j1} = \sum_{k=1}^{K} \hat{\beta}_k X_{jk} + \hat{\delta}_1 \tag{3}$$

where $\hat{\beta}_k$, $\hat{\delta}_1$, and $\hat{\delta}_t$ are estimated parameters. Eq (3) implies

$$\ln\left(\hat{p}_{jt}/\hat{p}_{j1}\right) = \widehat{\delta_t} \tag{4}$$

and

$$\ln\left(\hat{p}_{jt}/\hat{p}_{jt-1}\right) = \hat{\delta}_t - \hat{\delta}_{t-1} \tag{5}$$

Table 2 provides the sources of the six variables employed in our empirical exercise (i.e. real estate prices, population, the old age dependency ratio, the interest rate, and new housing supply). Regional unit is prefecture in Japan and state in the U.S. The sample period is 1976 to 2010 for Japan, and 1975 to 2011 for the U.S.

2.3 Demographic changes

Figure 2 shows the evolution of populations by age group. We focus on the population aged 30-44, who are the driving force of housing demand. Looking first at Japan, in the 1980s bubble period the baby boomer generation entered the 35 to 40 age group, and the population aged 35 to 44 reached a historic peak. The movement among the age 35 to 44 population was especially notable. This population then decreased in tandem with the bubble's collapse, while in recent years, one can see that the younger generation has been entering the housing market in the 30 to 34 age range. In addition, a distinctive feature of Japan is that population influx from the outside through immigration is quite restricted, so the baby boomer peak has remained as is with the passage of time. In the U.S. on the other hand, the population aged 30 to 44 grew considerably through 2001, but rather than the population of a specific age group increasing as in Japan, the age 30 to 34 population group, age 35 to 40 population group, and age 40 to 44 population group all grew considerably. This shows that there was significant population influx from the outside, in contrast to Japan.

As for the dependency ratio, Nishimura (2011) shows that there exists a positive correlation between the inverse of the dependency ratio, which is defined as the ratio of the population aged 0-19 and 65+ to the population aged 20-64, and housing price fluctuations. Figure 3 shows the relationship between real estate prices and the dependency ratio for key regions in Japan and the U.S. In the figure, we also shows the old age dependency ratio, i.e. the ratio of population aged 65+ to population aged 20-64, which is used in the empirical analysis by Takáts (2012). For these two ratios, we eliminate trend by applying the Hodrick-Prescott filter with the multiplier λ set at 100. For Japan, one can see that Tokyo land prices peaked in 1988, while the old age dependency ratio consistently declined from 1980 to 1990, suggesting that the old age dependency ratio is inversely correlated with land prices. Similar tendency is observed between the dependency ratio and land prices. For Osaka, land prices, the old dependency ratio, and the dependency ratio moved in roughly the same manner as in Tokyo. However, in rural regions, such as Aomori and Kagawa, which did not experience any significant price hikes even during the 1980s bubble period, we do not see any clear negative relationship between land prices and demographic changes.

Turning to the U.S., we look at California, center of economic activity in the west, and New York, center of economic activity in the east. In both regions, significant increases in housing prices occurred in the latter half of the 1980s and the mid-2000s. Looking at the relationship with population indicators, the dependency ratio declined substantially in the late 1980s and the mid-2000s, suggesting a negative correlation between the two. Similarly, we can see a negative correlation between the age dependency ratio and housing prices. However, we do not see a clear negative correlation for Texas and West Virginia.

3 Empirical Results

3.1 Tests on unit root

We employ the two methods to test the stationarity of our panel data: (1) "common unit root test" in which the null hypothesis is that the time series in each region share a unit root; (2) "individual unit root test" in which the null is that the time series in each region has a different unit root.

Suppose that, for a panel series y_{it}, a first order AR process is given by

$$\begin{aligned} &y_{it} = \rho_i y_{it-1} + \theta_{mi} d_{mt} + \epsilon_{it} \\ &d_{1t} = \{0\}, \quad d_{2t} = \{1\}, \quad d_{3t} = \{1, t\} \end{aligned} \tag{6}$$

for $i = 1, 2, \ldots, N$, $t = 1, 2, \ldots, T$, $m = 1, 2, 3$. To test $\rho_i = 1$, we run a regression of the form

$$\Delta y_{it} = \delta_i y_{it-1} + \sum_{k=1}^{L_i} \gamma_{ik} \Delta y_{it-k} + \theta_{mi} d_{mt} + \epsilon_{it} \tag{7}$$

The common unit root test proposed by Levin, Lin and Chu's (2002) is a unit root test that assumes regions have a common unit root, and the null and the alternative are given by

$$H_0 : \delta_i = \delta = 0; \quad H_1 : \delta_i = \delta < 0$$

where δ_i is defined by $\delta_i \equiv \rho_i - 1 = 0$. The individual unit root test proposed by Im, Pesaran and Shin (2003) and Maddala and Wu (1999) is a unit root test that assumes the unit roots differ between regions. The null and the alternative hypotheses are given by

$$H_0 : \delta_i = 0 \qquad \text{for all } i$$

and

$$H_1 : \delta_i = \begin{cases} < 0, & \text{for} \quad i = 1, 2, \ldots, N_1 \\ = 0, & \text{for} \quad i = N_1 + 1, N_1 + 2, \ldots, N \end{cases}$$

We apply the above tests to real land price, population, the old age dependency ratio, new housing supply, income, and the interest rate. The results are given in Table 3, showing that, for each of the six variables, the null is rejected when the first difference is taken.[5]

[5]Note that the null is not rejected for some variables even without taking first difference. In what follows, however, we assume that all variables are I(1) and take first difference for all of them unless otherwise mentioned.

Table 3: Unit Root Tests

	Level				First difference			
	Common unit root Levin-Lin-Chu		Individual unit root ADF-Fisher		Common unit root Levin-Lin-Chu		Individual unit root ADF-Fisher	
Japan								
Real land price	-5.7	(0.00) ***	123	(0.03) **	-12.9	(0.00) ***	333	(0.00) ***
Per capita GDP	-10.5	(0.00) ***	144	(0.00) ***	-23.9	(0.00) ***	591	(0.00) ***
Dependency ratio	0.6	(0.72)	24	(1.00)	-3.1	(0.00) ***	94	(0.47)
Population	0.1	(0.53)	99	(0.34)	-4.3	(0.00) ***	89	(0.62)
Real interest rate	-12.2	(0.00) ***	285	(0.00) ***	-47.0	(0.00) ***	1347	(0.00) ***
New housing starts	5.3	(1.00)	50	(1.00)	-33.6	(0.00) ***	1011	(0.00) ***
U.S.								
Real housing price	-6.9	(0.00) ***	209	(0.00) ***	-9.1	(0.00) ***	379	(0.00) ***
Per capita GDP	-3.4	(0.00) ***	50	(1.00)	-19.5	(0.00) ***	701	(0.00) ***
Dependency ratio	-4.3	(0.00) ***	-6.3	(0.02) **	-4.2	(0.00) ***	-7	(0.00) ***
Population	-2.7	(0.00) ***	84	(0.89)	-18.6	(0.00) ***	547	(0.00) ***
Real interest rate	-2.8	(0.00) ***	230	(0.00) ***	0.0	(0.00) ***	786	(0.00) ***
New housing starts	-3.6	(0.00) ***	225	(0.00) ***	-18.2	(0.00) ***	536	(0.00) ***

Note: Figures in the table represent test statistics with the associated p-values in parentheses. ***, **, and * indicate that the null hypothesis is rejected at the 1 percent, 5 percent, and 10 percent significance level. The lag of each ADF test is chosen based on the SIC criterion.

