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Real Exchange Rate Dynamics and Demographic Structure in Korea*

Dong-hoon Lee† Cheolbeom Park‡

Abstract We employ a non-parametric approach to examine the real exchange rate and the entire age distribution in South Korea. We find that movements of the real exchange rate are tightly related to the evolution of the demographic structure and that the estimated age response function is consistent with a life-cycle model in which older generation and younger generation have a positive effect on the real exchange rate. Finally, the real exchange rate is forecasted to appreciate gradually, which suggests that the growing proportion of the older population has a stronger impact than the falling proportion of the younger generation on the real exchange rate.

Keywords Aging; Demographic structure; Exchange rate; Life-cycle income hypothesis; Non-parametric approach

JEL Classification J11, F31, C14

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†Department of Economics, Korea University, e-mail:ldhinkoreau@naver.com

‡Department of Economics, Korea University, e-mail:kjs@korea.ac.kr

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1. INTRODUCTION

Drastic changes in demographic structures are a global phenomenon. Fertility rates in Organization for Economic Cooperation and Development (OECD) countries have dramatically declined over the past few decades from an average fertility rate of 2.7 in 1970 to 1.7 in the 2000s. Moreover, the fertility rates are below their replacement levels of 2.1 in most OECD countries.[1] At the same time, the aging of the population is unprecedented. According to the United Nations (UN), the number of individuals aged 60 or over has tripled over the last 50 years due to increase in life expectancy.[2] Since most economic decisions in a market economy are made at the household level or at the individual consumer level, sudden changes in the population structure must have a significant impact on macroeconomic variables. Hence, economists have paid attention to the impact that rapid changes in the demographic structure have on macroeconomic variables.

Abel (2001, 2003) and Geanakoplos, Magill, and Quinzii (2004) perform a theoretical analysis of the impact of the population distribution on stock prices, while Bakshi and Chen (1994), Geanakoplos, Magill, and Quinzii (2004), Ang, and Maddaloni (2005), DellaVigna and Pollet (2007), Park (2010), and Kim and Park (2012) conduct empirical analyses on this issue. Fair and Dominguez (1991), Park, Shin, and Whang (2010), and Park and Yu (2013) examine the relationship between the demographic structure and the consumption-saving behavior. Bloom et al. (2007) empirically examine whether economic growth is related to the age structure, and Domeij and Floden (2006) study population aging and international capital flows.

Extending the study on the economic consequence of demographic changes, we attempt to explain the dynamics of the real effective exchange rate based on the age distribution in South Korea. Although the exchange rate plays an important role in an open economy like South Korea, a big challenge for economists has been to understand dynamics of the real exchange rate. The purchasing power parity (PPP) and the Balassa-Samuelson effect are appealing theories that nevertheless have a limited ability to explain the movements of the real exchange rate (see Rogoff (1996)). However, Rose, Supaat and Braude (2009) have reported that the fertility rate has a significant impact on the real exchange rate. Our study is similar to that of Rose, Supaat and Braude (2009) in that we re-

[1] These numbers are from OECD Factbook 2013 (http://www.oecd-ilibrary.org/sites/factbook-2013-en/01/01/02/index.html?itemId=/content/chapter/factbook-2013-2-en).

[2] See World Population Ageing 1950 – 2050 reported by United Nations (UN). The web address is http://www.un.org/esa/population/publications/worldageing19502050/.

late movements of the real exchange rate to the evolution of the demographic structure. But, our approach is different from theirs in several aspects. First, we employ a nonparametric approach that is similar to that employed by Park, Shin, and Whang (2006), Park (2010), Kim and Park (2012), and Park and Yu (2013). Hence, we do not impose a functional form for the relation between the demographic structure and real exchange rate *a priori*. Second, we also utilize the entire age distribution to explain the fluctuations of the real exchange rate instead of selecting a certain aspect of the distribution, such as the fertility rate. As a result, we can avoid the arbitrariness that possibly arises from the choosing a demographic measure. Third, we deliberately examine data from South Korea because Korea is reported to have the lowest fertility rate among OECD members[3] and it is experiencing an extremely quick aging phenomenon.[4] Figure 1 shows how fractions of each age group (age 0 – 19, age 20 – 39, age 40 – 64, and age 65 or above) have evolved over time in South Korea. The low fertility rate and rapid aging are reflected in the steady decline of the fraction of age 0 – 19 group and the steady rise of the fraction of age 65 or above, respectively. Although the use of time-series data for a single country results in fewer observations than the use of panel data, as in Rose, Supaat and Braude (2009), it does not require enough heterogeneity in the population distribution that is slowly changing.[5] Furthermore, focusing on the time-series data enables us to avoid any problem arising from the possibility that different series functions are selected across countries in a panel dataset to approximate the age response function. Hence, if there is any impact from the population structure on the real exchange rate, it will be more pronounced in the Korean time-series data.

