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ARTICLES

ACCOUNTING FOR LIFE-CYCLE WEALTH ACCUMULATION: THE ROLE OF HOUSING INSTITUTION

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This paper constructs a quantitative general equilibrium life-cycle model with uninsurable labor income to account for the differences in wealth accumulation and homeownership between Korea and the United States. The model incorporates different structures in the housing market in the two countries, namely, the mortgage market and the rental arrangements. The results from the calibrated model quantitatively explain some empirical findings in the aggregate and life-cycle profiles of wealth and homeownership. Quantitative policy experiments show that the mortgage market alone can account for more than 40% of the differences in the aggregate homeownership ratios. When coupled with the rental arrangements, both institutions can account for approximately 52% of the differences in the cross-country homeownership ratios.

Keywords: Life-Cycle Model, Consumption, Wealth, Homeownership, Housing Institution

1. INTRODUCTION

In this paper, I examine cross-country differences in household wealth accumulation and homeownership patterns over the life cycle. Specifically, I compare the United States and Korea. Empirical studies about household portfolios have been undertaken in some developed countries, but little attention has been paid to developing countries, mainly due to the lack of quality data. I use the recent Korea Labor Income Panel Study (KLIPS) from 1999 to 2005 to examine how average Korean households accumulate wealth over the life cycle. I then make a cross-country comparison with the United States based on the Panel Study of Income Dynamics (PSID), in order to highlight the differences in the profiles of various assets and homeownership in the aggregate as well as over the age-groups. This enables me to pay close attention to the points that are specific to the two countries.

Unique to the Korean housing market is the wide existence of *chonsae*, a rental market system in which a tenant pays a large deposit up front, with no additional

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periodic rent payments, and receives the nominal value of the deposit from the landlord upon maturation. The *chonsae* system means that renters in Korea have a proportion of their assets indirectly tied up in housing with zero nominal returns. By contrast, in the United States renters have no assets tied up in housing and are able to diversify their financial portfolios. Another characteristic of the Korean market is a relatively undeveloped housing mortgage system. For instance, Lam (2002) reports the average mortgage-to-GDP ratio in Korea between 1996 and 2000 to be around 11% and the average loan-to-value (LTV) ratio to be 28%.[1] A full-scale government-endorsed mortgage system was introduced only in 2004, with such a system being almost nonexistent before then.

I set up a general equilibrium life-cycle model allowing for these country-specific housing features in the United States and Korea and calibrate the model to match the aggregate level of wealth, portfolio choice, and homeownership ratio. The profiles of wealth, portfolio, and homeownership over the life cycle from the calibrated model are compared with the data, and the fit of the model is discussed. Next, I assess the roles played by the country-specific housing features, specifically, the institutional features of the mortgage market and the rental market arrangement, and ask how much they can individually and jointly account for the observed differences in the wealth accumulation and homeownership between Korea and the United States, both in the aggregate and over the life cycle.

For the mortgage market, an expansion of the current mortgage system in Korea is represented by a higher LTV ratio. Expanding the current mortgage system slightly raises the overall level of wealth accumulation in the economy, while increasing the homeownership ratio and the fraction of wealth invested in housing. Despite an increase in the aggregate wealth, the demographic impacts are mixed, as wider availability of mortgage loans increases the saving motives for younger households once they become homeowners, whereas retired households accumulate less wealth. Homeownership increases for working households but slightly decreases for retirees. For reasonable parameter values, I find that increasing the LTV ratio from 25% to 75% in Korea will cause a 1.1% increase in the aggregate net worth–to–output ratio and a 0.9% increase in the housing-to-output ratio. Despite small increases in the aggregate wealth, we see bigger changes in the homeownership patterns, with the aggregate homeownership ratio increasing from 58.0% to 62.3%. As for the cross-country comparison of homeownership, this change in the LTV ratio alone could potentially account for more than 40% of the observed differences.

In addition to the changes in the mortgage system, the rental arrangement in the benchmark Korean model is altered to mimic the American rental arrangement; that is, households pay periodic rent. When both housing institutions are modified, I find that the aggregate net worth–to–output ratio increases by 2.9% while the housing-to-output decreases by 7.1%. This shift in the aggregate composition of wealth matches the fact that the United States has a greater fraction of wealth invested in financial assets. Despite an overall increase in the net worth–to–output ratio, age–demographic implications are mixed. Households have a higher net

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worth–to–output ratio during their working periods, but the ratio is lower during retirement. As for homeownership, altering both housing institutions results in a larger increase in the aggregate homeownership ratio, as well as an unambiguous rise in homeownership for all age cohorts. With the aggregate homeownership ratio increasing from 58.0% to 63.2%, changes in both institutions can account for approximately 52% of the differences in the homeownership ratios between the United States and Korea.

This paper builds on the emerging literature that documents household portfolio allocation. With a few papers that include housing in models of portfolio choice, the role of housing wealth has received greater attention due to its unique role: people can borrow against housing; housing is indivisible and relatively illiquid (buying and selling entail significant liquidation costs); and housing not only provides a flow of real benefits to the owner as a consumption good, but also acts as an investment good that provides potential for capital gains or losses. Among the recent general equilibrium literature, Chambers et al. (2009a) uses a life-cycle framework with state-of-the-art computational techniques to account for the recent changes in the U.S. homeownership ratio. Another paper by Chambers et al. (2009b) models mortgage choice in detail to account for the observed patterns in housing consumption, homeownership, and portfolio allocation in the United States. Some papers explore the importance of housing in explaining the patterns of wealth distribution in the United States. The most relevant papers are Díaz and Luengo-Prado (2010), which uses an infinite horizon model, and Silos (2007), which uses a life-cycle framework. A similar strand of literature explicitly introduces tenure decisions, where people can rent instead of purchasing a house and receive a similar flow of services not subject to capital gains or losses. Yang (2009) incorporates the rental choice in a general equilibrium model to study the hump-shaped nonhousing consumption profile and the non-hump-shaped housing consumption profile in the U.S. data.

In general, models of housing have made predictions closer to those that have been observed empirically in areas such as wealth distribution, household portfolio allocations, and tenure decisions; however, these models have been calibrated only to the U.S. data. One underexplored question is whether it is possible to explain data from other countries using the same model applied to the United States. This paper is one of the first attempts to conduct a cross-country comparison of the life-cycle model with housing in a general equilibrium framework. This paper conducts an empirical study of wealth in Korean households from the KLIPS data and points out some stylized aggregate facts, as well as the cross-sectional profile of various assets and homeownership ratios by age groups. It highlights the similarities and the differences in the patterns of wealth accumulation and portfolio choice from those shown in the United States. In sum, this paper evaluates the predictions of the life-cycle models on different economies while incorporating their unique institutional features. Given that homeownership and wealth accumulation attract a great deal of interest from policymakers around the world, another significant question is how important the institutional characteristics are in determining the observed outcomes of interest across different economies.