3.2 Tests on cointegration

We apply the following cointegration tests to our panel data. The first is the Kao test proposed by Kao (1999), which assumes that cointegration relationship in each region is identical. The second one is the Pedroni test proposed by Pedroni (1999), which assumes that cointegration relationship is heterogeneous across regions. Specifically, when we test cointegration between y_{it} and x_{it}, we regress y_{it} on x_{it} to obtain an estimated error, which is denoted by $\hat{e}_{it}$. Note that the Kao test assumes that the coefficient on x_{it} does not depend on i while the Pedroni test allows the coefficient on x_{it} to be different across i. Then, we run a regression of the form

$$\Delta\hat{e}_{it} = \mu_i\hat{e}_{it-1} + \sum_{k=1}^{L_i}\varphi_{ik}\Delta\hat{e}_{it-k} + \epsilon_{it} \tag{8}$$

to see whether the estimate of μ_i is close to zero or not. The null and the alternative hypotheses in the Kao test are given by

$$H_0 : \mu_i = \mu = 0 \qquad H_1 : \mu_i = \mu < 0$$

On the other hand, the null and the alternative hypotheses in the Pedroni test differ depending on whether homogeneity in terms of μ_i is assumed or not. If μ_i is assumed to be homogeneous

Table 4: Cointegration Tests

Kao test		Pedroni test							
ADF		Panel rho		Panel ADF		Group rho		Group ADF	
Japan		Japan							
-5.8	(0.00) ***	0.3	(0.63)	-4.1	(0.00) ***	2.7	(1.00)	-7.2	(0.00) ***
U.S.		U.S.							
0.0	(0.00) ***	-4.2	(0.00) ***	0.0	(0.00) ***	-4.3	(0.00) ***	0.0	(0.00) ***

Note: Figures in the table represent test statistics with the associated p-values in parentheses. ***, **, and * indicate that the null hypothesis is rejected at the 1 percent, 5 percent, and 10 percent significance level. The lag of each ADF test is chosen based on the SIC criterion.

across i, which is referred to as the panel test, the null and the alternative are given by

$$H_0 : \mu_i = \mu = 0 \qquad H_1 : \mu_i = \mu < 0$$

On the other hand, if one assumes that μ_i may not be identical across i, which is referred to as the group test, the null and the alternative hypotheses are given by

$$H_0 : \mu_i = \mu = 0 \qquad H_1 : \mu_i < 0 \quad \text{for all} \quad i$$

We conduct cointegration tests for log land prices, $\ln P_{it}$, the log of per capita GDP, $\ln GDPPC_{it}$, the log of the old age dependency ratio, $\ln OLDDEP_{it}$, and the log of population, $\ln TPOP_{it}$. Specifically, we run a regression of the form

$$\ln P_{it} = \alpha_i + \beta_{1i} \ln \mathrm{GDPPC}_{it} + \beta_{2i} \ln \mathrm{OLDDEP}_{it} + \beta_{3i} \ln \mathrm{TPOP}_{it} + e_{it} \tag{9}$$

to obtain the estimate of e_{it} and the estimate of the corresponding μ_i. The results are presented in Table 4, showing the presence of conintegration relationship among the four variables.

3.3 Regression results

Given that the four variables are cointegrated, we need to change our estimating equation, eq (1), into

$$\Delta \ln P_{it} = a_i + b_1 \Delta \ln \mathrm{GDPPC}_{it} + b_2 \Delta \ln \mathrm{OLDDEP}_{it} + b_3 \Delta \ln \mathrm{TPOP}_{it} + \mathrm{ECT}_{it-1} + v_{it}. \tag{10}$$

The new term ECT_{it-1} is the error correction term which is defined by

$$\mathrm{ECT}_{it} \equiv \ln P_{it} - (\alpha_i + \beta_1 \ln \mathrm{GDPPC}_{it} + \beta_2 \ln \mathrm{OLDDEP}_{it} + \beta_3 \ln \mathrm{TPOP}_{it})$$

Table 5: Baseline Regressions

	No. of OBS	Adj. R2	GDP per capita	Old age dependency ratio	Total population	EC term
			Japan			
	1,645	0.629	0.2188	-1.3167	0.9177	-0.1033
s.e.			0.067	0.202	0.341	0.011
t-stat			3.25	-6.50	2.69	-9.66
			U.S.			
	1,836	0.439	0.4515	-0.9067	0.7514	-0.1272
s.e.			0.111	0.142	0.141	0.013
t-stat			4.06	-6.40	5.32	-9.54

Note: White's heteroskedasticity-consistent standard errors are reported.

Note that we add time dummies to eq. (10) in our baseline regression, which capture unobserved price fluctuations across regions, although we employ a specification without time dummies as robustness check.[6]

The regression results are presented in Table 5. We see that each of the estimated coefficients is statistically significant and meet the corresponding sign condition. However, the estimated coefficients differ to some extent between the two countries. The coefficient on per capita GDP is greater in the U.S. than in Japan; it is 0.2188 in Japan while it is 0.4515 in the U.S. However, the two coefficients associated with demographic changes are larger in Japan. Specifically, the coefficient on Japan's old age dependency ratio is -1.3167 while the corresponding coefficient in the U.S. is -0.9067. The coefficient on total population in Japan is 0.9177 and the corresponding estimate in the U.S. is 0.7514.

When comparing with the results of Takáts (2012) estimated using panel data from 22 countries, the coefficient on the per capita GDP is 0.8842, the coefficient on the old age dependency ratio is -0.6818 and the coefficient on the total population is 1.0547. Since the estimation period differs with Takáts (2012) from 1970 and this paper from 1975, a simple comparison cannot be made, but our estimate for the coefficient on per capita GDP in Japan is much smaller than the Takáts estimate. As for the coefficients regarding demographic changes, the coefficient on the old age dependency ratio is much larger than the corresponding Takáts estimates, while the coefficient on total population is almost identical.

In Figure 4, we decompose changes in the real land price over the last 30 years (i.e. 1976-2010) into the contribution of per capital GDP growth and the contribution of demographic

[6]For the specification test, we run (a) a F-test for OLS and fixed effects model, (b) Lagrange multiplier test based on OLS residuals, and (c) Hausman test for fixed and random effects model. These tests show that a random effects model is appropriate for this equation. We, however, estimate a fixed effects model to put an emphasis on the comparison with the results of Takáts (2012).

changes, which is defined as the sum of the contribution of OLDDEP and that of TPOP. Figure 4a shows the result for the entire sample period, while Figures 4b and 4c show the results for subsample periods (i.e. 1976-1990 for Figure 4b and 1991-2010 for Figure 4c). Real land prices rose by 0.8 percent per year for the entire sample period. Decomposing this into the economic and demographic factors, the contribution of the economic factors (i.e. the contribution of per capita GDP growth) is +0.2 percent per year while the contribution of demographic changes is -3.7 percent per year. In subsamples, the land price inflation rate was 7.3 percent per year for 1976-1990, while it was -3.4 percent per year for 1990-2010. For the period of 1976-1990, the contribution of economic growth is +0.6 percent per year while the contribution of demographic changes is -2.9 percent per year. For the period of 1990-2010, the contribution of economic growth is -0.1 percent per year while the contribution of demographic changes is -4.2 percent per year. Note that the price decline in the latter period is mainly due to demographic changes, although low economic growth during this period also contributed to the price decline.

Figure 4 also shows that the regions with positive demographic impacts in 1976-2010 were only areas surrounding Tokyo, such as Ibaraki, Kanagawa, Saitama and Chiba, and areas such as Nara and Shiga, which are adjacent to Osaka, center of the second largest economic zone, and Okinawa. As seen in Figure 4b, the contribution of demographic changes in those areas was much larger in 1976-1990. Note that the contribution of demographic changes was consistently negative in Tokyo, suggesting that population outflowed to suburban areas due to high housing prices in Tokyo resulting from the housing bubble.

