Aging and Property Prices: A Theory of Very-Long-Run Portfolio Choice and Its Predictions on Japanese Municipalities in the 2040s*

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Abstract

In this paper we investigate the effect of aging population on property (land) prices. A theory of very-long-run portfolio choice is developed for a transition economy from young and growing to rapidly aging population and applied to estimate property price inflation in Japanese municipal markets. The results are stunning. The simulation results in which income factors are assumed to be fixed at the 2005-10 growth level suggest that the average residential property price (land price) in the Japanese municipalities may decrease by as much as 19 percent from the present to 2020, 24 percent to 2030, and 32 percent to 2040.

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1. Introduction

Many economies in the world will soon be or have already begun aging rapidly. Figure 1, based on the United Nations' Population Prospects, depicts the pace of aging in selected developed and emerging economies. Japan is a leader in worldwide population aging,[1] and other developed economies are following suit. Even some emerging economies will soon face this problem while they pursue economic development.

In this paper we investigate the effect of such a rapidly aging population on property prices, especially their land components. Specifically, we focus on the characteristics of land as a *physically* non-depreciable asset enabling transfer of purchasing power from the present to a distant future—say, one generation away.[2] Thus, the demand for properties (their land components) and their prices are determined by people's choice of their very-long-run portfolio for retirement. In this very-long-run portfolio choice, there is another *physically* non-depreciable asset, which is money.[3] Although money was clearly rate-dominated by other assets and thus excluded from the very-long-run portfolio in previous high-inflation eras, recent price stability allows money to become an important asset class for people to prepare for their retirement.

In fact, when the economy's inflation rate is high, holding a large amount of nominal money is not a wise strategy in asset management. This is especially so when people are considering the distant future, say, 30 years from now. Then, it is safe to assume away nominal money from a very-long-run portfolio and to postulate nominal money is held only for transaction purposes. In effect, money is a veil.

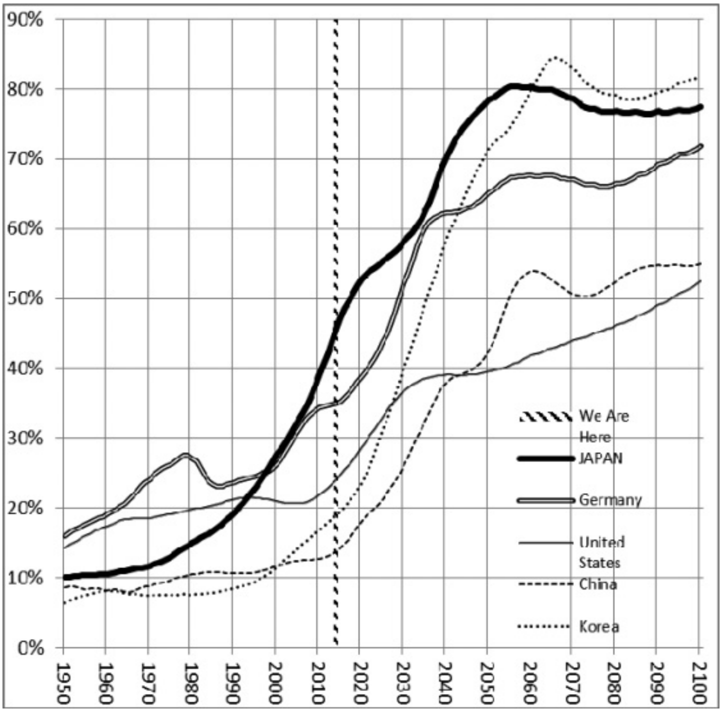
Since the 1980s, however, a so-called Great Moderation of tamed inflation has been achieved. Moreover, we have been witnessing disinflationary or even deflationary trends to date. This change has been brought about by a change in the monetary policy regime, in

1 There are many studies about a substantial growth slowdown and its policy implications in recent years (see, for example, Nishimura and Shirai 2003 and Nishimura and Saito 2003 in the case of Japan). Demographic factors, however, have not been fully discussed in this context.

2 Much research has been devoted to studying the effects of demographic factors on property prices. See Mankiw and Weil (1989), DiPasquale and Wheaton (1994), Engelhardt and Poterba (1991), Hamilton (1991), Hendershott (1991), Kearl (1989), and Poterba (1984) for the United States; and Ohtake and Shintani (1996) and Saita, Shimizu, and Watanabe (2016) for Japan. These studies, however, are mostly base short-run demand and supply relations. Our analysis is based on very-long-run portfolio choice and in the same direction as Takáts (2012) and Nishimura and Takáts (2012), which is based on Nishimura (2011).

3 Money, especially in the form of bank deposits, is not physically depreciated. Money also has no maturity. Therefore, money is not depreciated in the nominal terms. Of course, its real value and thus its real rate of return depends on inflation, as discussed next.

Figure 1. Rapidly aging developed and emerging economies: Old-age dependency ratio



Source: *United Nations World Population Prospects, 2012 Revision.*

which central banks now explicitly target price stability by inflation targeting. They now make it clear that price stability, which does not change in the future, is their mandate.

The most important consequence (not understood well, unfortunately) is that money becomes an important asset even in a very-long-run portfolio. A good example is Japan. For more than two decades of almost zero inflation, people are holding a large amount of money in the form of bank deposits. In fact, during this period, money as a long-run asset has fared well compared with the performance of stock markets and property markets.

In Section 2, we develop a theory of very-long-run portfolio choice between these two physically non-depreciable assets: one is real (land) and the other is nominal (money), in an economy in transition from a young and growing population to a rapidly aging one. We show that aging has profound negative effects on (very-long-run) real property prices, and that the monetary regime is a key factor influencing (very-long-run) real property prices. In particular, real property prices in the population bonus phase are higher in a constant-monetary-quantity regime such as gold standards than in an inflation-targeting monetary regime.

In Section 3, we apply this theory to estimate a long-run model of property price inflation in Japanese municipal markets and attempt to predict municipal real property prices (land prices) in a very long run—specifically, in a quarter century from now. Because ad valorem property taxes based on property prices are the most important municipal tax revenue source in many economies, especially in developed countries like Japan, future movement of property prices is a vital concern of municipal governments. In predicting future property prices, we carefully consider the possibility that short-run (and even medium-run) real prices are influenced by non-fundamentals such as so-called bubbles and busts caused by credit expansions and other events.

The results are stunning. The simulation results in which income factors are assumed to be fixed at the 2005–10 growth level suggest that the average residential property price (land price) in Japanese municipalities may decrease by as much as 19 percent from the present to 2020, 24 percent to 2030, and 32 percent to 2040. Moreover, there is a significant variation among municipalities. The property value of three Tokyo wards (where many new industries are located: Minato, Koutou, and Suginami) is expected to be doubled in 25 years. In comparison, a remote island (Nishino-Omote), a mountainous township (Yoshino) and city (Obanazawa), the only remaining village in a prefecture (Ohira), and a manufacturing town hit by the global financial crisis (Oizumi) would see their property prices to fall by more than 70 percent, alongside a municipality in the periphery of the Tokyo metropolitan area whose commuting population is expected to decline eventually (in Chiba Prefecture: Sakae Town).

The importance of income factors is clear. We conduct another simulation, which compares a 1 percent increase in the income factors across all municipalities with a 0 percent increase. We find that the average expected decline in property prices is reduced to approximately 10 percent in the 1 percent case from a whopping 38 percent in the 0 percent case.

Section 4 contains concluding remarks on the limitation of this study and possible future research.

2. A theory of very-long-run portfolio choice

2.1. Model setup

To set up a theory of very-long-run portfolio choice between two physically non-depreciable assets (land and money), we use a stylized overlapping generation model with a lifecycle, following Allais (1947), Samuelson (1958), and Diamond (1965), and incorporating utility from real money and land holdings. Identical agents live for two periods, which we call young age and old age. Young agents work for an income and save to consume in old age. Saving is done through a divisible utility-bearing real asset called land and through utility-bearing money. Old agents do not work; they sell their accumulated assets (land and money) and consume. At time t, there are n_t young agents; hence, at time $t+1$ there are n_t old agents. Formally, an individual agent's utility function (U) can be written as follows:

$$U\left[c_t^Y, c_{t+1}^O, h_t, M_t\right] \equiv \ln\left(c_t^Y\right) + \ln\left(h_t\right) + \ln\left(\frac{M_t}{P_t}\right) + \beta \ln\left(c_{t+1}^O\right), \tag{1}$$

where ln(.) is the natural logarithm, c^Y is consumption when young, c^O is consumption when old, $0 < \beta < 1$ is the discount factor, and t is the time period index.