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The rest of this paper is organized as follows. Section 2 presents the empirical findings and stylized facts from the data and documents some characteristics of wealth accumulation and homeownership patterns for average households in the United States and Korea. Section 3 describes the calibrated life-cycle model framework, followed by the calibration and the parameterization of the model in Section 4. In Section 5, results from the benchmark simulation are presented and the fit of the model is evaluated. Section 6 quantitatively assesses the roles played by the housing market institutions. Brief concluding remarks are provided in Section 7. The Appendix presents the algorithm for the computation.

2. DATA AND EMPIRICAL EVIDENCE

2.1. Average Wealth Portfolio

To analyze the profile of wealth in Korea, I use the Korean Labor Income Panel Study (KLIPS) from 1999 to 2005. It is a sociodemographic panel study that includes data about household income and wealth. In the wealth category, the KLIPS survey asks households about various types of assets and liabilities. Assets are grouped into primary housing ("House"), financial assets, and other nonfinancial assets such as secondary home, land, and rental real estate ("Other nonfinancial"). Within the financial assets category, I closely examine different financial assets, such as rent deposits, time deposits (checking and savings account), stocks and bonds, and life insurance. A rent or *chonsae* deposit is an upfront lump-sum deposit made by renters at the beginning of the contract period in lieu of periodic rental payments. Because renters receive the exact nominal amount back at the end of the contract, a *chonsae* is considered to be a financial instrument with a zero nominal interest rate.[2] Table 1 summarizes the assets, liabilities, and net worth holdings of the average household from the 1999–2005 KLIPS data. The table also shows comparable estimates of average household assets and liabilities for the United

TABLE 1. Summary statistics of average wealth: Korea vs. United States (normalized by average income)

	Korea (1999–2005)	United States (1995)
Total asset	6.11	5.56
House	3.15	1.67
Financial asset	1.21	2.04
• Rent deposit	0.48	—
• Time deposit	0.52	0.40
• Stock & bond	0.07	0.85
• Other	0.14	0.79
Other nonfinancial	1.75	1.85
Total liabilities	0.99	0.81
Net worth	5.12	4.75

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TABLE 2. Wealth portfolio comparison: Korea vs. United States (% of total asset)

	Korea (1998)	United States (1995)	Korea (1999–2005)
Total asset	100.0	100.0	100.0
House	51.4	30.0	51.5
Financial asset	19.8	36.7	19.8
Time deposit	8.1	7.2	8.5
Stock	0.7	12.5	1.1[a]
Bond	0.3	2.8	—
Other[b]	10.8	14.2	10.2
Other nonfinancial	28.8	33.3[c]	28.6
Total liabilities	10.0	14.6	16.2

[a] Stocks and bonds are combined under the KLIPS survey.
[b] Mainly rent deposits in Korea and pension funds in the United States.
[c] Out of other nonfinancial assets, business equity (18%) is the main component.

States compiled by Kennickell (2003), which uses the 1995 Survey of Consumer Finances.

For a comparison of the composition of wealth, Table 2 presents the share of different assets as well as the different components of financial assets for the two countries. Additional estimates for Korea by Lee and Lee (2001a) are provided in Table 2, which uses a different panel study (Korean Household Panel Study) for 1998.

From the cross-country comparison-of-wealth portfolio, I summarize some idiosyncracies of the Korean households' wealth portfolio.

- Housing is the most important asset in Korea (around 50% of total assets), whereas financial assets are the major portion of total assets in the United States (37%).
- As a proportion of their total assets, Korean households have a relatively smaller proportion (around 20%) in financial assets than their U.S. counterparts.
- In Korea, the most common form of financial asset is deposits, in the form either of rent deposits or of time deposits. As rent deposits take almost 40% of total financial assets in Korea, renters have a large share of their financial assets indirectly tied up to housing.
- The fraction of financial assets invested in stocks and bonds is only 6% in Korea, whereas the fraction of financial assets held in stocks alone stands at 35% in the United States.

2.2. Wealth Portfolio by Age Cross Section

The level of household wealth and the composition of the wealth portfolio strongly vary by age of the household head.[3] Figure 1 shows the average accumulation of different types of assets taken from the KLIPS data by age cohorts over the survey period (1999–2005), normalized by average income.

Typically, young households do not invest in risky assets. Most live in rental housing and are saving to buy houses. This is more pronounced in Korea, where

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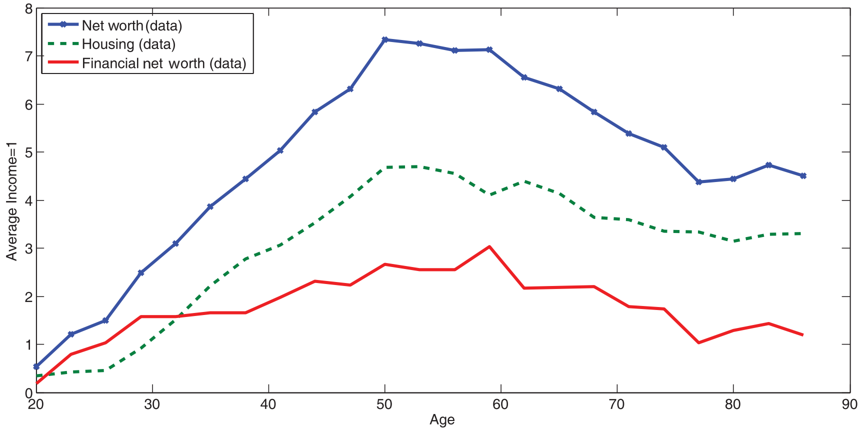

FIGURE 1. Age profile of wealth accumulation (Korea).

young households are not eligible to receive mortgage loans and, thus, most have no option but to live in rental housing. Once they accumulate enough savings to buy a house, they start investing in risky assets. Apart from primary housing, investment in risky assets predominantly goes into other nonfinancial (mostly property) assets rather than financial assets such as stocks. Older families seem to sell their risky assets and shift their portfolios into safer assets. Some older households move in with their children, which involves significant inter vivos transfers.[4]

For the United States, corresponding figures for the age profile of wealth composition were taken from the cross-section study of Panel of Income Dynamics 2001 survey data and are shown in Figure 2.

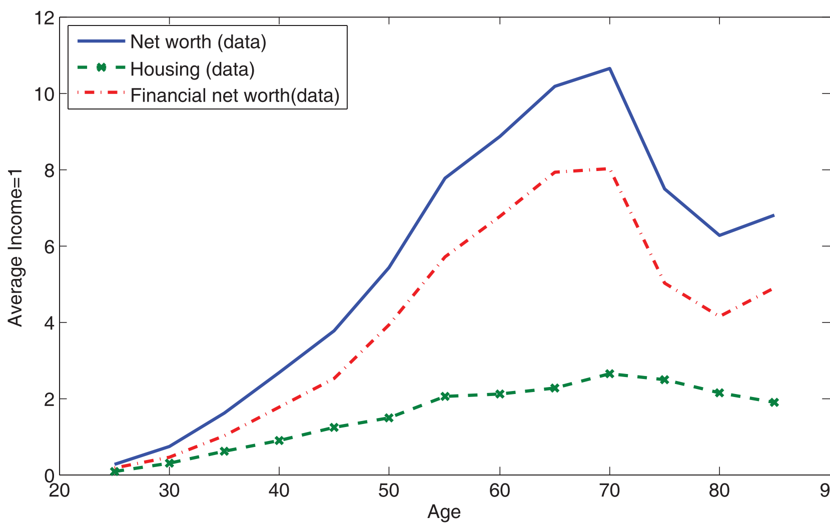

FIGURE 2. Age profile of wealth accumulation (United States).