To check the robustness of the regression results, we estimate different versions of eq (10). First, we change the specifications of the estimating equation by (1) dropping the time dummies; (2) adding regional dummies; (3) dropping the error correction term. Note that eq (10) coincides with the original specification adopted by Takáts (2012) if one keeps the time dummies but drops the error correction term. The results are presented in Table 6, showing that the coefficients of our interest, i.e., the coefficients on the old age dependency ratio and on the total population, are of the same sign as in the baseline specification, and significantly different from zero. However, the absolute size of the estimated coefficients tends to be larger than in the baseline specification, suggesting that the demographic impact may be slightly underestimated in the baseline specification.

Second, we add new variables to eq (10) such as the interest rate and new housing supply.[7]

[7] For the interest rate, we use the average contractual interest rate on bank loans for Japan, and the contract rate on 30-year, fixed-rate conventional home mortgage commitments for the U.S. Note that the interest rate data was not available by region, so that we use national figures. The nominal interest rates are converted into real terms by subtracting consumer price inflation, which is available by region. As for new housing supply,

Table 6: Robustness Check

Specification	Per capita GDP	Old age dep ratio	Population	Interest rate	Housing supply	EC term
			Japan			
Baseline specification (BS)	0.2188***	-1.3167***	0.9177***			-0.1033***
No time dummies	0.4401***	-1.9702***	2.5376***			-0.0993***
Regional dummies	0.2302***	-1.7280***	2.0220***			-0.1056***
Regional dummies & No time dummies	0.3891***	-2.2071***	4.0806***			-0.0951***
No EC term	0.1468**	-1.0790***	0.8333**			
BS+Interest rate	0.1433**	-1.4071***	1.0508***	0.0079***		-0.1115***
BS+Housing supply	0.2297***	-1.2701***	1.1372***		-0.0901***	-0.0916***
BS+Interest rate+Housing supply	0.1664**	-1.3675***	1.2517***	0.0073***	-0.0862***	-0.1069***
BS+Interest rate+HS with a lag	0.0890	-1.3569***	1.1941***	0.0082***	-0.0794***	-0.1080***
			U.S.			
Specification	Per capita GDP	Old age dep ratio	Population	Interest rate	Housing supply	EC term
Baseline specification (BS)	0.4515***	-0.9067***	0.7514***			-0.1272***
No time dummies	0.5874***	-1.1576***	0.6163***			-0.1143***
Regional dummies	0.4525***	-0.5363***	1.8079***			-0.1199***
Regional dummies & No time dummies	0.5847***	-1.2666***	0.8503***			-0.1116***
No EC term	0.4714***	-0.7821***	0.8222***			
BS+Interest rate	0.4415***	-0.9375***	0.7385***	-0.0020		-0.1328***
BS+Housing supply	0.3819***	-0.7824***	0.6308***		0.0430***	-0.1292***
BS+Interest rate+Housing supply	0.3725***	-0.8128***	0.6139***	-0.0018	0.0422***	-0.1356***
BS+Interest rate+HS with a lag	0.4555***	-0.6489***	0.4272***	0.0027	0.0432***	-0.1358***

Note: ***, **, and * indicate that the null hypothesis that the estimated coefficient is zero is rejected at the 1 percent, 5 percent, and 10 percent significance level.

For the specification with the interest rate, the coefficient on the interest rate is negative for the U.S., which is consistent with the theoretical prediction. However, the coefficient is not statistically significant. For Japan, the coefficient on the interest rate is positive, inconsistent with the theoretical prediction, although it is not significantly different from zero. Turning to new housing supply, the coefficient associated with it is negative and statistically significant, implying that an increase in housing supply exerts downward pressure on land prices. In the U.S., on the other hand, the coefficient on housing supply is positive and significantly different from zero, which is consistent with the implication of stock flow models, in which housing price hikes leads to an increase in new housing supply.

Finally, we replace GDPPC_{it} with GDPPC_{it-1} in order to eliminate the potential endogeneity problem. The coefficient on per capita GDP is now smaller than before, but it is still positive and significantly different from zero.

we use housing start data for both Japan and the U.S.

4 Demographic Impact over the Next 30 Years

In this section, we forecast real land prices in Japan using the regression coefficients obtained in the previous section, as well as the projection on demographic changes released by the IPSS, which were based on natural increases/decreases calculated from the survival probability and the number of births by cohort and social increases/decreases due to movement between regions. Population projections used in the paper are the medium variant projection, which is based on the assumption of medium fertility, unless otherwise mentioned.

Figure 5 shows the contributions of demographic changes over that past 35 years (1976 to 2010) as well as over the next 30 years (2011 to 2040). All figures represent percentage contributions per year. As far as the national average is concerned, the contribution of demographic changes over the past 35 years was -3.7 percent per year,[8] while it will be -2.4 percent per year over the next 30 years. The contribution of demographic changes is negative in all regions, but it is more pronounced in rural areas, suggesting that, in these rural areas, the decline in real estate prices will be accelerated by substantial population outflow to the urban areas.

Figure 6a shows the cumulative contribution of demographic changes on real land prices: it shows the cumulative contributions in 2011-2020, 2011-2030, 2011-2040. This suggests that in many prefectures, real land prices in 2040 will drop by about 50 percent from their current levels, but there will even be drops of 70 to 80 percent in the rural areas such as Hokkaido, Aomori, and Ibaraki, so one can see that the effects of demographic changes on land prices will be extreme.

Figure 6a uses future population estimates that take inter-prefectural population migration into account, but Figure 6b looks at the extent to which the impact of demographics on land prices changes if one assumes that there will no such migration. In this figure, we plot the difference between land prices if there is population movement and land prices if there is no population movement. As seen in the figure, the difference exceeds zero for the seven prefectures including Tokyo, Aichi, and Osaka, while it is below zero for the other prefectures, suggesting that inter-prefecture immigration from rural to urban areas will contribute to an increase in land price inequality across regions.

[8] The contribution of demographic changes in 1976-1990 was -2.9 percent per year, while it was -4.2 percent per year in 1991-2010.

Table 7: Contributions of Demographic Changes With and Without Inter-prefectural Migration