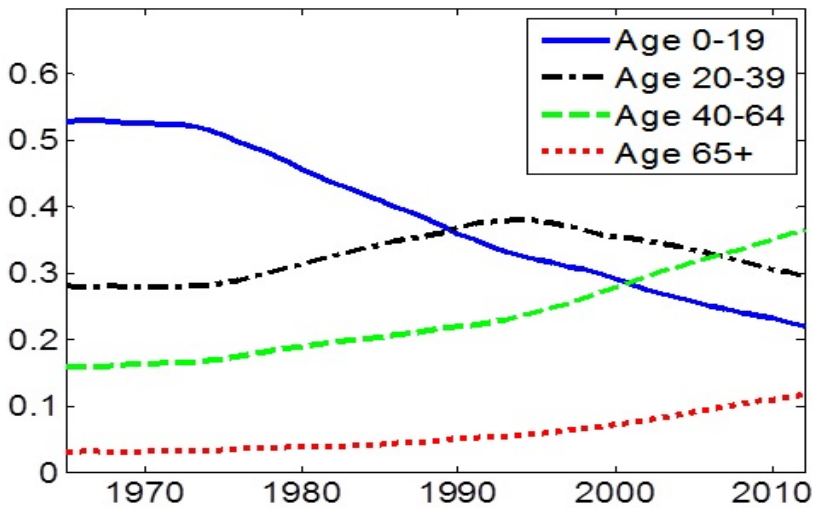
The non-parametric approach and time-series data for Korea exhibit a strong relation between the real exchange rate dynamics and the population distribution. Specifically, an increase in the proportion of the young generation and/or the old generation of the total population results in an increase in the real exchange rate, which is in agreement with the implications of the life-cycle theories as well as empirical findings from Rose, Supaat and Braude (2009). The projections for the

[3]According to OECD Factbook 2013, the Korean fertility rate in 2010 is 1.23, which is the lowest one among OECD members. (Source: http://www.oecd-ilibrary.org/sites/factbook-2013-en/01/01/02/index.html?itemId=/content/chapter/factbook-2013-2-en)

[4]The Korean Herald reports that over the last four decades, Korea's elderly population has grown at the fastest pace among OECD members. The fraction of people aged 65 or older has grown by four times in Korea over the last four decades, which is more than double the OECD average of 1.6 times. (Source: http://www.koreaherald.com/view.php?ud=20140915000556)

[5]In an extreme case, if all countries in a panel dataset experience falls in the fertility rate by the same amount or rises in the fraction of elderly population by the same amount, then the effect of age distribution on the real exchange rate will not be captured.

Figure 1: Evolution of Demographic Structure in South Korea



Note: Thie figure shows how fractions of each age group (age 0 – 19, age 20 – 39, age 40 – 64, and age 65 or above) have evolved over time.

distribution of the Korean population are combined with the estimates obtained from the non-parametric regressions, to produce forecasts for the real exchange rate based on the demographic structure only. The real exchange rate is predicted to rise, which suggests that in the future, the increase in proportion of the older generation will be more dominant than the decrease in younger generation.

This study is presented as follows. Section II briefly presents the econometric methodology employed in this study. Section III contains a description of the data and the main empirical results. The concluding remarks are provided in Section IV.

2. ECONOMETRIC METHODOLOGY

Although it might seem odd to state that the movements of the real exchange rate are related to the demographic structure of a country, a link between the two can be derived in a straightforward manner by referencing a simple life-cycle model, such as that presented in Rose, Supaat and Braude (2009). Under the assumption that both the young and old population consume disproportionately high amounts of non-tradeables in a small open economy (mainly, education for the younger generation and healthcare for the older generation), the increase in the fraction of the young and/or the old population increases the demand for these non-tradeable goods, which results in an appreciation of the exchange rate. In addition, the increase in the proportion of the young and/or old individuals out of the total population would reduce savings and stimulate consumption and investment which, again, will cause the exchange rate to appreciate. For both of these reasons, the age distribution could be related with movements in the real exchange rate.[6]

We consider the following econometric model to examine whether the above implications of the life-cycle model are empirically borne out:

$$reer_t = \mu + \int_T f_t(m)g(m)dm + u_t \tag{1}$$

where $reer_t$ is the real effective exchange rate, f_t denotes the density function of age distribution at time t, and T is a common compact support for f_t. Since f_t, the regressor, is the density function of the age distribution, $\int_{T_j} f_t(m)dm$ (where T_j is a subinterval of T) is the fraction of the individuals for age group T_j in the total population. Since we are relating the variation in the real exchange rate to the variation in the entire age distribution, denoted as f_t, we can avoid any arbitrariness arising from the choice of a specific age range or a particular demographic measure.