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The main features of wealth accumulation and portfolios in Korea are summarized as follows:

- Housing assets and net worth show a hump-shaped pattern over the life cycle, reaching their peaks in the mid-50s age groups. After the peak is reached, the decumulation of housing assets is less steep than that of net worth. On the other hand, the profile of financial net worth is relatively flat over the age groups but does show a downward trend after hitting the peak.
- Financial net worth is the most important source of wealth for younger households in the 20s to early 30s, but afterwards its share declines. Housing, on the other hand, becomes the dominant asset type after the late 30s age group. The share of housing in total wealth increases with age and stays almost constant until the early 60s. In the latter part of the life cycle, housing share increases even further, as housing assets stay high while the net worth declines.

2.3. Homeownership

Figure 3 shows the average fractions of households in Korea and the United States that are homeowners, or the homeownership ratio across the age cohorts. For the United States, the numbers were taken from the Survey of Consumer Finance (SCF) (2001).

The average homeownership ratio in Korea is around 58%, whereas in the United States, the average ratio is 68% (SCF, 2001). A comparison of homeownership ratios for different age groups in Korea and the United States shows a wider gap for younger households than for older ones. For example, in the 25–30-year age groups, the gap was the largest, around 15 percentage points, whereas the corresponding gap was the smallest, around 3 percentage points, for age groups 50–55 years. The comparatively low homeownership ratio in the early stages of

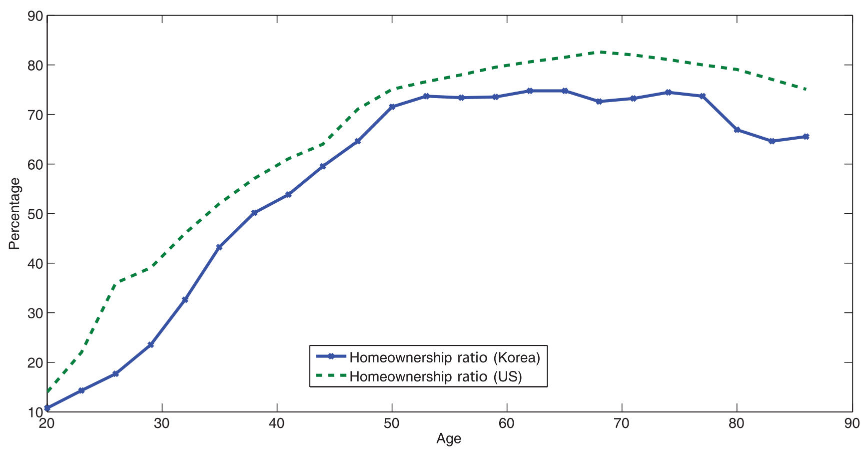

FIGURE 3. Homeownership over cross section (Korea vs. United States).

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the life cycle can be somewhat explained by the lack of long-term mortgage loans and the unusually high down payment ratio required, which ranges between 70% and 80% in Korea. The lack of long-term mortgage loans also makes the time needed for young households to purchase a house longer.

2.4. Rental and Mortgage Markets

As discussed earlier, *chonsae* is a rental market system in Korea in which a tenant pays an upfront deposit upon entering the rental contract, with no additional periodic rent payments. The deposit is usually 40%–80% of the property value. The tenant receives the nominal value of the deposit from the landlord upon expiration of the contract, which typically lasts two years. Landlords can earn interest income from the deposit or use the deposit for other investment purposes. The current legal system offers tenant protection in case the landlord does not return the deposit. An estimate by Cho (2005) indicates that, as of 2003, the aggregate *chonsae* deposit is around 40% of GDP, or 80% of total equity value in Korea.

Historically, the housing market in Korea was under heavy government regulation, with controls on interest rates and new housing prices. After 1996, commercial banks were allowed to provide long-term mortgages. The most typical mortgage products are adjustable-rate three-year bullet-type mortgages, which contrast to longer term balloon-type U.S. mortgages. This leads to another unique aspect in Korea, which is the lack of long-term mortgage contracts. Existing loans to households secured by residential properties in Korea have very short maturity (typically 3–5 years) and low LTV ratios. For instance, Lam (2002) reports the average mortgage-to-GDP ratio in Korea between 1996 and 2000 to be around 11%, whereas the corresponding figure in the United States was approximately 55%. The average LTV ratio during the same period was 28% in Korea, as opposed to around 80% in the United States. A full-scale government-endorsed mortgage system was only introduced in 2004, prior to which such a system was almost nonexistent.

3. BENCHMARK MODEL

A simple and parsimonious finite-horizon general equilibrium life-cycle model will be set up to calibrate the wealth accumulation and homeownership choices of households in both Korea and the United States.

3.1. Demographics

Each model period is calibrated to correspond to three years. Agents or households, which will be considered as equivalent concepts, are assumed to actively enter into working life at 20 (denoted as $j = 1$ in the model), and live with some probability until a maximum age of 86 (denoted as $J = 23$), at which time they die for certain. All agents enter their working life with zero financial assets and some positive

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transfers. Agents work and receive earnings until the age of mandatory retirement, which is denoted as j^*. Agents also face mortality risk during their lifetime. This is denoted by s_j, which is the exogenously given survival probability at age $j+1$ conditional on being alive at age j. The unconditional survival probability for an agent aged j is thus given by $\prod_{t=1}^{j} s_t$. Upon death, the household's net worth is seized by the government and evenly redistributed to all working households as transfers.[5] Population grows at a constant rate, ψ, and the fraction of total population attributable to age cohort j is given as $\pi_j = s_{j-1}\pi_{j-1}/(1+\psi)$ for $j = 2, 3, \ldots$, and $\sum_{j=1}^{J} \pi_j = 1$.

3.2. Preferences

Agents derive utility from consumption of nonhousing goods, c, and from the flow of services from housing stock, $f(h)$, as well as from bequests, q, left upon death. Agents deriving utility from leaving bequests (or the "warm glow" bequest motive) is a simple way to incorporate bequests into the model without introducing the complexities of strategies between parents and children. The service flow from housing, $f(h)$, is proportional to the housing stock h.

The instantaneous utility function reflects the empirical evidence on the nonlinearity of housing to nonhousing consumption ratio as suggested by Jeske (2005) and employed in Chambers, Garriga and Schlagenhauf (2009a), given as follows:

$$U(c, f(h)) = \omega \frac{c^{1-\sigma_1}}{1-\sigma_1} + (1-\omega)\frac{f(h)^{1-\sigma_2}}{1-\sigma_2}. \tag{1}$$

The parameter ω measures the importance of nonhousing consumption relative to housing expenditures, whereas σ_1 and σ_2 are the curvature parameters with respect to nonhousing and housing consumption.