Individual agents maximize their utility function (1) subject to young and old age resource constraints, described by equations (2) and (3), respectively. In period t, the young age consumption (c_t^Y) is limited by young age exogenous income (y^Y) reduced by land investment (i.e., land purchase (h_t) multiplied by price (q_t)) and by real money holding (i.e., nominal money held (M_t) divided by the price level (P_t)). Formally:

$$c_t^Y \leq c^Y\left(h_t, M_t, y^Y\right) \equiv y^Y - h_t q_t - M_t/P_t. \tag{2}$$

In period $t+1$, the young generation of period t turns old, the old age population of period t dies and a new young age population is born. The consumption of the old at $t+1$ (c_{t+1}^O) is constrained by the value of their savings. This is the sum of the value of their land (i.e., real land purchases (h_t) in the previous period multiplied by the current land price (q_{t+1})),[4] and of their real money holding (i.e., nominal money acquired in the previous period (M_t) divided by the current price level (P_{t+1})):

$$c_{t+1}^O \leq c^O\left(h_t, M_t\right) \equiv h_t q_{t+1} + M_t/P_{t+1}. \tag{3}$$

We assume that the land supply is exogenously set at a constant stock ($0 < H^*$). Thus, in equilibrium, as agents are identical, the land price is related to land stocks and the young age population as $h_t = H^*/n_t$.

We will explore two versions of the model depending on how money is supplied: one with constant monetary quantity and the other with price stability in which money is supplied elastically to achieve price stability.

4 The land traded in this model may be assumed to be a limited ownership of land with residence rights of the old, so that the old can keep living in the land they purchased in the previous period even after they sell the land to the young of the next generation.

Table 1. Demographic transition

Time	Young Population Size	Old Population Size	Name of Period
$t = 0$	$n + \gamma$	$n + \gamma$	old steady state
$t = 1$	$n + \Delta$	$n + \gamma$	baby boom
$t = 2$	n	$n + \Delta$	aging
$t = 3, 4, \ldots$	n	n	new steady state

We examine a stylized demographic transition, which captures the phase transition from a demographic bonus phase to a demographic onus phase. Table 1 summarizes the stages of this stylized demographic transition. The economy starts in a steady state ($t = 0$) with population size at $n + \gamma$. Then, unexpectedly, the population increases to $n + \Delta$ ($t = 1$, baby boom, where $0 < \gamma < \Delta$). In the baby boom period, there are more young productive workers than old people, which can be thought of as a demographic bonus. The next generation, however, is assumed to be smaller at size n ($t = 2$, aging period), which implies that old people now outnumber the working-age population. In the following period, the system stabilizes at this new, lower population steady state ($t = 3, 4, \ldots$).

2.2 Demand for land and for real money holdings

The demand for land and for real money holdings of each generation-t young are determined by their own life-time utility maximization. By the linear homogeneity of the Cobb-Douglas utility function like equation (1), the utility maximization can be decomposed into two phases: (i) optimal allocation of the endowment y^Y into consumption and saving when they are young (consumption and saving choice), and (ii) how the saving should be divided into land and real money (portfolio choice).

In the log utility framework, it turns out that the optimal saving rate is constant and independent of prices. Because budget constraints would bind in equilibrium, each individual's utility maximization is reduced to the maximization of $U[c^Y(h_t, M_t, y^Y), c^O(h_t, M_t), h_t, M_t]$ with respect to h_t and M_t, for which the first order conditions are

$$\frac{\partial U}{\partial c_t^Y}\frac{\partial c_t^Y}{\partial h_t} + \frac{\partial U}{\partial c_{t+1}^O}\frac{\partial c_{t+1}^O}{\partial h_t} + \frac{\partial U}{\partial h_t} = \frac{-q_t}{y^Y - h_t q_t - M_t/P_t} + \frac{1}{h_t} + \frac{\beta q_{t+1}}{h_t q_{t+1} + M_t/P_{t+1}} = 0, \qquad (4)$$

$$\frac{\partial U}{\partial c_t^Y}\frac{\partial c_t^Y}{\partial M_t} + \frac{\partial U}{\partial c_{t+1}^O}\frac{\partial c_{t+1}^O}{\partial M_t} + \frac{\partial U}{\partial M_t} = \frac{-1/P_t}{y^Y - h_t q_t - M_t/P_t} + \frac{1}{M_t} + \frac{\beta/P_{t+1}}{h_t q_{t+1} + M_t/P_{t+1}} = 0. \qquad (5)$$

Equation (4) $\times\, h_t$ + equation (5) $\times\, M_t$ implies that the optimal saving rate $s_t{}^* \equiv (h_t q_t + M_t/P_t)/y^Y$ is constant at $s^* = (2 + \beta)/(3 + \beta) = 3/4 - (1 - \beta)/(12 + 4\beta)$ regardless of real land prices q_t and q_{t+1} and goods and services prices P_t and P_{t+1}.

Thus, land prices and goods and services prices influence the economy only through portfolio choice between land and real money balances. By the property of the Cobb-Douglas

Table 2. Notations

$s_t^* \equiv (h_t q_t + M_t/P_t)/y^Y$	Optimal saving rate : $s_t^* = s^* \equiv (2+\beta)/(3+\beta)$ (constant)
$\theta_t \equiv h_t q_t/(M_t/P_t)$	Ratio of land investment to real money investment
q_{t+1}/q_t	Rate of return on land for the period-t young
P_t/P_{t+1}	Rate of return on real money for the period-t young
$\rho_t \equiv (q_{t+1}/q_t) \div (P_t/P_{t+1})$	Relative rate of return of land to real money
$z_t \equiv P_t q_t$	Nominal price of land

utility function, the optimal ratio of land to real money is determined by relative rate of return of land with respect to real money. For notational simplicity, we use notations shown by Table 2 in the following discussion.

Equation (4) $\times\, h_t -$ equation (5) $\times\, P_t \times h_t \times q_t$ yields

$$1 + \frac{\beta \rho_t \theta_t}{1 + \rho_t \theta_t} = \theta_t + \frac{\beta \theta_t}{1 + \rho_t \theta_t}, \tag{6}$$

which implies that $\theta_t > 0$ is a strictly increasing function of ρ_t, $\theta_t = \theta(\rho_t)$. It is obvious from equation (6) that $\theta(1) = 1$, that is, if land is equivalent to the money holdings with respect to the rate of return, it is optimal for the young to divide their savings equally between land and real money.

It can also be verifiable that $\theta(\cdot) < 1 + \beta$, $\theta'(\cdot) > 0$, and $\theta(0) = 1/(1+\beta)$ (see Appendix A). The demand for the real land h_t^d and for the money M_t^d are determined by the fact that the optimal saving rate is s^* and the optimal portfolio choice $(h_t^d q_t)/(M_t^d/P_t)$ is equals $\theta(\rho_t)$. In aggregate forms, we have

$$n_t\, h_t^d\, z_t + \, n_t\, M_t^d = \, n_t\, s^* y^Y\, P_t \tag{7}$$

and

$$\frac{n_t h_t^d z_t}{n_t M_t^d} = \theta\left(\rho_t\right)\ . \tag{8}$$

2.3 Supply of assets

As was seen in section 2.1, the aggregate supply of land is exogenously given and constant at H^*.

As for the aggregate money supply, we will discuss two regimes, (1) Constant Monetary-Quantity Regime (Quantity Stability), and (2) Inflation-Targeting Regime (Price Stability). In the former, the aggregate money supply is exogenously constant at M^*, as is the case of the gold-standard regime. In the latter case, each of the young demands money holdings under the expectation that the price is constant at some level $\bar{P}$, while the central bank supplies money as much as the quantity that is consistent with the young's expectation. We will consider the equilibrium in each of these two regimes in the subsequent subsections.

Note that this overlapping-generation economy is inherently dynamic, and prices are so-called jumping variables. To determine the equilibrium path of the economy, we assume that the economy should not explode, or equivalently, that the economy should converge to a steady state.

2.4 Constant monetary quantity regime (quantity stability)

The constant monetary quantity regime is quite similar to a strict gold standard regime: Even though paper money exists, it behaves as if it is fully backed by gold.