	With migration			Without migration		
Prefecture	2020	2030	2040	2020	2030	2040
Hokkaido	-41.5%	-54.0%	-68.2%	-39.8%	-52.0%	-64.9%
Aomori	-41.9%	-57.7%	-70.8%	-38.3%	-51.3%	-61.8%
Iwate	-36.2%	-50.5%	-63.3%	-33.1%	-44.9%	-54.7%
Miyagi	-34.9%	-47.5%	-61.9%	-33.9%	-47.0%	-60.2%
Akita	-41.2%	-57.0%	-68.7%	-37.3%	-50.2%	-58.5%
Yamagata	-36.8%	-50.8%	-62.3%	-34.0%	-45.3%	-53.3%
Fukushima	-38.6%	-53.2%	-65.6%	-32.9%	-45.2%	-54.4%
Ibaraki	-38.4%	-48.7%	-63.5%	-38.4%	-48.9%	-62.0%
Tochigi	-38.1%	-49.4%	-64.2%	-38.0%	-49.5%	-62.7%
Gunma	-34.6%	-43.9%	-60.6%	-34.9%	-44.4%	-59.0%
Saitama	-34.4%	-43.1%	-62.4%	-37.0%	-48.6%	-66.4%
Chiba	-36.2%	-45.0%	-63.1%	-36.7%	-47.8%	-65.1%
Tokyo	-23.0%	-34.1%	-58.5%	-31.5%	-48.6%	-71.0%
Kanagawa	-29.1%	-39.6%	-61.3%	-32.5%	-47.0%	-67.6%
Niigata	-33.1%	-44.9%	-59.5%	-32.0%	-43.0%	-54.8%
Toyama	-33.6%	-41.2%	-58.8%	-34.4%	-42.0%	-56.8%
Ishikawa	-34.8%	-42.5%	-58.6%	-35.3%	-44.0%	-57.9%
Fukui	-32.1%	-44.0%	-58.8%	-29.9%	-40.3%	-51.7%
Yamanashi	-31.4%	-46.4%	-63.4%	-29.3%	-42.6%	-57.2%
Nagano	-29.7%	-40.5%	-58.3%	-29.0%	-38.2%	-52.6%
Gifu	-30.9%	-40.5%	-57.3%	-30.8%	-40.0%	-54.2%
Shizuoka	-32.9%	-43.5%	-60.3%	-32.6%	-43.5%	-58.0%
Aichi	-26.3%	-33.5%	-54.1%	-29.2%	-40.1%	-59.4%
Mie	-28.3%	-38.3%	-56.0%	-29.4%	-40.0%	-55.3%
Shiga	-29.2%	-37.1%	-54.2%	-30.9%	-41.3%	-56.6%
Kyoto	-33.2%	-40.4%	-58.4%	-31.8%	-40.4%	-57.0%
Osaka	-30.0%	-37.8%	-59.6%	-31.4%	-40.9%	-60.8%
Hyogo	-30.9%	-40.1%	-58.9%	-31.9%	-42.4%	-59.2%
Nara	-36.2%	-46.8%	-63.0%	-34.5%	-44.7%	-58.9%
Wakayama	-33.4%	-45.7%	-61.7%	-31.9%	-42.4%	-55.2%
Tottori	-36.0%	-47.8%	-60.1%	-32.6%	-42.1%	-50.8%
Shimane	-31.7%	-41.9%	-54.6%	-28.7%	-36.3%	-44.0%
Okayama	-29.0%	-34.8%	-50.3%	-29.8%	-36.6%	-50.0%
Hiroshima	-33.7%	-41.0%	-57.4%	-32.8%	-41.3%	-55.8%
Yamaguchi	-36.0%	-42.7%	-56.5%	-34.6%	-40.3%	-50.7%
Tokushima	-40.9%	-51.9%	-64.9%	-38.5%	-47.8%	-58.1%
Kagawa	-35.4%	-43.7%	-58.8%	-34.5%	-42.1%	-54.3%
Ehime	-34.5%	-45.0%	-59.1%	-32.7%	-42.2%	-53.5%
Kochi	-39.1%	-49.7%	-63.0%	-36.1%	-44.6%	-54.6%
Fukuoka	-36.0%	-44.5%	-59.0%	-34.6%	-44.4%	-57.3%
Saga	-34.4%	-45.5%	-56.3%	-32.4%	-41.7%	-48.8%
Nagasaki	-37.7%	-51.4%	-63.4%	-33.7%	-44.9%	-52.9%
Kumamoto	-32.8%	-44.0%	-54.8%	-30.8%	-41.4%	-48.9%
Oita	-33.1%	-41.0%	-52.6%	-32.8%	-41.1%	-50.1%
Miyazaki	-36.7%	-47.5%	-57.2%	-34.2%	-43.7%	-49.6%
Kagoshima	-36.6%	-49.4%	-59.3%	-33.0%	-43.4%	-48.9%
Okinawa	-30.0%	-43.4%	-57.8%	-30.4%	-44.1%	-55.5%

Table 8: Contribution of Demographic Changes Estimated Based on IPSS and UN Population Projections

Estimates based on population projection by IPSS			
	Low variant projection	Medium variant projection	High variant projection
$TPOP_{2010}$		128,057	
$TPOP_{2040}$	102,350	107,276	112,506
$OLDDEP_{2010}$		0.390	
$OLDDEP_{2040}$	0.712	0.717	0.722
Demographic impact on land prices	-0.025	-0.024	-0.023
Estimates based on population projection by UN			
	Low variant projection	Medium variant projection	High variant projection
$TPOP_{2010}$		128,057	
$TPOP_{2040}$	106,182	114,517	122,988
$OLDDEP_{2010}$		0.390	
$OLDDEP_{2040}$	0.734	0.704	0.676
Demographic impact on land prices	-0.025	-0.022	-0.019

Note: IPSS projections are from "Population Projections for Japan (January 2012)" released by the National Institute of Population and Social Security Research (IPSS), which is available at `http://www.ipss.go.jp/site-ad/index_english/esuikei/gh2401e.asp`. UN projections are from "World Population Prospects: The 2012 Revision," which is available at `http://esa.un.org/unpd/wpp/index.htm`. The figures for TPOP are in thousand.

Finally, we check the robustness of the result by conducting the same exercise using different population projections. We use the low and high variant projections, both of which are released by the IPSS, instead of the medium variant projection. The low variant projection is based on the assumption of low fertility but high mortality rates, while the high variant is based on the assumption of high fertility but low mortality rates. We also use the UN population projections, which are taken from "World Population Prospects: The 2012 Revision." The result is presented in Table 8. For the estimates based on the IPSS projections, the total population in 2040 varies between 102 million and 112 million, while the old age dependency ratio in 2040 varies between 0.712 and 0.722. However, the resulting estimate on the demographic impact on land prices does not change that much from the one obtained in the case of the medium variant projection.[9] We also confirm that the result does not change

[9]Note that the old age dependency ratio in 2040 will be as high as 0.752 with the combination of low fertility

that much even if we use the UN projections instead of the IPSS projections.

5 Conclusion

In this paper, we have empirically investigated how real estate prices are affected by aging in Japan and the United States. We find that, both in Japan and the U.S., real estate prices in a region are inversely correlated with the old age dependency ratio in that region, and positively correlated with the total number of population in that region.

The demographic factor had a greater impact on real estate prices in Japan than in the U.S. Based on the regression result for Japan and the population forecast made by a government agency, we find that it will be -2.4 percent per year in 2012-2040 while it was -3.7 percent per year in 1976-2010, suggesting that aging will continue to have downward pressure on land prices over the next 30 years, although the demographic impact will be slightly smaller than it was in 1976-2010 as the old age dependency ratio will not increase as much as it did before.

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and low mortality rates. In this case, the estimate on the demographic impact on land prices is -0.026, which is again not that much different from the estimate obtained in the case of the medium variant projection.

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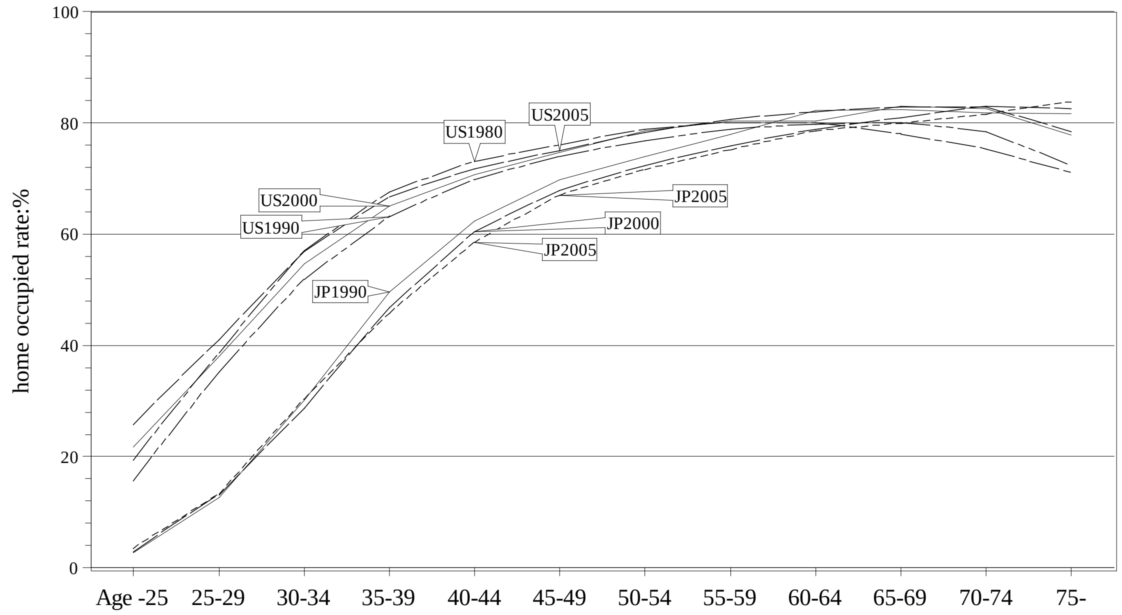