As for the utility derived from leaving bequests, q, we follow the specification made by De Nardi (2004), denoted as

$$\varphi(q) = \varphi_1 \left[1 + \frac{q}{\varphi_2}\right]^{1-\sigma_q}.$$

The term φ_1 reflects the parent's concern about leaving bequests to children, whereas φ_2 measures the extent to which bequests are luxury goods. σ_q refers to the curvature parameters with respect to bequests.

3.3. Technology

There is a representative firm producing an aggregate output good Y under the aggregate production function using aggregate capital stock K and aggregate labor input L:

$$Y = F(K, L). \tag{2}$$

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The production function is a standard Cobb–Douglas form. The aggregate output can be either consumed or invested into business capital or housing capital. Let I^k and I^h denote the aggregate investment in business capital and housing capital, respectively. The aggregate resource constraint is

$$Y = C + I^k + I^h + \Pi, \tag{3}$$

where C denotes aggregate consumption of nonhousing goods and Π denotes the transaction costs incurred from the housing transactions. In addition, the business capital and the housing capital depreciate at rates δ^k and δ^h, respectively.

3.4. Labor Income Dynamics

During each period prior to the mandatory retirement age, agents are endowed with one unit of time, which they supply inelastically. Agents also face the same exogenous age–efficiency profile, ϵ_j, during their working years. This profile is estimated from the data and replicates the fact that productive ability changes over the life cycle. Each unit of effective labor is paid the wage rate w. Workers are also subject to stochastic shocks to their productivity level. These shocks are represented by a finite-state Markov process with a transition function Q_υ. This Markov process is the same for all households. The total productivity of a worker of age j at period t is given by the product of the worker's stochastic productivity in that period and the worker's deterministic efficiency index at the same age: $\upsilon_t \epsilon_j$. Working agents also pay social security payroll taxes on their labor income. Under an unfunded pay-as-you-go social security system, the government distributes the tax revenue across the retired agents. For simplicity, the level of social security benefits (b) is fixed at a constant amount regardless of the contribution made during the working stage.

Let y denote the sum of income (labor earnings and transfers) and financial assets held:

$$y(j, a, \upsilon) = \begin{cases} (1-\tau)w\epsilon\upsilon + (1+r)a + T & \text{if } j < j^* \\ b + (1+r)a & \text{if } j \geq j^* \end{cases}. \tag{4}$$

3.5. Housing and Tenure Choice

In the economy, households can either own or rent a house. Owning a house provides several benefits. First, homeowners can borrow against their housing assets and tap into credit markets. We assume that homeowners can borrow up to a fraction κ of their housing value. Second, homeowners derive higher utility than renters. Following Platania and Schlagenhauf (2002) and Ortalo-Magné and Rady (2006), I assume that the utility derived from housing is higher for a homeowner than for a renter.[6] That is, renters will only derive a fraction $\lambda < 1$ of the utility that a homeowner does who has the same housing stock. Thus, $f(h) = Ih + (1-I)\lambda h$, where I is an indicator denoting whether the household is a homeowner ($I = 1$)

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or a renter ($I = 0$). Third, housing assets add to the level of bequest, from which agents derive utility. On the other hand, owner-occupied houses require a minimum size of $\underline{H}$ and those who cannot afford to own have no choice but to rent. Homeowners also pay a maintenance cost equal to the level of depreciation (δ^h) in the period during which the house was owner-occupied. In addition, buying or selling a house incurs a transaction cost, which is a fraction ϕ^s of its selling value and ϕ^b of its purchase value:

$$\phi(h, h') = \begin{cases} \phi^s h + \phi^b h' & \text{if } h' \neq h \\ 0 & \text{if } h' = h \end{cases}. \tag{5}$$

To distinguish rental choices in the two countries, I assume that in Korea, households either own or rent as *chonsae*. *Chonsae* rental units do not require a minimum size and are priced p per unit of housing stock. Therefore, in order to rent as *chonsae*, agents put down a rental deposit ph' in advance, which is returned next period net of any interest. On the other hand, U.S. households are either homeowners or renters paying periodic rental payments, p per unit of rental housing service, s. Renters in both countries cannot borrow and do not pay any maintenance or transaction costs related to housing.

3.6. Household Recursive Problems

The state variables are given by $\{j, a, h, \upsilon, I\}$, where j denotes age; a and h are financial assets and housing stock, respectively; υ is the idiosyncratic productivity shock; and I is an indicator of housing tenure. Households choose the next period's housing tenure by comparing the value of homeownership against the value of renting. For Korea, the value function $V(j, a, h, \upsilon, I)$ is given as $V(j, a, h, \upsilon, I) = \max\{V^o, V^c\}$, where V^o and V^c denote the value of being a homeowner and the value of being a (*chonsae*) renter. On the other hand, in the United States, the value function is $V(j, a, h, \upsilon, I) = \max\{V^o, V^r\}$, where V^r is the value of being a periodic renter.[7]

If agents choose to own, then the value function V^o is given by

$$V^o(j, a, h, \upsilon, I) = \max_{c,a',h'} [U(c, h') + s\beta \mathbf{E} V(j+1, a', h', \upsilon', 1) + (1-s)\varphi(a' + h')]$$

s.t.

$$c + a' + h' + \phi(Ih, h') \leq y(j, a, \upsilon) + I(1-\delta^h)h + (1-I)ph, \tag{6}$$

$$h' \geq \underline{H}, \tag{7}$$

$$a' \geq -\kappa h', \tag{8}$$

$$c \geq 0. \tag{9}$$

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If agents choose to *chonsae*-rent in Korea, then the value function V^c is as follows:

$$V^c(j, a, h, \upsilon, I) = \max_{c,a',h'}[U(c, f(h')) + s\beta\mathbf{E}V(j+1, a', h', \upsilon', 0)$$

$$+ (1-s)\varphi(a')]$$

s.t.

$$c + a' + ph' + \phi(Ih, 0) \leq y(j, a, \upsilon) + I(1-\delta^h)h + (1-I)ph, \quad \mathbf{(10)}$$

$$c, a', h' \geq 0. \quad \mathbf{(11)}$$

Finally, the value function V^r for agents renting in the United States is given by

$$V^r(j, a, h, \upsilon, I) = \max_{c,a',s}[U(c, s) + s\beta\mathbf{E}V(j+1, a', 0, \upsilon', 0)$$

$$+ (1-s)\varphi(a')]$$

s.t.

$$c + a' + ps + \phi(Ih, 0) \leq y(j, a, \upsilon) + I(1-\delta^h)h, \quad \mathbf{(12)}$$

$$c, a', s \geq 0.$$

3.7. Rental Agency

Following Gervais (2002), there is a two-period-lived institution that supplies rental housing in Korea. In the first period, this agency takes deposits (D) and buys rental properties (S). The rental properties are immediately rented out and the agency receives rental deposits priced p per unit. At the end of the second period, the institution earns interest on the rental deposits and returns the principal to the renters, as well as repaying deposits with interest at rate r. At the end of the second period, the institution sells the undepreciated part of the residential stock to a new institution. The no-arbitrage condition is given by

$$rp - \delta^h = r \quad \text{or} \quad p = \frac{\delta^h}{r} + 1. \quad \mathbf{(13)}$$

This implies that renting out a property, receiving interest on the rental deposit, and paying the maintenance costs yield the same profit as receiving interest income from opening a deposit. In other words, in a stationary equilibrium with constant prices, the rental rate on housing is uniquely determined given the interest rate and the depreciation rate.