Formally, we set aggregate money supply at constant M^* in the model. In this regime, the ratio of real land to the money holding is constant and the equilibrium condition implies

$$\frac{H^* z_t}{M^*}\left(=\frac{n_t h_t^d z_t}{n_t M_t^d}\right)=\theta\left(\frac{z_{t+1}}{z_t}\right). \tag{9}$$

Equation (9), which is the difference equation of z_t and z_{t+1}, determines the dynamics of the nominal price of land. In fact, equation (9) implies that, by setting $z_t = z_{t+1} = z^*$, $z^* \equiv M^*/H^*$ is the unique steady state. Moreover, this steady state is locally unstable (see Appendix B), hence the immediate jump to the steady state is the only path that converges to the steady state. Therefore, $\theta = 1$ and the aggregate savings of the young are equally divided between land and real money balances every period, that is, $H^* q_t = M^*/P_t = n_t s^* y^Y/2$. Thus, both the real value of land and the real value of money (i.e., the inverse of the price level) are proportionate to the aggregate real savings, which is proportionate to aggregate real income of the young, $n_t y^Y$. Hence the real price of land and the price of goods and services depend on both economic and demographic factors as follows.

$$q_t = \frac{n_t}{H^*}\frac{1}{2}s^* y^Y \text{ and } P_t = \frac{M^*}{n_t}\frac{2}{s^* y^Y}. \tag{10}$$

2.5 Inflation target regime (price stability)

Under inflation targeting, we consider a fully elastic money supply. We assume that there is an inflation targeting central bank that stabilizes the price level at $\bar{P}$. The central bank supplies money to keep the price level constant.[5]

5 In the overlapping generation framework, how money is supplied matters. We assume the following helicopter-drop procedure. At the dawn of period t, the old generation has aggregate money holdings $n_{t-1}M_{t-1}$. When this amount is not equal to the amount $n_t M_t$ necessary to keep the price level constant, the central bank dispatches helicopter squads to drop the difference to the old generation's home before the markets open. (If the difference is negative, helicopter squads seize the difference from the old generation.) When the markets open, the monetary stocks of the old

In general, combining equations (7) and (8) and noting that per capita money supply for the young M_t equals to money demanded by each agent M_t^d, $H^* z_t(1 + 1/\theta(\rho_t)) = n_t P_t s^* y^Y$ and $H^* z_{t+1}(1 + 1/\theta(\rho_{t+1})) = n_{t+1} P_{t+1} s^* y^Y$ hold. Dividing the former by the latter side by side,

$$\frac{z_t}{z_{t+1}} \left[\frac{1 + 1/\theta\,(\rho_t)}{1 + 1/\theta\,(\rho_{t+1})} \right] = \frac{n_t P_t}{n_{t+1} P_{t+1}}. \tag{11}$$

Inflation targeting can be written formally as $P_t = \bar{P}$ for all t.[6]

As is customary in such a dynamic framework, we will solve this difference equation backwardly from the future.

2.5.1 Equilibrium from period 2 and thereafter Under the demographic transition shown in Table 1, the population size of the younger generation is constant for all $t \geq 2$, hence equation (11) implies

$$\frac{1 + 1/\theta\,(\rho_t)}{1 + 1/\theta\,(\rho_{t+1})} = \rho_t \text{ for all } t \geq 2. \tag{12}$$

Because $\theta(1) = 1, \theta'(\cdot) > 0$, equation (12) implies $1 \lesseqgtr \rho_t \lesseqgtr \rho_{t+1} \lesseqgtr \rho_{t+2} \lesseqgtr \cdots$, hence the only path of z that converges to the steady state is the immediate jump of z_2 to the steady state. Let M^{SS}, z^{SS}, and $q^{SS} \equiv z^{SS}/\bar{P}$ denote the steady state values of per capita demand for nominal money of the young, nominal and real value of the real land price respectively. Equations (7) and (8) imply

$$\frac{M^{SS}}{\bar{P}} = \frac{1}{2} s^* y^Y, \text{ and } q^{SS} = \frac{n}{H^*} \frac{1}{2} s^* y^Y. \tag{13}$$

It is noteworthy that q^{SS} is the same as the real land price in the constant monetary quantity regime from the period 2 and thereafter.

2.5.2 Equilibrium of period 1 (population bonus period) In period 1, the population of the young is $n + \Delta (> n + \gamma)$. This population bonus is unexpected for the old generation, and we assume that the young generation in the period 1 expect that the population size of each generation from period 2 onwards will be n, and that the equilibrium will be the steady state as shown by equation (13).

generation are $n_t M_t$, which is demanded by the young generation. The helicopter drop (or seizure) is assumed to be unexpected for the old generation when they are young in the previous period.

6 It is evident that the inflation target of x percent can easily be incorporated in this difference equation.

Let us first give an intuitive interpretation of the difference between the inflation target regime and constant monetary quantity regime. In the inflation target regime, there exists no inflation caused by the decrease in population and the money becomes more valuable assets for the young generation than in the constant monetary quantity regime. This implies land in the inflation target regime is less valuable than in the constant monetary quantity regime for the period 1 young generation, so that the real land price is lower in the inflation target regime than in the constant monetary quantity regime.

Formally, in the inflation target regime, equation (11) as for $t = 1$ implies

$$\frac{1}{2}\left\{1+\frac{1}{\theta\left[(q^{SS}/q_1)\div(P_1/P_2)\right]}\right\}=\frac{n+\Delta}{n}\frac{q^{SS}}{q_1}. \tag{14}$$

Given the rate of return on real money holdings for the young in the period 1, (P_1/P_2), equation (14) gives the equilibrium rate of return on real land (q^{SS}/q_1). Because θ, the rate of expenditure on the real land to the expenditure on the real money holdings, is increasing in (q^{SS}/q_1) and decreasing in (P_1/P_2), the left-hand side is decreasing in (q^{SS}/q_1) and increasing in (P_1/P_2). The right-hand side is obviously increasing in (q^{SS}/q_1). Therefore, the larger the rate of return on money (P_1/P_2), the larger is the equilibrium (q^{SS}/q_1). As equation (10) shows, the price of goods and services is proportionate to the inverse of the population size of the young in each period in the constant monetary quantity regime, so the young generation in period 1, expecting the decrease in population of the next generation, expects the inflation when they are old, and the rate of return of money (P_1/P_2) is $n/(n+\Delta) < 1$, while in the inflation target (price stability) regime on the other hand, P_1/P_2 is unity. Therefore, by equation (14), we obtain

$$\frac{n}{n+\Delta}=\frac{q^{SS}}{q_1^{CMQ}}<\frac{q^{SS}}{q_1^{IT}}<1 \text{ or } q_1^{CMQ}>q_1^{IT}, \tag{15}$$

where q_1^{CMQ} and q_1^{IT} are period-1 real price of the land in the constant monetary quantity regime and in the inflation targeting regime, respectively. As expected, the real land price is lower in the inflation target regime than the constant monetary quantity regime.

Appendix C shows that the rate of per capita money demand in period 2 to that in period 1, M_2/M_1 is less than unity, which implies that price stability generates more demand for money as an asset.

2.5.3 Equilibrium up to period 0 Up to period 0, the population of each generation is constant at $n+\gamma$, and equation (12), and thus equations (7) and (8), imply

$$\frac{M_0}{\bar{P}}=\frac{1}{2}s^*y^Y, \text{ and } q_0=\frac{n+\gamma}{H^*}\frac{1}{2}s^*y^Y. \tag{16}$$

Table 3. Real land prices in demographic transition

Period	$t = 0$	$t = 1$	$t = 2$	$t = 3$	$t = 4 \ldots$
Constant money supply	$q^*(n+\gamma)$	$q^*(n+\Delta)$	q^*n	q^*n	q^*n
Inflation targeting	$q^*(n+\gamma)$	q_1	q^*n	q^*n	q^*n

2.6. Real land prices in demographic transition

It is useful to recognzse that real land prices are the same under the constant monetary quantity and inflation target regimes in all periods, *except for the population bonus period* (period $t = 1$), as Table 3 summarizes. That is, monetary regimes are neutral except for the period of demographic transition. Equation (15) shows that the real land prices are lower under inflation target than under fixed money supply at time $t = 1$.

In Table 3, q^* is the per capita optimal land investment $(0.5 \cdot s^* y^Y)$ per unit square of land, that is, $q^* \equiv (0.5 \cdot s^* y^Y)/H^*$. q_1 is determined by equations (13) and (14) and the fact that $P_1 = P_2 = \bar{P}$. By equation (15), we have $q^*(n + \Delta) > q_1$.

In sum, Table 3 shows that (1) demographic factors are important determinants of land prices in the very long run, and (2) monetary policy regimes (or whether we have price stability or not) greatly influence real land prices of the demographic transition period.[7]

2.7 From the very-long theory to short-run empirics: Bubbles and busts

We have shown that demographic changes may influence people's very-long-run portfolio for their retirement, and thus become an important determinant of land prices in the very long run. In the short run, however, demographic changes are slow-moving and predictable, and often considered as an almost constant factor. Rather, various factors are pointed out as culprits of sometimes volatile movement in land prices, which are often described as bubbles and subsequent busts.

Although these culprits are usually considered as being unrelated to demographic changes, some may be correlated to demographic changes in a very particular way (see Nishimura 2016). During a population "bonus" period, the economy has more prime-age, output-producing workers than before, relative to dependent children and elderly individuals. Thus, the economy as a whole produces more discretionary income for consumption or investing; there is more left over after supporting dependent children and seniors. This creates and fosters a vibrant economy for a substantial period. If people extrapolate from their past experience, a demographic bonus can nurture optimism—possibly excessive optimism—about the economy's future. When such excessive optimism is coupled with

7 Nishimura and Takáts (2012) examined a panel of 22 advanced economies over the 1950–2011 period to empirically confirm the theory. They found that baby boomers' saving demand drove both property prices and money demand higher.

the easy money that results from financial innovation, a vast expansion of credit occurs. Excessive optimism leads to excessive leveraging and temporarily high growth; in turn, feeding on each other, excessive leveraging and high growth reinforce excessive optimism.