Figure 1: Japanese and U.S. Home Ownership Rates by Age Group

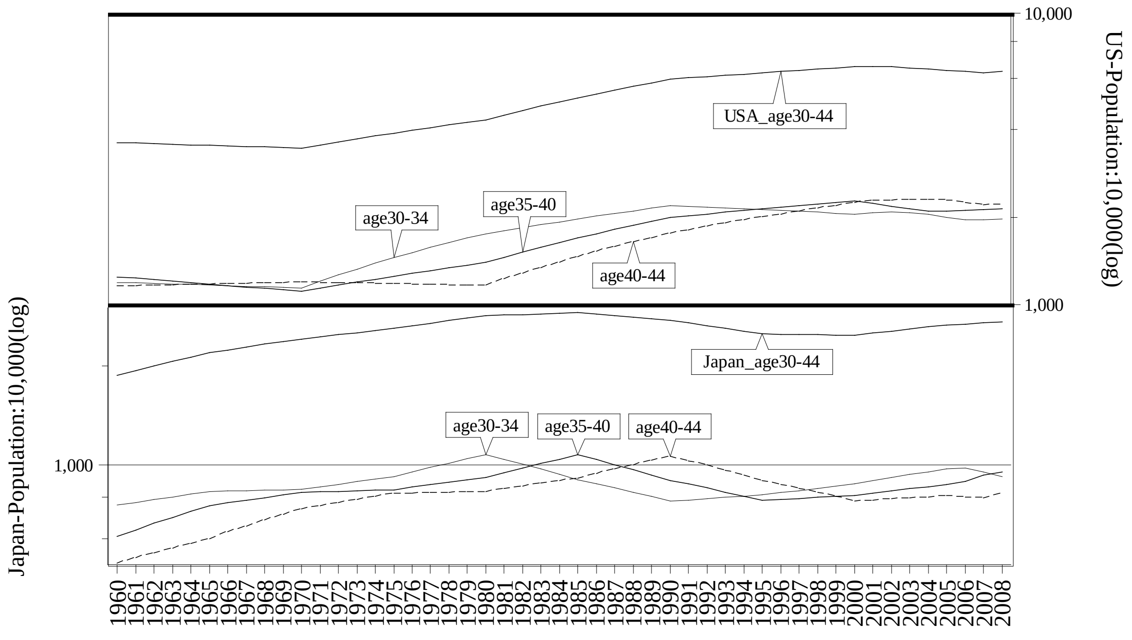
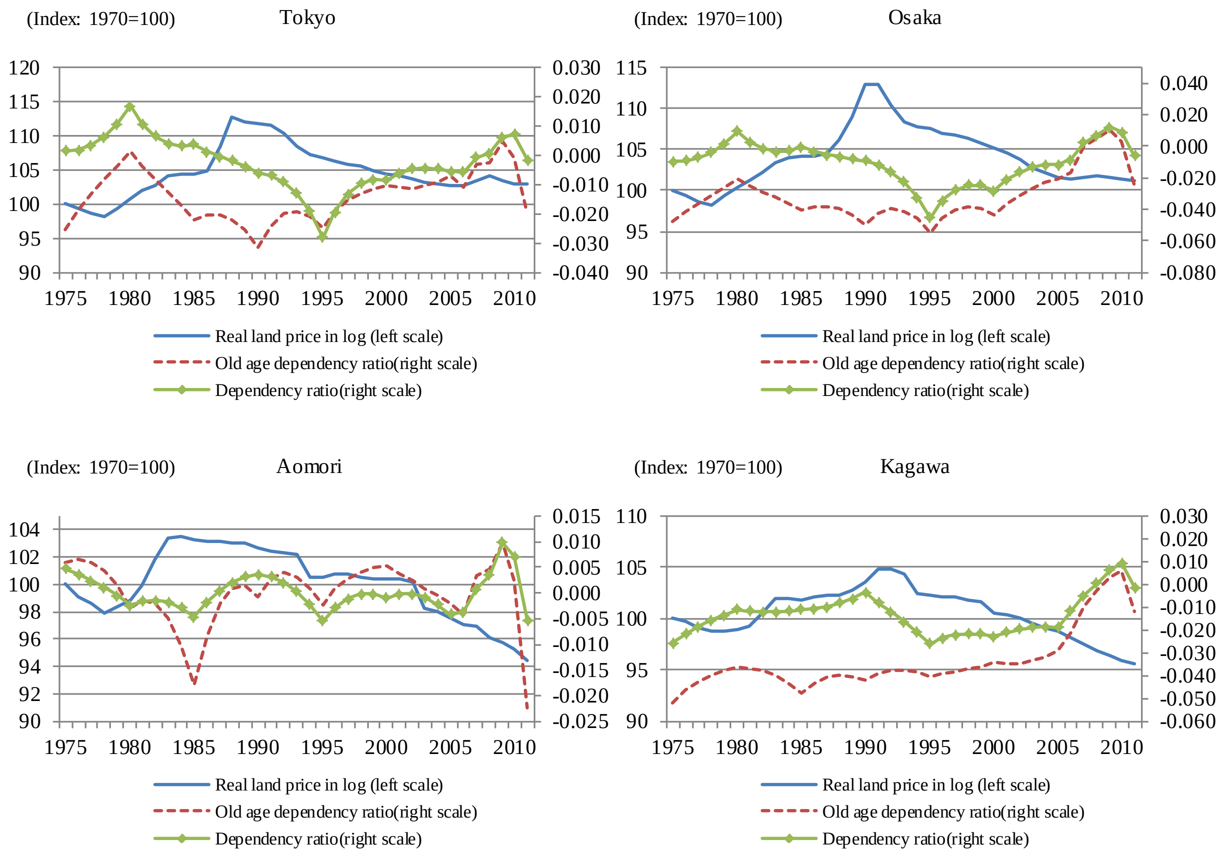


Figure 2: Japanese and U.S. Population by Age Group

Japan:



US:

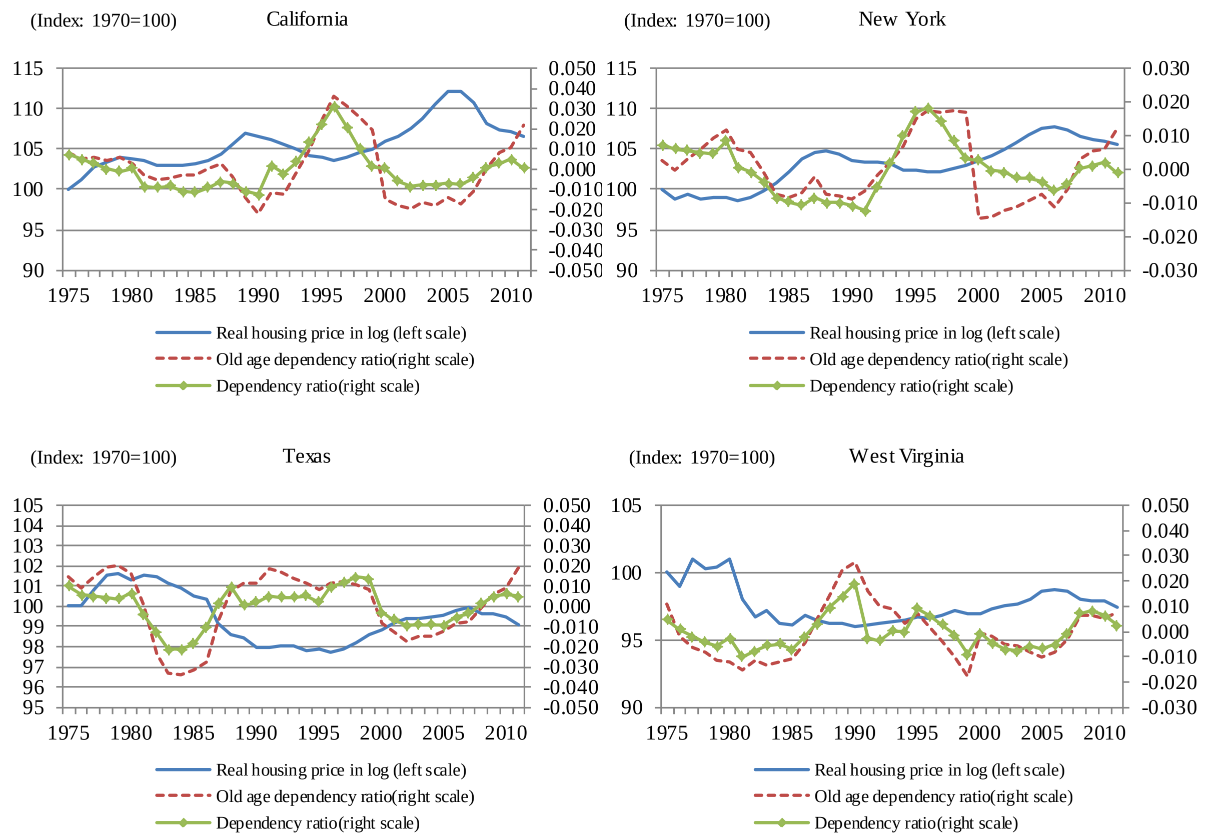


Figure 3: Real Estate Prices and Demographic Changes in Key Regions

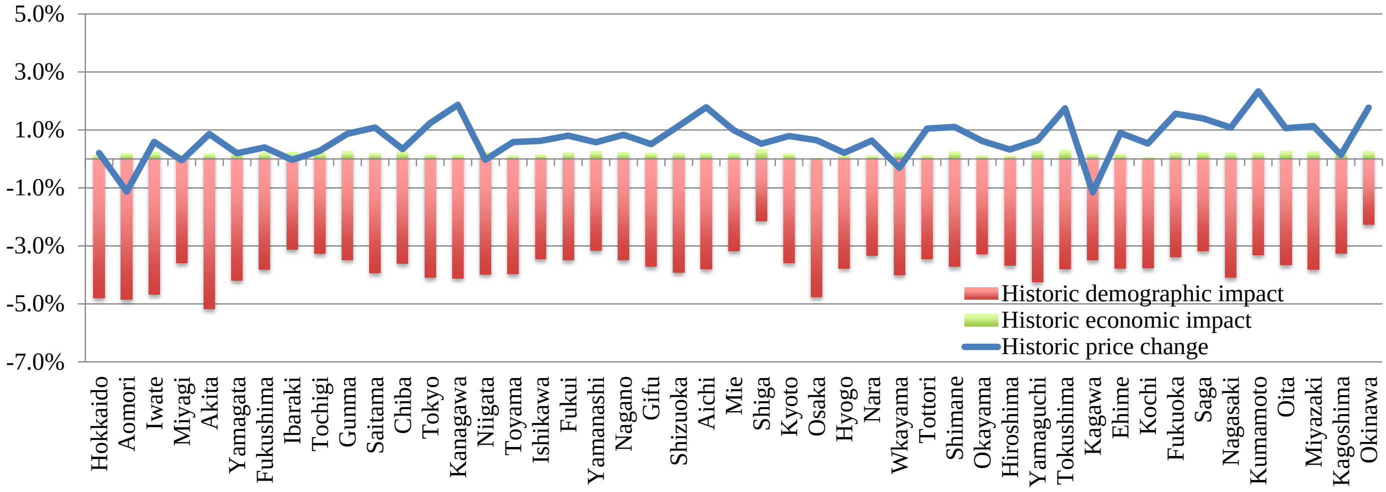


Figure 4a: Decomposition of Land Price Changes over 1976-2010

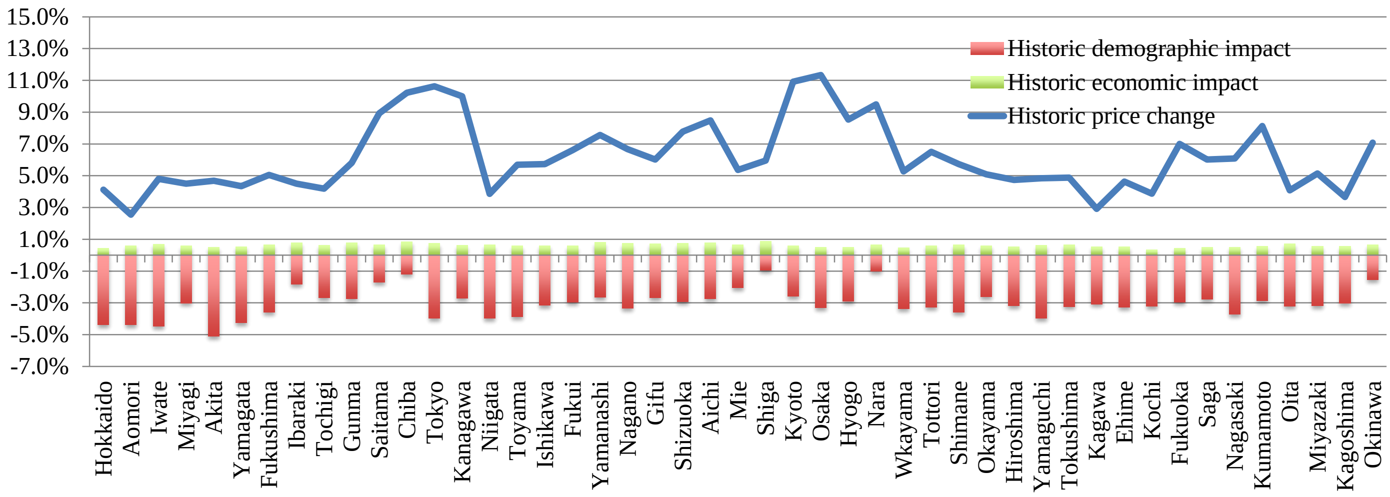


Figure 4b: Decomposition of Land Price Changes over 1976-1990

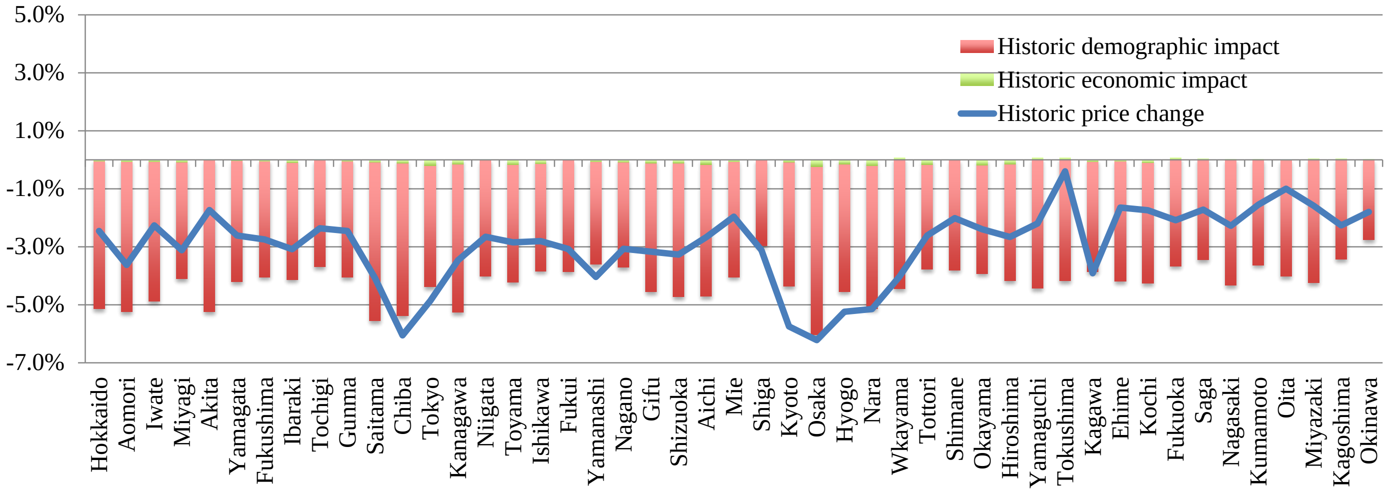