The rental agency setup in the United States is similar to the Korean case, and the corresponding no-arbitrage condition implies that

$$p = r + \delta^h. \quad \mathbf{(14)}$$

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3.8. Government

In this economy, the government taxes labor earnings at a proportional rate τ and uses the tax revenues to fund the retirees' income. For simplicity, the retirement benefits, b, are constant regardless of the actual contributions made in the past. The income replacement rate (θ) is linked to the average household earnings in the economy. In addition, when the household dies and leaves bequests, the government collects the bequests and redistributes equally to working households as transfers, T.

3.9. Definition of a Stationary Equilibrium

Given the state variables $\Lambda = \{j, a, h, \upsilon, I\}$, a stationary competitive equilibrium consists of a set of government policy arrangements $\{\tau, b, T\}$; prices $\{p, r, w\}$; value functions $V(j, a, h, \upsilon, I)$; allocations $c(j, a, h, \upsilon, I)$, $a'(j, a, h, \upsilon, I)$, $h'(j, a, h, \upsilon, I)$; and a time-invariant distribution of agents over the state variables, $m^*(j, a, h, \upsilon, I)$, such that

(i) Given prices and the government policies, the value function $V(j, a, h, \upsilon, I)$ and the allocations $c(j, a, h, \upsilon, I)$, $a'(j, a, h, \upsilon, I)$, $h'(j, a, h, \upsilon, I)$ solve the household maximization problem.

(ii) The factor prices are equal to their marginal products:

$$r = F_1(K, L) - \delta^k, \tag{15}$$

$$w = F_2(K, L). \tag{16}$$

(iii) The government policies satisfy

$$\int_{j=1,\ldots,j^*-1} \tau w L m^*(d\Lambda) = \int_{j=j^*,\ldots,J} \theta Y m^*(d\Lambda), \tag{17}$$

$$\int_{j=1,\ldots,j^*-1} T m^*(d\Lambda) = \int_{j=1,\ldots,J} q m^*(d\Lambda). \tag{18}$$

(iv) m^* is the invariant distribution of households over the state variables for this economy.

(v) All markets clear:

$$C = \int c m^*(d\Lambda), \tag{19}$$

$$H = \int h m^*(d\Lambda), \tag{20}$$

$$S = \int_{I=0} h m^*(d\Lambda), \tag{21}$$

$$L = \int \epsilon \upsilon m^*(d\Lambda), \tag{22}$$

$$K = \int a m^*(d\Lambda) - S. \tag{23}$$

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4. CALIBRATION

The set of parameters are divided into those that are based on the estimates provided by other studies and those that are chosen so that the predictions generated by the model's stationary equilibrium can match a given set of targets. Table 3 lists the parameters chosen for the two countries.

One period in the model is equal to three years. An individual starts life at age 20 years (model period 1) with a maximum life expectancy age of 86 years (model period 23). Mandatory retirement age is 65 (model period 16) in the United States and 59 (model period 14) in Korea. The conditional survival probabilities in the United States and Korea are taken from Bell, Wade, and Goss (1992) and the

TABLE 3. Parameter definitions and values

Parameter		United States	Korea
	Demographics		
j^*	Retirement age	65	59
J	Expected lifetime	86	86
ν_j	Survival probability	Bell et al.	Korea Life Table
ψ	Population growth rate	1.2%	1.8%
	Technology		
α	Capital income share	23.7%	23.7%
δ^h	Housing depreciation rate	3.0%	11.6%
δ^k	Business capital depreciation rate	6.4%	8.2%
ϕ^s	Selling transaction cost	7%	7%
ϕ^b	Buying transaction cost	2.5%	2.5%
$\underline{H}$	Minimum housing (% of annual income)	66.7	38.5
κ	Loan-to-value ratio	0.75	0.25
o	Homeownership ratio for initial cohort	14%	11%
	Endowment		
ϵ_j	Age–efficiency profile	Hansen	Hansen
ρ	Persistence of income process (3 years)	0.90	0.90
σ_y^2	Innovation of income process (3 years)	0.20	0.12
τ	Social security tax rate	8.9%	8.6%
θ	Replacement ratio	0.4	0.3
	Preference		
σ_1	Risk-aversion coefficient (nonhousing)	3	3
σ_2	Risk-aversion coefficient (housing)	1.5	1.5
σ_q	Risk-aversion coefficient (bequest)	3	3
φ_1	Bequest parameter	−9.5	−9.5
φ_2	Bequest parameter	11.6	11.6
β	Discount factor	0.913	0.929
ω	Share of nonhousing consumption	0.879	0.926
λ	Homeownership premium	0.7	0.7

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Korea Life Table (2005), respectively. The rate of population growth, ψ, is set to equal the average population growth from 1950 to 2005 in the two countries.

In the aggregate production function, the National Income and Product Accounts (NIPA) from 1959 to 2004 is used to calibrate α, the share of income that goes to the nonresidential stock of capital, at 23.7% in the United States, and I assume the same value for Korea. The annual depreciation rates of the capital stock and the housing stock in the United States are set at 7.6% and 4.2%, respectively. For Korea, I use the National Accounts data from 1970 to 2005 to set the corresponding values of depreciation at 8.2% and 11.6%. For transaction costs, Gruber and Martin (2003) estimate the relocation cost of tax and agency cost from the U.S. Consumer Expenditure Survey (CEX), and find that the median household pays approximately 7% for sales and 2.5% for purchase. I accordingly set the transaction cost parameters $\phi^s = 0.07$ and $\phi^b = 0.025$ for both countries. The loan-to-value ratio, κ, is taken from the average loan-to-value ratio between 1996 and 2000 compiled by the Housing and Commercial Bank in Korea, which is around 25%. For the United States, I take the average loan-to-value ratio to be 75%. The average loan-to-value ratios are lower than those reported in Jappelli and Pagano (1994), which reports maximum loan-to-value ratios of 89% and 30% for the United States and Korea, respectively. In the model, I assume that some households enter into the life cycle as homeowners with minimum housing size. The fraction o of the agents starting as homeowners are exogenously taken from the average homeownership ratio of households aged 20 to 22 from the SCF and the KLIPS data.