The demographic bonus can eventually give way to the onus of an aging population, however, as the market and the public realize that past high growth cannot be sustained. Thus, a feedback process begins, reversing course: Excessive pessimism leads to excessive deleveraging and persistently low growth; in turn, excessive deleveraging and low growth reinforce excessive pessimism. This leveraging and subsequent deleveraging process—the alteration between bubbles and busts—is a key trait of credit cycles (Buttiglione et al. 2014). In the next section, we will also examine this possible correlation between demographic changes and bubbles and busts.

3. Empirical analysis

3.1 Estimated models

This section presents the estimation model, which measures the magnitude of the impacts of demographic changes on property prices. The very-long-run model of real property prices (land prices, to be precise) in the previous section suggests that the average change in real property prices during one generation (roughly 25–30 years) is determined by three factors: income per capita of the young population (y_t), the old-age dependency ratio (n_{t-1}/n_t), and the total population ($n_{t-1} + n_t$).[8] In the empirical analysis, we approximate young population by the working-age population aged 20–64 years, and the old population by the population aged 65+ years.[9] Also, as explained in the last subsection of the Section 2, we should properly consider bubble factors in actual Japanese property inflation. These arguments imply the appropriate model for estimation is

$$\Delta lnP_{it} = (\alpha + \delta_t) + \beta_{1t}\Delta lnY_{it} + \beta_{2t}\Delta lnOLDDEP_{it} + \beta_{3t}\Delta lnTPOP_{it} + v_{it}, \quad (17)$$

where $i = 1, \ldots, I$ $t = 1, \ldots, T$; P_{it} is the period t residential land price (real value) at municipality i; Y_{it} is the period t income per capita of the population aged 20–64 (real value) at municipality i; $OLDDEP_{it}$ is the period t old-age dependency ratio (= population aged

8 The demographic factor in the model describes the size difference between two successive working age generations. This can be divided further into size and composition effects. First, total population captures the size effect, that is, the demographic factor given unchanged age structure. Second, the old-age dependency ratio, the ratio of old to working age population, captures the composition effect. In sum, total population and old age dependency ratio capture together the demographic factor.

9 Note that the sum of the effects of total population in log and the old-age dependency ratio in log, which is a log difference of the population aged 65+ and the population aged 20–64, implicitly accounts for the effect of the population aged 0–19, which is not explicitly analyzed in the theoretical overlapping generation model of Section 2.

65+/population aged 20–64) at municipality i; $TPOP_{it}$ is the period t total population at municipality i; υ_{it} are error terms; and $(\alpha + \delta_t)$, β_{1t}, β_{2t}, and β_{3t} are (possibly period-dependent) parameters to be estimated.

Because we are concerned with municipal property markets in the same country (Japan), the monetary policy regime is the same for all municipalities and thus the effect of the change (or no change) of the monetary regime is captured by the intercept α and the period dummy δ_t of the intercept. Also, the bubble factors that may not be related to income and demographic factors are represented in these period dummies. Finally, interaction between demographic and bubble factors are possibly captured by time-varying parameters β_{2t} and β_{3t}. Time-varying β_{1t} represents the interaction between income and bubble factors.

3.2 Data

To estimate the very-long-run model of real property prices as described and to use the model to predict real property prices in Japanese municipalities a quarter century from now, we prepare a municipality-level balanced panel data set. Specifically, we collect and organize the data every five years from 1980 to 2010 (i.e., seven time points)[10] for 892 municipalities[11] for which common data could be obtained at these time points.[12] Based on estimate results, simulation analysis is conducted to predict property prices of 877 municipalities, excluding Fukushima Prefecture.[13] We also conduct another simulation of all 1,683 municipalities, including some municipalities for which official land price surveys are not conducted and are thus excluded from the estimation.

The variables we consider are as follows. For property prices, we use the officially announced land prices (residential land) published on 1 January of each year by the Ministry of Land, Infrastructure, Transport, and Tourism.[14] Because these prices are nominal values, they are converted into real terms using the local consumer price index.

10 Although it is theoretically possible to apply techniques such as unit-root tests and co-integration tests with respect to the data's stationarity, we do not report the results of those tests because the data do not have much information in the time-series direction and fundamentally do not meet the requirements for those techniques in terms of the assumed number of observations.

11 Note that in areas where municipal mergers occurred, we consolidated and aggregated the data for the post-merger area.

12 Municipalities for which the Ministry of Land, Infrastructure, Transport, and Tourism did not survey land prices were excluded from the analysis. Hence, the number of municipalities in the cross-section sample is less than the number of actual municipalities.

13 The National Institute of Population and Social Security Research has not published a Population Projection for Japan (by Municipality) for Fukushima Prefecture; it was therefore excluded from the simulation analysis.

14 Ministry of Land, Infrastructure, Transport and Tourism: *Land Market Value Publication*. The average land price in yen per square meter is published for each pre-specified location each year.

As for an income factor, the theory implies the income per capita of the working age population plays an important role. Thus, we use income per capita of the population aged 20–64 (seemingly most suitable definition of working-age population in Japan).[15] We first convert the municipal taxable income[16] into real values by using the local consumer price index, in the same manner as property prices. We then divide this by the municipality's population aged 20–64. In addition, we calculate and examine income per capita of employed workers aged 20–64 by using the number of employed workers aged 20–64 as the denominator rather than the total population aged 20–64, taking into account the employment rate by gender for the municipality. Because the changes in the results are almost indistinguishable between the "employed worker" model and "total population" one, we report only the latter in this paper.

With respect to the population factors that are the focus of our study, we use two variables: the old-age dependency ratio and total population. The old-age dependency ratio, obtained by dividing the municipality's population aged 65+ by its population aged 20–64, is an indicator that expresses how many elderly people are supported by each productive-age person. In addition, we also calculate and examine the employment-adjusted old-age dependency ratio as an alternative indicator, which is obtained by using the number of employed workers aged 20–64 as the denominator instead of the population aged 20–64, while taking into account the employment rate by gender for the area. This indicator expresses how many elderly people are supported by each employed worker among the productive-age population. Because the changes in the results are almost indistinguishable between the employment-adjusted version and not-adjusted one, we report only the latter in this paper.

3.3 Estimation results

Before conducting any estimation, we test the specifications of the model. First, we investigate which of the fixed effect- or random effect-based estimation is supported by the data with respect to the individual and period effects. Specifically, we test the null hypothesis that the individual (municipality / period) factor is correlated with explanatory variables by performing the Hausman test. The results indicate that the null hypothesis is rejected for the model, and the fixed effect-based specification is used throughout this paper.

Second, to examine the significance of the individual and/or period fixed effects, we performed F tests. The results support an estimation based on period fixed effects only, with no individual fixed effects. This is consistent with the "nationwide-bubble story" that a

15 Statistics Bureau, Ministry of Internal Affairs and Communications: *Population Census*.

16 Local Tax Bureau, Ministry of Internal Affairs and Communications: *Taxable Income.*

Table 4. Estimation results: A panel of 892 municipalities, baseline and IV models with time-invariant effects of demographic factors (bubble components are assumed to be unrelated to demographic factors)

	(1) Baseline		(2) Instrumental variable	
	Estimate	Std. error	Estimate	Std. error
$\Delta\ln Y_{it}$	1.230	0.045***	1.383	0.048***
$\Delta\ln OLDDEP_{it}$	−0.617	0.046***	−0.618	0.049***
$\Delta\ln TPOP_{it}$	0.409	0.053***	0.741	0.076***
Intercept	0.392	0.011***	0.071	0.014***
1990 Dummy	−0.280	0.011***	na	na
1995 Dummy	−0.545	0.010***	−0.249	0.011***
2000 Dummy	−0.379	0.012***	−0.056	0.015***
2005 Dummy	−0.468	0.012***	−0.141	0.015***
2010 Dummy	−0.406	0.011***	−0.082	0.014***
Individual effect	None		None	
Period effect	Fixed effect		Fixed effect	
Instrument	None		$\Delta\ln TPOP_{i,\ t-1}$	
Number of observations	5,352		4,460	
Estimation period	1985–2010 (every five years)		1990–2010 (every five years)	
Adjusted R^2	0.643		0.520	

Note: ****Statistically significant at the 1 percent level.*

credit bubble has affected each municipality in the same way. Drawing on those results, we estimate the model that takes into account period fixed effects only.

Third, we check the robustness of the results by conducting instrumental variable estimation. It is conceivable that changes in property prices may induce population migration among municipalities. Population variables (total population and old-age dependency ratio) may thus correlate with the residuals. We therefore apply instrumental variable estimation to correct for possible ordinary least squares bias as a robustness check. One candidate for instrumental variables is lagged population variables and we use them as an instrument.

Table 4 presents the estimation results for the baseline and the instrumental variable (IV) model, assuming that "bubble components" in the property prices are not related to income and demographic changes. Both the baseline model and the IV one produce very similar results, suggesting the results reported here are robust with respect to econometric specifications.