Figure 4c: Decomposition of Land Price Changes over 1991-2010

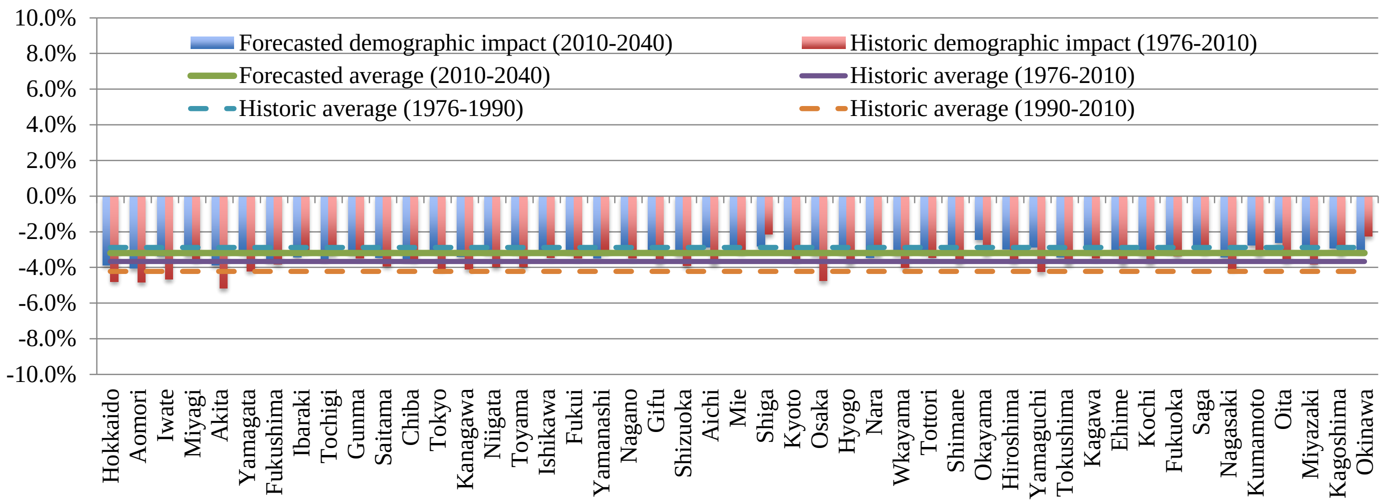


Figure 5: Historic and Forecasted Demographic Impacts on Land Prices

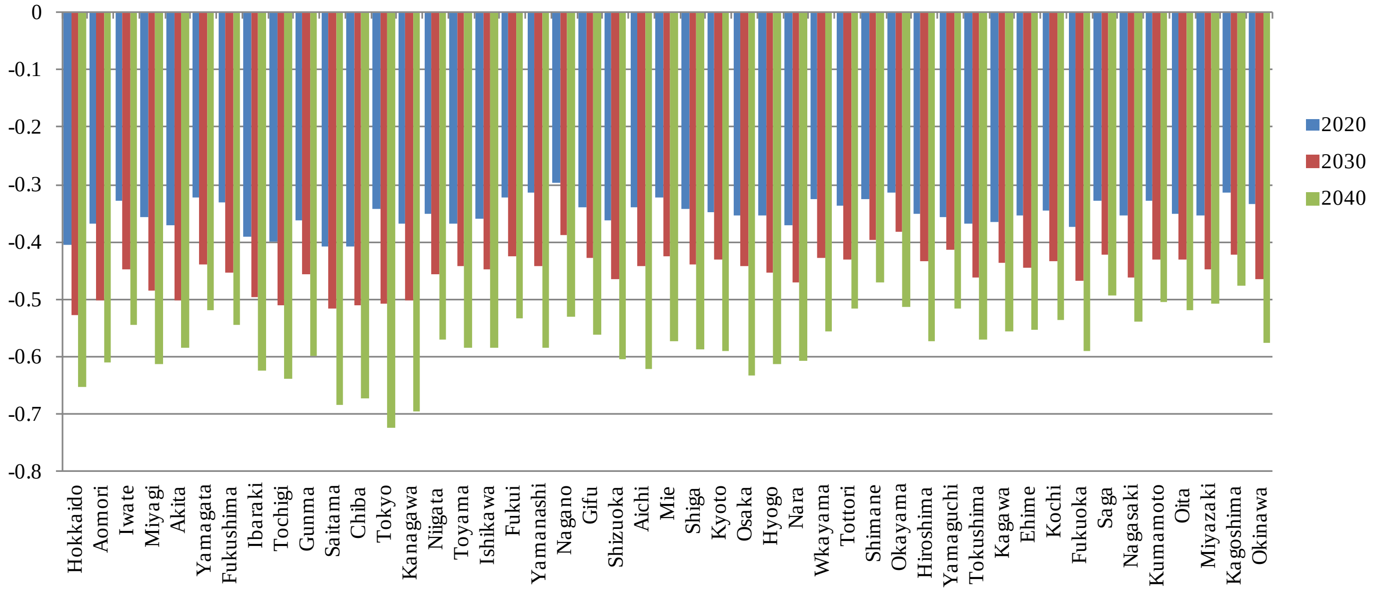


Figure 6a: Contributions of Demographic Changes in 2011-2040

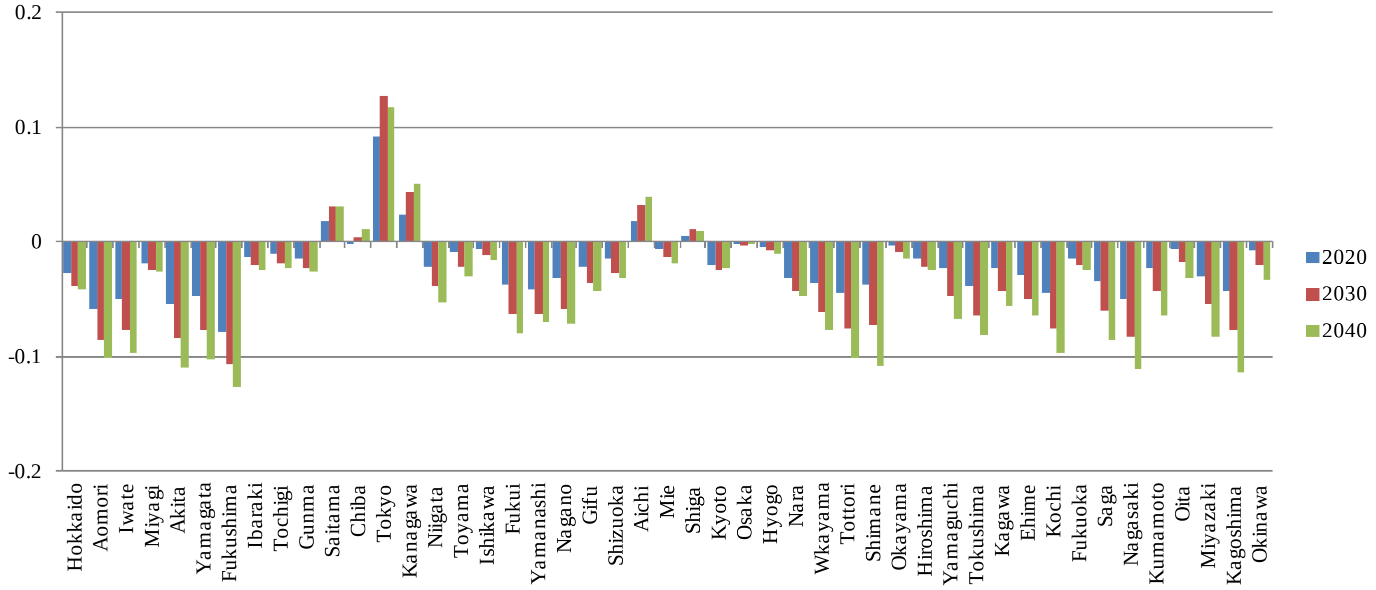


Figure 6b: Effects of Inter-Prefectural Migration on Demographic Impacts in 2011-2040