The deterministic age-efficiency profile ϵ_j is calculated from the estimate of the mean age-income profile from Hansen (1993) for the United States. The corresponding profile in Korea is adjusted accordingly taking into account the differences in the retirement age. The logarithm of the stochastic productivity process is a first-order autoregressive process following Huggett (1996): $\ln \upsilon_j = \rho \ln \upsilon_{j-1} + \mu_j$. The disturbance term μ_j is normally distributed with mean zero and variance σ_υ^2. The variance σ_υ^2 as well as the persistence parameter ρ for the United States are taken from De Nardi (2004). For Korea, the persistence parameter is assumed to be the same as the value chosen for the United States, whereas the variance term is adjusted to match the Gini coefficient for earnings. The productivity shocks are discretized into a four-state Markov chain according to Tauchen and Hussey (1991). The resulting gridpoints for the productivity process are $\{0.2714, 0.7167, 1.3953, 3.6845\}$ for the United States and $\{0.3642, 0.7726, 1.2944, 2.7461\}$ for Korea, respectively. The transition matrix Q_υ, identical for both countries, is given by

$$\begin{bmatrix} 0.7722 & 0.2081 & 0.0194 & 0.0003 \\ 0.2081 & 0.5245 & 0.2480 & 0.0194 \\ 0.0194 & 0.2480 & 0.5245 & 0.2081 \\ 0.0003 & 0.0194 & 0.2081 & 0.7722 \end{bmatrix}.$$

The discretized income process produces a cross-sectional earnings distribution that is similar to the data reported in Budría Rodríguez et al. (2002) and Lee and

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Lee (2001b), with Gini coefficients of 0.44 for the United States and 0.37 for Korea. The replacement ratio for retirees is $\theta = 0.4$ in the United States and 0.3 in Korea. Social security payroll tax rates are endogenously determined from the model to finance the social security system. Despite the differences in the replacement ratios, the social security tax rates are around 9% in both countries due to differences in the demographics.

Regarding the preference parameters, although standard constant relative risk aversion (CRRA)-type utility functions assume that $\sigma_1 = \sigma_2$, this is not consistent with the data on consumer behavior, which show that income increases are likely to be spread evenly between housing and nonhousing consumption. Different values for σ_1 and σ_2 can take into account the nonlinearity of the housing to nonhousing consumption ratio. A similar approach has been employed by Chambers et al. (2009a) to match the observed ratio of housing to nonhousing consumption as income increases. We take $\sigma_1 = \sigma_q = 3$ and $\sigma_2 = 1.5$ to take into account the nonlinearity of housing to nonhousing consumption ratio. The bequest parameters, φ_1 and φ_2 are taken from De Nardi (2004); they match the bequest distribution in the United States. For λ, which measures the degree of households' preference for homeownership over renting, we choose a value of 0.7. A similar value was introduced in Platania and Schlagenhauf (2002).

The remaining parameters, β, ω, and $\underline{H}$, are chosen simultaneously, so that the predictions generated by the model can match a given set of aggregate targets. The first aggregate target is the physical capital–to–output ratio, K/Y. Here, physical capital stock is the sum of private and government nonresidential fixed assets and inventories, whereas output is defined as the gross domestic product minus the expenditure on housing services. For the United States, using the NIPA tables, the average over the period 1959–2004 was 1.95. For Korea, the corresponding ratio over the period 1970–2005 was 1.96, using the National Accounts data provided by the National Statistics Office (NSO).[8] The second target is the housing capital–to–output ratio, H/Y. The housing capital corresponds to the stock of private and public residential fixed assets. This ratio is 1.22 in the United States, and 0.49 in Korea. The third aggregate target is the aggregate homeownership ratio, where the Survey of Consumer Finances in 2001 reports that 68% of households in the United States are homeowners. In Korea, the corresponding figure taken from the average of 1999–2005 KLIPS surveys is 58%.

5. BENCHMARK RESULTS

In this section, the results from the benchmark simulation for the United States and Korea are presented (see Tables 4 and 5) and the fit of the model is evaluated. We first construct the cross-sectional profiles of net worth and homeownership for different age cohorts. Net worth in the model is defined as the sum of the housing asset (h) and financial net worth (a). All units are normalized by average annual household income.

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TABLE 4. Age profile of wealth and homeownership: United States

	Net worth		Housing		Homeownership	
Age	Data	Model ($\frac{K+H}{Y}$)	Data	Model ($\frac{H}{Y}$)	Data	Model
20–34	0.86	1.08	0.32	0.67	38.3%	47.5%
35–49	3.85	4.67	1.21	1.76	67.7%	78.5%
50–64	8.94	6.87	2.14	2.11	80.0%	83.0%
65–86	7.79	5.88	2.28	1.84	79.8%	70.8%
Average	3.17	3.17	1.22	1.22	68.0%	67.9%

5.1. Age–Wealth Profile

The model is able to replicate the hump-shaped pattern of net worth over the life cycle in both countries as well as match the peak of the profile occurring around retirement age. Cross-country comparison between the United States and Korea suggests that when we change only a minimal set of parameters, the model does a good job at matching the wealth profile of Korean households. In the model, agents initially start with little or no wealth. Because they expect higher earnings in the future, they will borrow to smooth their life-cycle consumption, which can be achieved by taking on a mortgage and becoming homeowners. Once agents become homeowners, they will first pay off the mortgage debt and save in the form of financial assets. The overall profile of net worth shows a hump-shaped pattern with peaks occurring at the age of mandatory retirement. Note that the model only incorporates a one-period bond as financial instrument and does not explicitly consider stocks with higher returns. This explains why the level of net worth at the peak of the life-cycle profile is lower than the level observed in the data. After retirement, agents run down their assets to finance retirement consumption. Due to the presence of transaction costs for housing, agents run down their financial assets more quickly than their housing assets. Some agents may even borrow during retirement to remain homeowners and derive higher utility than renters. In addition, the presence of a bequest motive generates lifetime saving profiles more

TABLE 5. Age profile of wealth and homeownership: Korea

	Net worth		Housing		Homeownership	
Age	Data	Model ($\frac{K+H}{Y}$)	Data	Model ($\frac{H}{Y}$)	Data	Model
20–34	2.12	0.64	0.86	0.28	21.7%	44.1%
35–46	4.54	2.90	2.74	0.62	51.6%	65.4%
47–58	6.63	6.22	4.26	0.75	70.7%	73.6%
59–70	6.12	6.05	3.85	0.64	73.9%	65.9%
71–86	4.65	3.36	3.21	0.52	70.4%	54.1%
Average	2.45	2.45	0.49	0.49	58.0%	58.0%

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consistent with the data, as the depletion of assets during retirement is slower than it would be in a model without a bequest motive. Despite the introduction of a bequest motive, the profile of net worth during retirement in the model is lower than it is in the data for both countries. This is due to the fact that the model abstracts from other sources of uncertainty that arise during retirement, such as health shocks that may spur additional precautionary saving.