The results in Table 4 suggest that demographic factors have significant effects on property prices in the very long run, alongside with income factors. In the baseline model, when income per capita increases by 1 percent, property prices increase by 1.23 percent (or 1.38 percent in the IV model). Similarly, if the old-age dependency ratio increases by 1 percent, property prices decrease by 0.617 percent (or 0.741 percent in IV model), and if total population increases by 1 percent, property prices increase by 0.409 percent (or 0.071 in IV

Table 5. Estimation results: A panel of 892 municipalities, time-variant effects of demographic factors (bubble components are related to demographic factors)

	Estimate	Std. error		Estimate	Std. error
$\Delta \ln Y_i$ 1985	0.235	0.130*	$\Delta \ln TPOP_i$ 1985	−0.115	0.111
$\Delta \ln Y_i$ 1990	2.322	0.105***	$\Delta \ln TPOP_i$ 1990	0.191	0.130
$\Delta \ln Y_i$ 1995	1.343	0.065***	$\Delta \ln TPOP_i$ 1995	0.839	0.157***
$\Delta \ln Y_i$ 2000	0.933	0.148***	$\Delta \ln TPOP_i$ 2000	−0.570	0.159***
$\Delta \ln Y_i$ 2005	0.525	0.161***	$\Delta \ln TPOP_i$ 2005	−0.437	0.168***
$\Delta \ln Y_i$ 2010	0.486	0.172***	$\Delta \ln TPOP_i$ 2010	1.062	0.146***
$\Delta \ln OLDDEP_i$ 1985	−0.653	0.150***	Intercept	0.529	0.028***
$\Delta \ln OLDDEP_i$ 1990	−1.702	0.165***	1990 dummy	−0.480	0.049***
$\Delta \ln OLDDEP_i$ 1995	−0.875	0.172***	1995 dummy	−0.659	0.044***
$\Delta \ln OLDDEP_i$ 2000	−0.649	0.117***	2000 dummy	−0.509	0.036***
$\Delta \ln OLDDEP_i$ 2005	−0.662	0.089***	2005 dummy	−0.619	0.034***
$\Delta \ln OLDDEP_i$ 2010	0.130	0.084	2010 dummy	−0.667	0.032***
Number of observations			5,352		
Estimation period			1985–2010 (every five years)		
Adjusted R^2			0.677		

Note: *Signs *** and * represent the estimated parameters are significant at 1 percent and 10 percent respectively.*

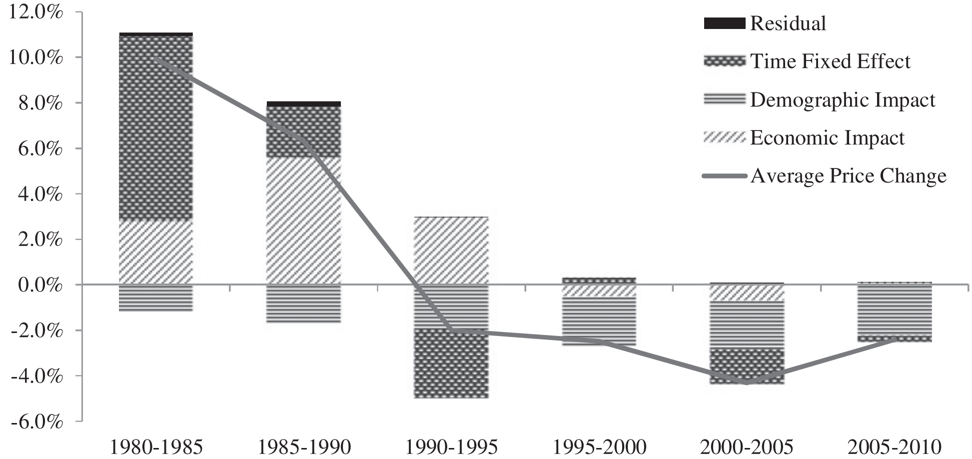
model). These results are largely consistent with the findings of Takáts (2012) and Saita, Shimizu, and Watanabe (2015).

As expected, we obtain statistically significant intercept and period dummies in Table 4. This suggests the importance of the bubble and bust component unrelated to income and demography in understanding actual property price changes in the 5-year interval.

In Section 2.7, we argued that the bubble and bust component of property price changes may be strongly correlated with the demographic bonus and onus, through alternating optimism and pessimism induced by the turn from the demographic bonus to onus, when they are coupled with financial innovation-induced credit factors. The results reported in Table 5 strongly support this conjecture. The time-varying coefficient of the old-age dependency rate has a statistically significant, strong negative effect (except for the last period, 2010). This suggests that a rapidly aging population in the municipality since the 1980s has induced growing pessimism over the future of the municipality economy, and thus put a downward pressure on its property prices.

Based on these empirical results, we decompose the municipal property–price inflation for each period into economic and demographic impacts as well as time effects incorporating bubble components and residuals, using the baseline estimation. Economic impacts are calculated as the contribution of the rate of change in income per capita to the municipality's property price inflation, and demographic impacts are calculated as the contribution of the rate of change in the total population and old age dependency ratio. Figure 2 illustrates the decomposition results averaged over the municipalities examined.

Figure 2. Breakdown of property–price inflation: Economic and demographic impacts



Source: *Authors' calculation.*

In the early 1980s, when Japan still enjoyed a demographic bonus,[17] bubble components (in "time fixed effect") induced by optimism about the future apparently prevailed in municipal property markets, leading to greater than 10 percent annual average property inflation. Then the late 1980s saw municipal property–price inflation drop to around 6 percent nationally, and the bubble components subsided and municipal property–price inflation became largely influenced by economic factors (income). Throughout the 1980s, demographic factors exerted negative impacts, reflecting an increasing old-age dependency ratio.

A popular perception of the Japanese "bubble economy" is that it began forming in the late 1980s, peaked to an absurd level in 1990, and then imploded. At first glance, our findings of fewer bubble effects in the late 1980s than the early 1980s look inconsistent with this popular image of the Japanese bubble—for example, that of unbelievable increases in central Tokyo property prices in the late 1980s. In fact, our results show that the Japanese "bubble" is a local phenomenon concentrated in high-price metropolitan areas and property prices in most local municipalities were showing marked moderation at that time. This bipolarization of property prices seems a hallmark of the property price "bubble."

To see this, we examine the average rate of change in land prices for the 892 municipalities by prefecture in Table 6. From 1980 to 1985, land prices rose in all 47 prefectures, with an average change of 9.9 percent. During the bubble formation period (from 1985 to 1990),

17 The total dependency ratio, which is the sum of child and old dependency ratios, was still declining in the first half of the 1980s.