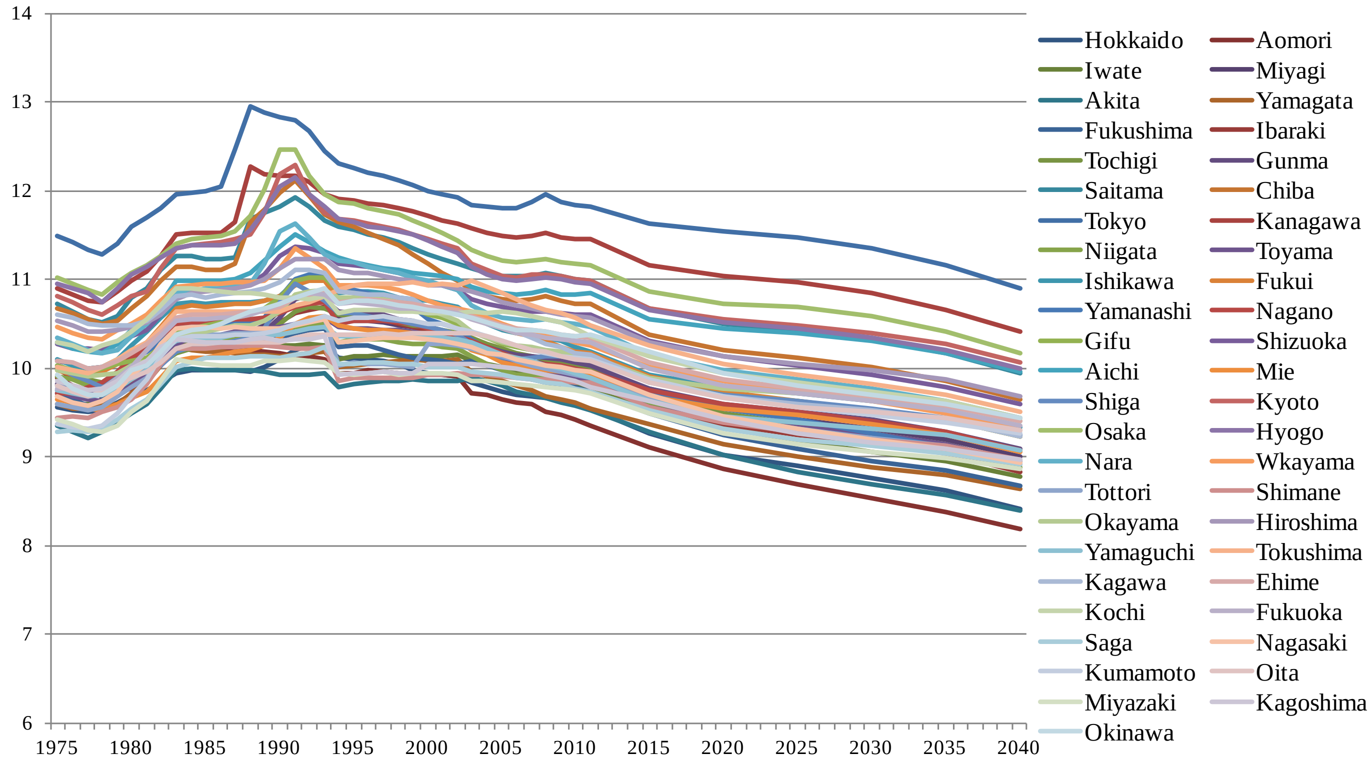


Figure A1: Land Prices Forecasted

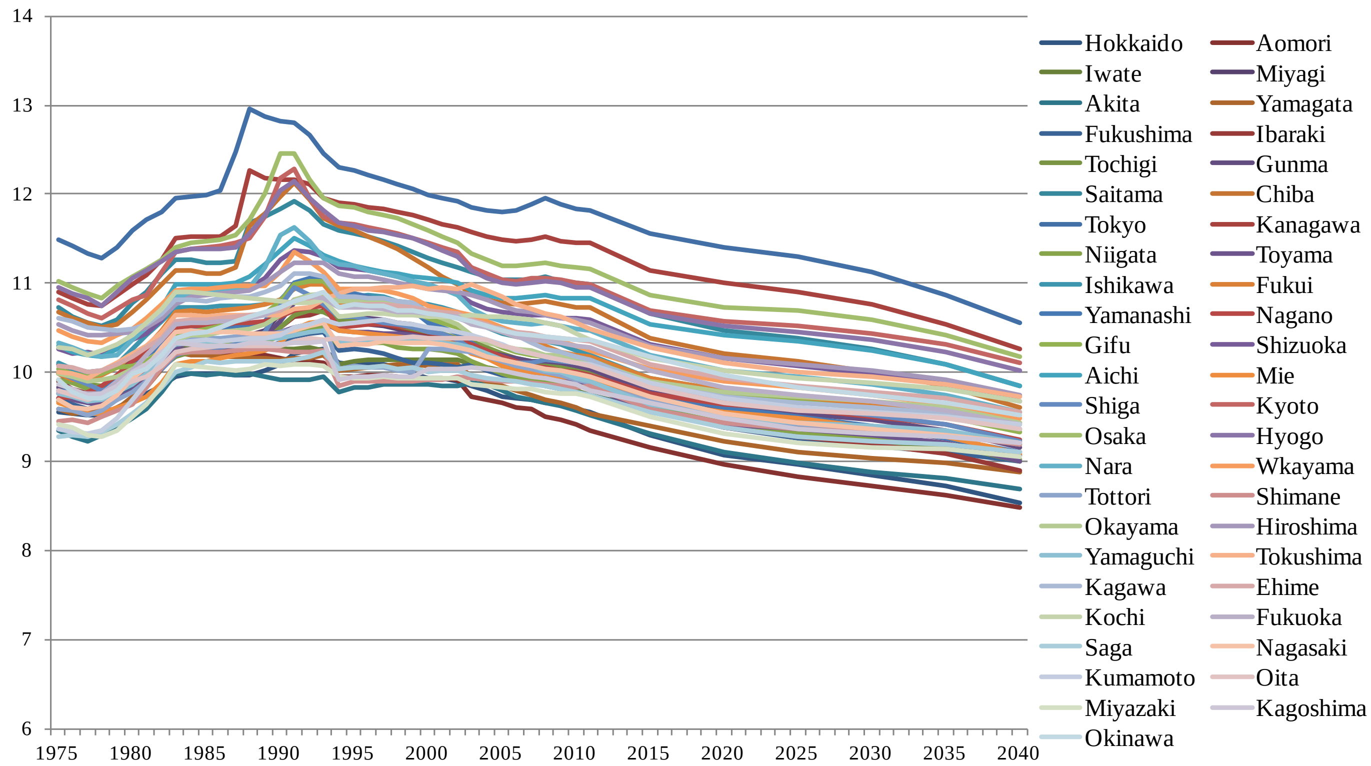


Figure A2: Land Prices Forecasted with the Assumption of No Inter-Prefectural Migration