The cross-country comparison shows that the model is better able to match the U.S. data than the Korean data. One part where the model is not consistent with the Korean data is in the profile of housing assets over the life cycle. The KLIPS data show that the profile of housing assets exhibit a more pronounced hump-shaped profile, with average households investing a significantly larger fraction of their wealth in housing than in financial assets. One reason that the model underpredicts the data is that the preference parameter ω in the model is calibrated to match the aggregate housing–output ratio taken from the National Accounts data, which is significantly lower than the average housing wealth–to–income ratio in the KLIPS data. In addition, the model abstracts from housing price fluctuations and the possibility of using housing as an investment good for Korean households, which may partly help the model predictions to be more consistent with data.

5.2. Age–Homeownership Profile

The standard life-cycle model with tenure choice produces a hump-shaped pattern of homeownership over the life cycle in both countries. In the model, most young households start as renters. In Korea, renters put some *chonsae* deposit down, which acts as a form of savings towards homeownership. At the same time, because there is no minimum size requirement for rental units, renters live in smaller units than homeowners. Because renters are not allowed to borrow, they accumulate financial assets until they are able to afford down payments to become homeowners. Because homeownership generates higher utility than renting, most households with sufficient wealth will become homeowners. Homeownership in the model peaks around retirement and declines slowly afterwards. However, in the U.S. data, homeownership shows no sign of decline after retirement. As for Korea, homeownership in the data peaks after retirement among cohorts aged between 59 and 70. The cross-country comparison shows that for both countries, the model overpredicts homeownership when agents are working and underpredicts it during retirement periods. The former may be attributed to the fact that the model abstracts from uncertainty regarding job mobility, and that some agents with a sufficiently high level of wealth prefer to rent rather than own due to the characteristics of their employment.

6. QUANTITATIVE POLICY EXPERIMENTS: CHANGES IN THE HOUSING INSTITUTIONS

In this section, given that the benchmark model does a good job in generating the life-cycle profiles of wealth and homeownership, I use the model to examine the

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quantitative roles played by the institutional features of the housing market. First, to highlight the role of the mortgage system, I modify the LTV ratio in Korea from 25% to 75%, which is the average LTV ratio in the U.S. benchmark model. I also assume that households with a mortgage can refinance and adjust their mortgage balance without any adjustment cost. Relaxing the collateral constraint enables households to purchase a house earlier and accumulate more housing assets.

Next, in addition to an increase in the LTV ratio, the rental arrangements in the benchmark Korean model are altered to mimic the rental system in the United States. Under the U.S. rental market arrangement, renters pay a periodic rental payment. I investigate the joint effect of changing both the mortgage system and the rental arrangement.

Third, I look at the effect of changing the utility premium parameter, λ. Although λ is a preference parameter, it can be interpreted as capturing other institutional features not explicitly taken into account in the benchmark model such as the preferential tax treatment of homeowners.[9]

For each of the experiments, we report the changes in the aggregate ratios as well as the age profiles of net worth and homeownership. All other calibrated parameters in the benchmark simulation remain unchanged. All experiments follow households who receive the same sequence of stochastic shocks over the life cycle as in the benchmark simulation, making the numerical experiments more tractable and comparable.

6.1. Mortgage Expansion

To highlight the role of the mortgage system and the down payment requirement, the LTV ratio in Korea is modified from 25% to 75%. Table 6 compares the aggregate and life-cycle profiles of net worth and the homeownership ratio.

In the model, a higher LTV ratio implies a more relaxed borrowing constraint. Thus, additional young households, which previously could not afford to buy a house, can now borrow more and purchase houses earlier in their life cycles. When agents become homeowners earlier, their savings in the form of interest-bearing financial assets start earlier in the life cycle. Subsequently, agents accumulate higher wealth during their working period. This is evidenced from the fact that

TABLE 6. Korea mortgage expansion

	Net worth		Homeownership	
Age	Benchmark	Experiment 1	Benchmark	Experiment 1
20–34	0.64	0.65	44.1%	46.6%
35–46	2.90	2.95	65.4%	77.0%
47–58	6.22	6.29	73.6%	77.4%
59–70	6.05	6.09	65.9%	65.7%
71–86	3.36	3.35	54.1%	53.9%
Average	2.45	2.48	58.0%	62.3%

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the largest increases in homeownership and wealth accumulation occur among the same age cohorts aged between 35 and 58. An increase in the overall capital–output ratio implies a lower interest rate and a higher wage rate. A lower interest rate adversely affects retired households, whose main source of income is asset income. This explains why the homeownership of retired households shows a small drop when compared to the benchmark case.

Quantitatively, raising the loan-to-value ratio from 25% to 75% results in an increase in the capital–output ratio by 1.2% and the housing–output ratio by 0.9%. Aggregate net worth increases by 1.1%. The homeownership ratio, on the other hand, increases by 7.4%, or 4.3 percentage points, which accounts for 43% of the observed differences in the homeownership ratios between the United States and Korea.

6.2. Changes in Rental Arrangement and Mortgage Expansion

The second experiment examines the effect of changes in the LTV ratio as well as the rental arrangement. For the latter, I substitute the existing *chonsae* rental arrangement with one where agents pay for periodic rental service. Table 7 reports the general equilibrium effects when the mortgage system is fully expanded to the U.S. level and the rental market is altered to a periodic rental arrangement.

In the model, a change from *chonsae* to a periodic rental implies that renters no longer put down a rental deposit [priced $p = 1+(\delta^h/r)$], which does not yield any interest over time. Instead, renters pay price $p = r+\delta^h$ per unit of housing service rented and do not carry any assets related to housing. With the introduction of a lower down payment requirement, homeownership has become an easier path for younger households, which can then move on to accumulate financial assets during their working career. Thus, both the profiles of homeownership and net worth are higher for working households compared to the benchmark scenario. For retired households, homeownership is also higher than the benchmark case, which is different from the experiment in which only the mortgage market was altered. When both arrangements are altered, the homeownership ratio is unambiguously higher for all age cohorts, and the increase in the overall homeownership ratio is larger than in the case when only the mortgage market was expanded. As for the

TABLE 7. Korea mortgage expansion and periodic rental

	Net worth		Homeownership	
Age	Benchmark	Experiment 2	Benchmark	Experiment 2
20–34	0.64	0.67	44.1%	47.7%
35–46	2.90	3.03	65.4%	77.1%
47–58	6.22	6.60	73.6%	77.0%
59–70	6.05	6.03	65.9%	69.1%
71–86	3.36	2.88	54.1%	54.7%
Average	2.45	2.52	58.0%	63.2%

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TABLE 8. Korea utility premium

	Net worth		Homeownership	
Age	Benchmark	Experiment 3	Benchmark	Experiment 3
20–34	0.64	0.66	44.1%	47.2%
35–46	2.90	3.01	65.4%	80.0%
47–58	6.22	6.42	73.6%	81.3%
59–70	6.05	6.31	65.9%	74.8%
71–86	3.36	3.48	54.1%	58.0%
Average	2.45	2.55	58.0%	65.4%

profile of net worth, retired households draw down their wealth faster compared to the benchmark case. Quantitatively, while the peak profile of net worth is 6% higher (cohorts aged 47–58), average net worth for the retired cohorts aged 71–86 is 14% lower than in the benchmark case.