Table 6. Average land price fluctuations in prefecture

ID	Prefecture	Number of municipalities	1980–1985	1985–1990	1990–1995	1995–2000	2000–2005	2005–2010
1	Hokkaido	45	6.2%	−0.8%	−1.0%	−0.6%	−2.4%	−3.2%
2	Aomori	13	8.8%	−1.4%	−2.2%	−0.6%	−2.6%	−3.8%
3	Iwate	14	12.1%	−1.3%	−1.4%	−0.1%	−0.7%	−4.3%
4	Miyagi	18	8.0%	1.7%	0.3%	0.1%	−4.2%	−4.2%
5	Akita	10	11.5%	−3.2%	−3.3%	−0.2%	−1.6%	−4.1%
6	Yamagata	15	8.9%	−0.8%	−1.2%	0.8%	−1.8%	−4.7%
7	Fukushima	15	8.8%	1.0%	−0.1%	−2.9%	−3.9%	−3.6%
8	Ibaraki	34	8.8%	4.6%	3.4%	−3.3%	−5.9%	−3.9%
9	Tochigi	18	7.5%	4.4%	3.0%	−1.9%	−4.9%	−3.9%
10	Gunma	17	7.1%	5.7%	2.8%	−3.4%	−6.3%	−2.3%
11	Saitama	53	9.6%	12.5%	−4.3%	−5.8%	−5.3%	−1.2%
12	Chiba	34	8.3%	16.6%	−5.3%	−8.0%	−7.9%	−0.8%
13	Tokyo	49	9.4%	19.0%	−10.7%	−5.4%	−2.8%	1.2%
14	Kanagawa	28	12.5%	10.9%	−3.1%	−3.0%	−4.5%	−1.3%
15	Niigata	17	9.3%	−0.4%	−2.7%	−0.9%	−3.7%	−2.7%
16	Toyama	9	13.4%	1.5%	−1.0%	−1.4%	−5.1%	−4.1%
17	Ishikawa	11	10.6%	0.7%	1.2%	−1.7%	−6.3%	−4.2%
18	Fukui	8	11.1%	1.4%	0.1%	−1.3%	−3.7%	−6.0%
19	Yamanashi	10	7.7%	6.1%	2.5%	−4.3%	−7.3%	−3.3%
20	Nagano	19	10.1%	2.0%	−0.2%	−1.9%	−5.2%	−3.9%
21	Gifu	21	9.4%	5.0%	3.3%	−3.6%	−6.0%	−2.9%
22	Shizuoka	24	11.4%	8.6%	−2.1%	−3.3%	−4.4%	−1.5%
23	Aichi	50	12.0%	6.6%	−1.6%	−2.1%	−3.5%	−1.0%
24	Mie	18	11.2%	4.2%	1.4%	−1.5%	−3.8%	−2.8%
25	Shiga	14	8.7%	9.2%	−1.5%	−3.1%	−5.2%	−0.5%
26	Kyoto	18	12.3%	14.1%	−5.0%	−3.6%	−6.4%	−1.4%
27	Osaka	41	8.7%	21.4%	−11.1%	−4.8%	−7.8%	−0.9%
28	Hyogo	27	7.9%	8.4%	−2.6%	−2.4%	−6.8%	−1.5%
29	Nara	28	11.0%	11.2%	−5.3%	−3.3%	−6.0%	−1.6%
30	Wakayama	7	5.5%	1.8%	−1.8%	−1.9%	−4.0%	−4.6%
31	Tottori	5	14.3%	0.5%	−0.6%	−0.6%	−3.3%	−5.4%
32	Shimane	7	11.0%	−0.1%	−7.1%	0.4%	−0.1%	−1.8%
33	Okayama	13	8.9%	2.9%	3.1%	−1.2%	−5.5%	−2.8%
34	Hiroshima	16	10.5%	3.1%	−2.3%	−1.4%	−2.8%	−3.2%
35	Yamaguchi	14	8.8%	1.0%	−0.6%	0.5%	−3.4%	−3.5%
36	Tokushima	8	7.4%	0.2%	5.4%	0.4%	−3.8%	−5.5%
37	Kagawa	6	7.8%	2.1%	−1.7%	−1.5%	−4.8%	−5.5%
38	Ehime	12	11.2%	1.3%	0.8%	−0.6%	−3.3%	−2.4%
39	Kochi	11	11.4%	−1.7%	−1.2%	−0.5%	−0.8%	−4.3%
40	Fukuoka	32	13.2%	1.7%	1.3%	−0.9%	−2.8%	−3.2%
41	Saga	8	11.5%	0.5%	0.6%	0.1%	−0.4%	−2.7%
42	Nagasaki	10	11.7%	−0.7%	0.3%	0.6%	−4.1%	−4.1%
43	Kumamoto	13	15.5%	0.9%	3.5%	−0.9%	−3.1%	−4.5%
44	Oita	11	10.8%	0.2%	−1.9%	−0.2%	−1.3%	−3.4%
45	Miyazaki	11	11.1%	−0.2%	−3.1%	0.1%	−0.1%	−0.9%
46	Kagoshima	14	10.1%	−1.3%	−3.2%	−0.9%	−1.0%	−3.8%
47	Okinawa	16	11.4%	6.7%	2.9%	−1.0%	−4.1%	−2.5%
	National	892	9.9%	6.3%	−2.0%	−2.5%	−4.3%	−2.4%

Source: *Authors' calculation.*

although there were significant increases in land prices exceeding 10 percent in the Tokyo metropolitan area (Tokyo, Kanagawa, Chiba, and Saitama) and the Kansai area (Osaka, Kyoto, and Nara), there was considerable moderation in price increases in non-metropolitan areas, and in some areas in Hokkaido and the Tohoku region, land prices decreased, so that the average increase was only 6.3 percent. In other words, the bubble that began around the mid 1980s was a localized phenomenon restricted to the Tokyo metropolitan area and the Kansai area. This explains why the time fixed effect was greater in 1980–85 than it was in 1985–90.

In the next 10-year period, from 1990 to 2000, the national average of municipal property prices continued to decrease by over 2 percent per year. This decline in municipal property prices was caused largely by demographic rather than economic impacts. This trend continued from 2000 to date, in which an aging population put a significant downward pressure on property prices.

3.4 Simulation analysis: Property price prediction based on demographic factors

In this section, we use the baseline model (Table 4) to predict real property prices (land prices) in Japanese municipalities every five years until 2040, a quarter century from the present, assuming that there are no bubble and bust effects (an intercept and period dummies are set to zero). We calculate the rate of change in the real property price for each municipality for each five-year period and add them up to get the level estimate of the real property price. As for population variables, we use the estimated rate of change in the total population ($\Delta \ln OLDDEP_{it}$) and old-age dependency ratio ($\Delta \ln TPOP_{it}$), which are derived from detailed estimates of each municipality's population and its components conducted by the National Institute for Population and Social Security Research (IPSS).

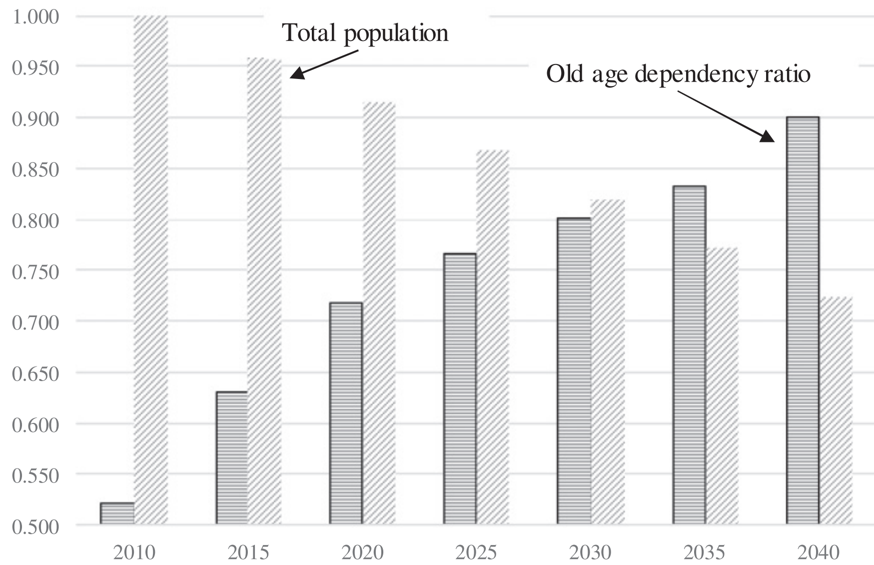
In the first set of simulations, we consider the same set of municipalities in the regression analysis of the previous section, except for those in Fukushima Prefecture, where a nuclear power plant accident occurred in 2011. The IPSS reports their estimates of population and its components for all municipalities except for those in Fukushima Prefecture, because of significant and persistent dislocation of residents near the failed power plant. Thus, the number of municipalities we consider is 877, instead of 892.[18]

We consider three cases in this simulation: (a) the growth rate of income per capita of working age population (aged 20–64) is set to zero ($\Delta \ln Y_{it} = 0$) [reference case], (b) the growth rate of income per capita of working age population is the five-year average growth rate during the 2005–10 period ($\Delta \ln Y_{it} =$: 2005–10) [baseline case], and (c) the growth rate of income per capita of working age population is the ten-year average growth rate during the 2000–10 period ($\Delta \ln Y_{it} =$: 2000–10) [alternative case].

For Japan as a whole, the total population is predicted to decrease by around 15 percent from approximately 126 million in 2010 to 107 million in 2040. By age, the population aged 20–64 is likely to decrease by about 27 percent by 2040, and the population aged 65+ is forecasted to increase by about 33 percent. The old-age dependency ratio was 0.39 in 2010, but it is predicted to rise to 0.72 in 2040. The predicted total population and old age dependency ratio are averaged over all 1,683 municipalities and shown in Figure 3 for year 2020,

18 IPSS's estimated population forecasts by municipalities are calculated in the following way: Natural increase / decrease by subtracting the number of expected deaths from the number of expected births + Social increase / decrease by subtracting the number of expected out-migrants from the number of expected in-migrants.

Figure 3. Total population and old-age dependency ratio



Source: *Authors' calculation.*

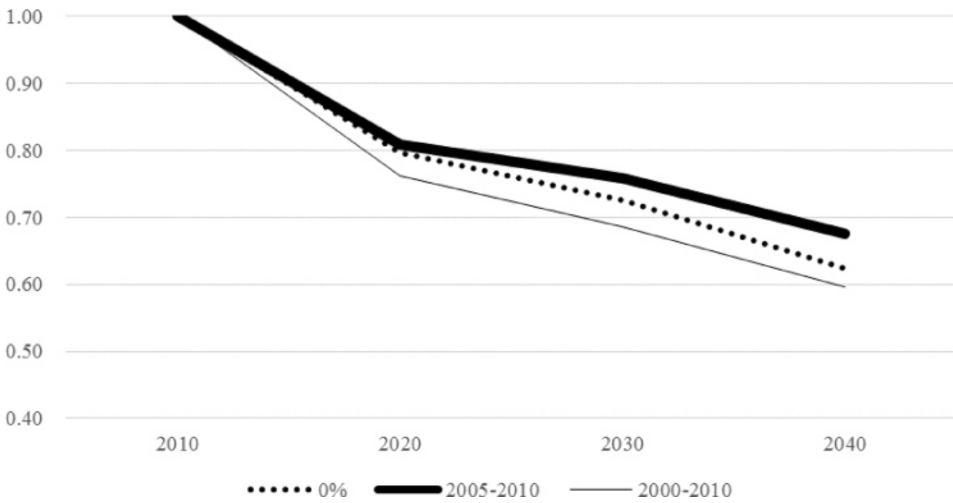
2030, and 2040. The 2010 value is normalized to unity for the total population.

Figure 4 reports the results of the first simulation. The baseline case, in which the growth rate of the income per capita of working age population is the five-year average growth rate during the 2005–10 period, is represented in a thick line, and the alternative case of the 2000–10 period average is shown in thin line. The results are stunning. In the baseline case, the average residential property price (land price) in the Japanese municipalities may decrease as much as 19 percent from the present to 2020, 24 percent to 2030, and 32 percent to 2040.

Some may argue that the 2005–10 period is not a suitable choice for income growth for a very-long-run analysis like ours, because the period includes the global financial crisis of 2007–08. Taking this into account, we conduct an alternative simulation based on the 2000–10 period average, which is depicted in the thin line. In reality, this alternative case is worse than the baseline case. This is partly because Japanese municipalities suffered more from the 1990 crash of the Japanese bubble than the global financial crisis of the late 2000s. In fact, the ten-year-average case is worse than the hypothetical zero-growth reference case.

Moreover, there is a significant variation among municipalities. The property value of three Tokyo wards (where many new industries are located: Minato, Koutou, and

Figure 4. Predicted future real property prices averaged over 877 municipalities



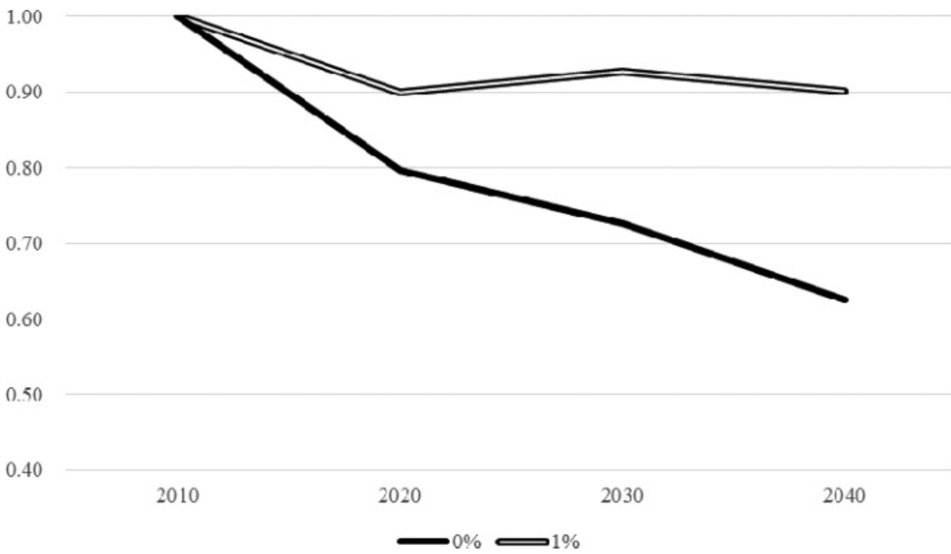
Source: *Authors' calculation.*

Suginami) is expected to be doubled in 25 years. In comparison, a remote island (in southern-most Kyushu: Nishino-Omote City on Tanegashima Island), a mountainous township (in Nara Prefecture: Yoshino Town) and city (in Yamagata Prefecture: Obanazawa City), the only remaining village in a prefecture (in Miyagi Prefecture: Ohira Village), and a manufacturing town hit by the global financial crisis (in Gunma Prefecture: Oizumi Town) would see their property prices fall by more than 70 percent, alongside with a municipality in a commuting periphery of the Tokyo metropolitan area whose commuting population is expected to decline eventually (in Chiba Prefecture: Sakae Town).

Figure 5 examines the magnitude of income growth effects on future real property prices averaged over 877 municipalities in question. A thick line represents the change in the average real property price when all municipalities have zero growth in income per capita of working age population. This corresponds to the thick line in Figure 4. In comparison, a double line represents the case in which the growth rate is 1 percent instead of 0 percent. From this future, we find that the average expected decline in property prices is reduced to approximately 10 percent in the 1 percent case from whopping 38 percent in the 0 percent case. From this simulation, it is clear that growth in income per capita of the working age population is crucial in halting a sizable decline in property prices in municipal markets.

In the second simulation, we consider all municipalities (1,683 of them) excluding those in Fukushima prefecture. Because the baseline model does not have individual municipality effect and the IPSS reports their estimates of population and its components for all

Figure 5. Predicted future real property prices under hypothetical growth rates averaged over 877 municipalities



Source: *Authors' calculation.*

municipalities except for those in Fukushima Prefecture, it is possible to simulate their property prices by using the baseline model, if we make an assumption about the growth in income per capita working age population for each municipality. We examine two cases: (1) 0 percent growth uniformly and (2) 1 percent growth uniformly.

Table 7 shows the results in the form of prefectural averages, which largely confirm the findings of the first simulation based on 877 municipalities. The average expected decline in property prices is reduced to 10 percent in the 1 percent case from a whopping 38 percent in the 0 percent case. Nevertheless, the result shows relative uniformity among prefectures, compared with the first simulation's significant variation among municipalities where the actual past average growth is used instead of the uniform income growth assumption.

4. Concluding remarks

We have developed a theory of very-long-run portfolio choice between two physically non-depreciable assets of which one is real (land) and the other nominal (money) in a non-inflationary environment, for an economy in transition from a young and growing population to a rapidly aging population. Aging has been shown to have profound effects

Table 7. Predicted future property prices: All municipalities (1,683)

ID	Prefectures	Number of municiparities	Growth assumption: 0% 2010	2020	2030	2040	Growth assumption: 1% 2010	2020	2030	2040
1	Hokkaido	179	1.000	0.767	0.669	0.575	1.000	0.867	0.855	0.830
2	Aomori	40	1.000	0.758	0.640	0.544	1.000	0.857	0.817	0.785
3	Iwate	33	1.000	0.777	0.667	0.583	1.000	0.878	0.852	0.842
4	Miyagi	35	1.000	0.780	0.684	0.609	1.000	0.881	0.874	0.879
5	Akita	25	1.000	0.769	0.659	0.578	1.000	0.870	0.841	0.835
6	Yamagata	35	1.000	0.788	0.677	0.612	1.000	0.891	0.865	0.884
8	Ibaraki	44	1.000	0.766	0.684	0.589	1.000	0.866	0.873	0.851
9	Tochigi	26	1.000	0.765	0.672	0.582	1.000	0.865	0.859	0.840
10	Gunma	35	1.000	0.772	0.684	0.585	1.000	0.873	0.874	0.845
11	Saitama	63	1.000	0.765	0.693	0.578	1.000	0.865	0.885	0.835
12	Chiba	54	1.000	0.761	0.682	0.581	1.000	0.860	0.871	0.839
13	Tokyo	62	1.000	0.848	0.765	0.628	1.000	0.958	0.977	0.907
14	Kanagawa	33	1.000	0.787	0.718	0.596	1.000	0.889	0.917	0.860
15	Niigata	30	1.000	0.797	0.707	0.625	1.000	0.901	0.903	0.903
16	Toyama	15	1.000	0.805	0.743	0.632	1.000	0.910	0.949	0.912
17	Ishikawa	19	1.000	0.781	0.714	0.617	1.000	0.883	0.911	0.891
18	Fukui	17	1.000	0.815	0.729	0.652	1.000	0.921	0.931	0.941
19	Yamanashi	27	1.000	0.795	0.680	0.579	1.000	0.898	0.869	0.836
20	Nagano	77	1.000	0.827	0.747	0.659	1.000	0.934	0.954	0.952
21	Gifu	42	1.000	0.798	0.727	0.634	1.000	0.902	0.929	0.916
22	Shizuoka	35	1.000	0.788	0.713	0.614	1.000	0.890	0.911	0.886
23	Aichi	54	1.000	0.829	0.782	0.667	1.000	0.937	0.998	0.964
24	Mie	29	1.000	0.815	0.744	0.638	1.000	0.921	0.950	0.921
25	Shiga	19	1.000	0.814	0.755	0.660	1.000	0.920	0.964	0.953
26	Kyoto	26	1.000	0.780	0.715	0.617	1.000	0.882	0.913	0.890
27	Osaka	43	1.000	0.794	0.734	0.606	1.000	0.898	0.937	0.875
28	Hyogo	41	1.000	0.795	0.720	0.621	1.000	0.898	0.920	0.897
29	Nara	39	1.000	0.766	0.675	0.584	1.000	0.866	0.862	0.843
30	Wkayama	30	1.000	0.797	0.704	0.605	1.000	0.901	0.899	0.873
31	Tottori	19	1.000	0.792	0.701	0.636	1.000	0.895	0.895	0.918
32	Shimane	19	1.000	0.776	0.702	0.643	1.000	0.878	0.897	0.929
33	Okayama	27	1.000	0.819	0.761	0.691	1.000	0.925	0.972	0.997
34	Hiroshima	23	1.000	0.798	0.737	0.650	1.000	0.902	0.942	0.938
35	Yamaguchi	19	1.000	0.789	0.735	0.655	1.000	0.892	0.939	0.946
36	Tokushima	24	1.000	0.761	0.670	0.587	1.000	0.860	0.856	0.848
37	Kagawa	17	1.000	0.792	0.729	0.645	1.000	0.895	0.932	0.932
38	Ehime	20	1.000	0.778	0.693	0.613	1.000	0.879	0.885	0.885
39	Kochi	34	1.000	0.781	0.689	0.618	1.000	0.882	0.880	0.892
40	Fukuoka	60	1.000	0.781	0.724	0.652	1.000	0.882	0.924	0.941
41	Saga	20	1.000	0.800	0.722	0.657	1.000	0.904	0.922	0.949
42	Nagasaki	21	1.000	0.773	0.666	0.591	1.000	0.874	0.851	0.853
43	Kumamoto	45	1.000	0.794	0.704	0.652	1.000	0.897	0.899	0.942
44	Oita	18	1.000	0.794	0.723	0.662	1.000	0.898	0.924	0.955
45	Miyazaki	26	1.000	0.779	0.691	0.644	1.000	0.881	0.882	0.930
46	Kagoshima	43	1.000	0.810	0.707	0.650	1.000	0.916	0.903	0.938
47	Okinawa	41	1.000	0.815	0.707	0.646	1.000	0.922	0.903	0.933
	National	1,683	1.000	0.789	0.705	0.616	1.000	0.892	0.901	0.889