With reasonable parameter values, I find that the changes in the rental arrangement and the LTV ratio result in an increase in the capital–output ratio by 5.4% and a reduction in the housing–output ratio by 7.1%. The aggregate net worth–to–output ratio increases by 2.9%. The homeownership ratio increases by 9%, or 5.2 percentage points, which accounts for 52% of the observed differences in the cross-country homeownership ratios.

6.3. Changes in Utility Premium for Homeownership

In this section, I look at the effect of lowering the utility premium parameter, λ, from 0.7 to 0.65. A lower value of λ can effectively capture disproportionately preferential treatment of homeowners versus renters such as tax benefits or network externalities. Table 8 reports the general equilibrium effects on the aggregate and life cycle profiles.

In the model, a lower λ parameter implies a bigger utility wedge between being a renter and a homeowner. Because agents now derive higher utility from being a homeowner compared to a renter, homeownership increases unambiguously for all age groups. Similarly, the profile of net worth is higher for all household age cohorts. In the aggregate, lowering the preference parameter λ from 0.7 to 0.65 results in increases in both the capital–output ratio and the housing–output ratio by 4.9% and 0.2%, respectively. As a consequence, the aggregate net worth output ratio increases by 3.9%. Homeownership ratio, on the other hand, increases by 12.8%, or 7.4 percentage points, which accounts for 74% of the observed differences in the homeownership ratios between the two countries.

7. CONCLUSION

In this paper, I ask to what extent the differences in homeownership and wealth accumulation between Korea and the United States are accounted for by the institutional differences in the housing market. To address this issue, I use a quantitative

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general equilibrium life-cycle model with housing with market incompleteness coming from uninsurable labor income risk and collateralized borrowing. Both the mortgage system and the rental arrangement in Korea play a significant role in accounting for the observed features of homeownership patterns. An expansion of the mortgage system is expected to increase the average homeownership ratio significantly, especially for the younger and working households. The changes in the loan-to-value ratio can account for more than 40% of the observed cross-country differences in the homeownership ratio. Changes in both the LTV ratio and the rental arrangement can account for more than 50% of the differences in the aggregate homeownership ratio.

It is important to note that the model abstracts from several issues in terms both of housing and of nonhousing institutions. First, in terms of the housing institution, although the model only addresses the differences in down payment requirements, mortgage loans also differ along other important dimensions such as liquidity, refinancing costs, and maturity, which could improve the model's ability to account for the patterns of wealth accumulation and homeownership in the two countries. Second, the model as constructed abstracts from different housing taxation issues. It is argued that in the United States, the home mortgage interest deduction can potentially play a large role in accounting for the heavily skewed distribution of wealth and this may have implications for wealth transfers across generations. In addition, mortgage interest deductibility may enable households to fund their businesses, thereby enabling a faster transition into entrepreneurship and economic growth.

As for nonhousing institutions, first, the model does not incorporate the existence of inter vivos intergenerational transfers, which might explain why the model underestimates the level of wealth for young households. In the data, Korean parents provide large financial support to their children, especially when they become independent and buy houses. Given the high down payment ratio, children either save for an extended period of time or receive parental support for purchasing a house. In fact, the average inter vivos transfer received as a fraction of average income is higher in Korea than in the United States, especially for younger households. This strengthens the importance of inter vivos transfers in Korea and their implications on the accumulation of wealth over the life cycle, especially in the presence of borrowing constraints.

Another issue abstracted from in the model is economic growth. For example, an inclusion of TFP growth in the model will likely decrease depreciation rates and increase the interest rate, which will generate a different age–wealth distribution, with the younger generation holding more wealth than elderly households. We leave these issues for future research on cross-country differences in the distribution of wealth.

NOTES

1. The corresponding figures for the United States are 55% and 80%, respectively.

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2. The survey also asks landlords whether or not they have received the *chonsae* deposit. Because this is considered part of the financial liabilities, there is no double counting of financial assets in the aggregate.

3. Household head in the KLIPS survey is defined as "the representative person in the household," not as the oldest or the person with the highest income. The summary statistic shows that 84.1% are male with median age of 47.

4. Korean census survey in 1993 shows that 74.7% of agents aged 60 and above live with their offspring [Won and Lee (1999)].

5. One way to interpret this redistribution is to consider it as the sum of inter vivos transfers and bequests.

6. Glaeser and Shapiro (2002) explain in detail about the externalities of homeownership over renting. Poterba (1992) details various tax benefits such as home mortgage interest deductions and tax deductions on the capital gains from selling the house. In addition, higher utility gains for homeowners than for renters incorporate the fact that housing can be used as an investment asset with possible capital gains, which is an aspect of housing the model abstracts from.

7. For U.S. households, renters carry no housing stock, $h = 0$.

8. Given the capital–output ratio, the implied interest rate in the stationary equilibrium is derived as $r = \alpha Y/K - \delta^k$, which is 5.8% in the United States and 3.9% in Korea.

9. For example, mortgage interest is tax-deductible in the United States but not in Korea.

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APPENDIX: COMPUTATION OF THE MODEL

Because there is no closed-form solution to the model, the stationary equilibrium of the model is solved numerically to work out optimal decision rules as a function of the state variables. The optimal decision rules were found by backward induction, starting at the terminal period J and working all the way recursively to the initial period. In period J, the value functions coincide with the sum of the period utility function and the bequest function, and, given the realization of the state variables, the consumption and bequest choices are trivial. Based on the period-J policy functions, in every period prior to J, the values associated with the different choices of housing in the next period were calculated, and consumption and asset portfolio choices conditional on different housing choices were obtained subsequently. For choices of control variables that violate various constraints, a large negative utility is given so that an optimizing household would never opt for these choices. The realization of the earnings process are approximated following Tauchen and Hussey (1991). The state space for housing and financial assets was discretized into a finite number of grid points:

$$a \in \{a_{\min}, \ldots, 0, \ldots, a_{\max}\},$$
$$h \in \{0, \ldots, \underline{H}, \ldots, h_{\max}\}.$$

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Whenever the upper limit for the grids turned out to be binding in the solution to the problem, the upper and lower bounds were increased and the problem was solved again. In the end, the boundaries for the grids became sufficiently wide and no longer imposed any constraint on the optimization process.

In order to solve for the stationary equilibrium, I take the following steps:

1. Guess the initial values of the interest rate r and solve for the rental price p using the no-arbitrage conditions (13) and the wage rate w using the equilibrium conditions in the factor market in (16).
2. Guess the initial level of transfers given to working households.
3. Solve for the individual household's recursive problem from the terminal period J.
4. Given the policy function in period J, iterate backwards until the first period in life. This yields the policy functions and the value functions for all periods.
5. Using forward induction of the policy function, compute the stationary distribution of households m^*.
6. Given the stationary distribution and policy functions, compute the level of transfers. If the transfers converge, then go to the next step. If not, update the level of transfers and go back to step 2.
7. Given the stationary distribution and prices, compute aggregate capital and compute interest rate r using equation (15). Iterate until the interest rate r converges.

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