Source: *Authors' calculation.*

on real property prices. The monetary regime is a key factor influencing (very-long-run) real property prices. We then applied this theory to estimate a long-run model of property price inflation in Japanese municipal markets and attempted to predict municipal real property prices (land prices) in a quarter century from now. The simulation results, in which income factors are assumed to be fixed at the 2005–10 growth level, suggest that the average residential property price (land price) in the Japanese municipalities may decrease as much as 19 percent from the present to 2020, 24 percent to 2030, and 32 percent to 2040.

There are limitations about the theory and empirical methods of this paper, which future research should address. First, the theory is based on a very stylized model of overlapping generations without capital stocks. This is partly justified by the fact that the product life of many capital goods is much shorter than the length of a generation. Some capital stocks, however, have a longer product life, spanning generations. Moreover, having only two generations at any point of time is also a restrictive assumption. By the same token, the way money is supplied in the model and people's expectations about it are also one specification among many possibilities. The incorporation of these features is the subject of future research.

Second, the empirical analysis focused attention only on the Japanese case. As Figure 1 reveals, aging is not a Japan-only phenomenon but an almost global one, which is likely to influence various economic activities. Thus, a multi-country panel study incorporating not only property prices but also product prices (general price level) is necessary to grasp the impact of aging on economic activities. The first attempt in this direction shows that the basic conclusion of this paper is still valid in the multi-country framework.[19]

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Appendix A. The properties of the function $\theta(\rho_t)$

Equation (6) implies that θ_t is the positive root for the quadratic equation $f(\theta_t) \equiv \rho_t\theta_t^2 - (1+\beta)(\rho_t - 1)\theta_t - 1 = 0$. Because $f(1+\beta) = (1+\beta)^2 - 1 > 0, \theta < 1+\beta$. By differentiating the equation $f(\theta_t) = 0$, $[2\rho_t\theta_t - (1+\beta)(\rho_t - 1)]d\theta_t - \theta_t((1+\beta) - \theta_t)d\rho_t = 0$. Evaluating at $f(\theta_t) = 0$, $[2\rho_t\theta_t - (1+\beta)(\rho_t - 1)] = 1/\theta_t + \rho_t\theta_t$ hence

$$\frac{d\theta_t}{d\rho_t} = \theta_t \left\{ \frac{(1+\beta) - \theta_t}{1/\theta_t + \rho_t\theta_t} \right\} > 0 \tag{A1}$$

where the inequality holds because $\theta_t < 1+\beta$. If $\rho_t = 0$, the equation $f(\theta_t) = 0$ is equivalent to $(1+\beta)\theta_t - 1 = 0$ hence $\theta(0) = 1/(1+\beta)$.

Appendix B. The instability of the steady state of equation (9)

Difference equation (9) implies

$$\frac{H^* z_{t+1}}{M^*} = \theta\left(\frac{z_{t+2}}{z_{t+1}}\right). \tag{B1}$$

Dividing equation (B1) by equation (9) side by side implies

$$\rho_t \theta\left(\rho_t\right) = \theta\left(\rho_{t+1}\right). \tag{B2}$$

Because $\theta(1) = 1$ and $\theta(\cdot)$ is positive and strictly increasing, equation (B2) implies that

$$1 \lesseqgtr \rho_t \Rightarrow 1 \lesseqgtr \rho_{t+s} \quad \forall s \geq 1$$

by induction, which is equivalent to $z_t \lesseqgtr z_{t+1} \lesseqgtr z_{t+2} \lesseqgtr \cdots$, hence the steady state of equation (9) is locally unstable.

Appendix C. Transition of money supply in the inflation targeting regime

In equilibrium, the ratio of aggregate nominal investment on land ($H^* z_t$) to the aggregate demand for the nominal money holdings ($n_t M_t$) should be equal to $\theta(z_{t+1}/z_t)$, that is

$$\frac{H^* z_t}{n_t M_t} = \theta\left(\frac{z_{t+1}}{z_t}\right) \tag{C1}$$

and

$$\frac{H^* z_{t+1}}{n_{t+1} M_{t+1}} = \theta\left(\frac{z_{t+2}}{z_{t+1}}\right). \tag{C2}$$

Dividing equations (C1) and (C2) side by side,

$$\frac{z_t}{z_{t+1}} \frac{n_{t+1} M_{t+1}}{n_t M_t} = \frac{\theta\left(\frac{z_{t+1}}{z_t}\right)}{\theta\left(\frac{z_{t+2}}{z_{t+1}}\right)}. \tag{C3}$$

If $t = 1$, equation (C3) is equivalent to

$$\mu \equiv \frac{n_2 M_2}{n_1 M_1} = \theta\left(\frac{z_2}{z_1}\right) \frac{z_2}{z_1} = \theta\left(\rho_1\right) \rho_1 \tag{C4}$$

where $\mu \equiv (n_2 M_2)/(n_1 M_1)$ is expansion rate of aggregate money.

On the other hand, equation (14) implies

$$1 + \frac{1}{\theta\left(\rho_1\right)} = 2 \cdot \frac{n + \Delta}{n} \frac{P_1}{P_2} \frac{z_2}{z_1}. \tag{C5}$$

Multiplying both sides by $\theta(\rho_1)$,

$$\theta\left(\frac{z_2}{z_1}\right)+1=2\cdot\frac{n+\Delta}{n}\frac{P_1}{P_2}\theta\left(\frac{z_2}{z_1}\right)\frac{z_2}{z_1}. \tag{C6}$$

Substituting equation (C4) into equation (C6) and rearranging, and considering that $P_1/P_2 = 1$,

$$\theta\left(\rho_t\right)=2\cdot\frac{n_1}{n_2}\mu-1 \tag{C7}$$

Substituting equations (C4) and (C7) into equation (6), equation (6) is equivalent to

$$1+\frac{\beta\mu}{\mu+1}=\frac{2\left(n+\Delta\right)}{n}\mu-1+\beta\left(\frac{2\left(n+\Delta\right)}{n}\frac{\mu}{\mu+1}-\frac{1}{\mu+1}\right),$$

which implies the quadratic equation,

$$g\left(\mu\right)\equiv 2\left(1+\frac{\Delta}{n}\right)\mu^2+\left(\beta+\frac{2\left(1+\beta\right)\Delta}{n}\right)\mu-\left(2+\beta\right)=0 \tag{C8}$$

and μ is the positive root of (C8). By the sign of coefficients, $g(\mu)$ is strictly increasing in positive μ and

$$-\left(2+\beta\right)=g\left(0\right)<0<g\left(\frac{n}{n+\Delta}\right)=\beta\cdot\frac{\Delta}{n+\Delta}$$

Therefore, $\mu < n/(n+\Delta) = n_2/n_1$ or equivalently,

$$\mu\equiv\frac{n_2}{n_1}\frac{M_2}{M_1}<\frac{n_2}{n_1}\quad\Leftrightarrow\quad\frac{M_2}{M_1}<1. \tag{C9}$$