$g(m)$ can be interpreted as the age response function that reflects the impact of the age distribution of the population on the real exchange rate. Although there could be numerous economic factors that affect the movement of the real exchange rate, we assume that the variation in the age distribution of the population is independent of such factors. As a result, $g(m)$ can be consistently estimated without the inclusion of additional variables in the regression. Once the

[6]Rose, Supaat, and Braude (2009) call the first channel as the composition of demand channel and the second channel as the saving channel. Refer to Rose, Supaat, and Braude (2009) for the theoretical model.

estimate of $g(m)$ has been obtained, the age group that has a significant impact on the movement of the real exchange rate can be determined, and the estimate of $g(m)$ can be compared with the implications of the life-cycle model.

When $g(m)$ is estimated, no functional form is imposed *a priori* for $g(m)$. The only assumption required for the characteristic of $g(m)$ is that it should be sufficiently smooth to be approximated with a series of polynomials, trigonometric functions, or a mixture of both series. That is, assume that $\|g_\kappa - g\| \to 0$ as $\kappa \to \infty$, where $g_\kappa(m)$ is an approximation of $g(m)$ given by a combination of a finite series of functions $\psi_1, \ldots, \psi_\kappa$. When $g_\kappa(m) = \sum_{j=1}^{\kappa} \alpha_j \psi_j$, Equation (1) can be written in a straightforward manner as:

$$reer_t = \mu + \sum_{j=1}^{\kappa} \alpha_j \int_T f_t(m)\psi_j(m)dm + u_{\kappa,t} = \mu + z_t^{'} a_\kappa + u_{\kappa,t} \tag{2}$$

where $u_{\kappa,t} = u_t + \int_T f_t(m)(g_\kappa - g)(m)dm$, $a_\kappa = [\alpha_1, \ldots, \alpha_\kappa]'$, and $z_t = [\int_T f_t(m)$ $\psi_1(m)dm, \ldots \int_T f_t(m)\psi_\kappa(m)dm]$. Letting Y and Z be vectors for $reer_t$ and z_t, respectively, the LS estimator of a_κ can be written as $\hat{a}_\kappa = (Z'Z)^{-1}Z'Y$. As a consequence, the corresponding series estimator of the age response function can be written as:

$$\hat{g}(m_h) = \sum_{j=1}^{\kappa} \hat{\alpha}_j \psi_j(m_h) = \prod_\kappa (m_h)' \hat{a_\kappa}$$

where $\prod_\kappa(m_h) = [\psi_1(m_h), \ldots, \psi_\kappa(m_h)]'$ and m_h is an interval on T. Once $\mathrm{Var}(\hat{a_\kappa})$ is obtained from the regression residuals, $Var(\hat{g}(m))$ can be expressed as $Var(\hat{g}(m))$ $= \prod_\kappa' Var(\hat{a_\kappa}) \prod_\kappa$.

Although we impose no functional form for $g(m)$, a series of functions is required to approximate $g(m)$. In the empirical analysis, we attempt to use a series of polynomials as well as mixtures of both polynomials and trigonometric functions, which is often referred to as the Fourier Flexible Form (FFF) introduced in Gallant (1981). The polynomial expansion of $g(m)$ can be written as $g_\kappa(m) = \alpha_1 m + \alpha_2 m^2 + \cdots + \alpha_\kappa m^\kappa$, and the FFF expansion of $g(m)$ can be expressed as $g_\kappa(m) = \alpha_1 m + \alpha_2 m^2 + \sum_{j=1}^{J}[\alpha_{3,j} cos(jm) + \alpha_{4,j} sin(jm)]$ where $\kappa = 2 + 2J$.[7] The selection of κ (or equivalently the selection of J in the FFF expasion) is made so that the selected κ is supported by the data as much as possible.

[7]Due to the characteristics of trigonometric functions, it is desirable to scale the data into the interval [0,1]. That is, with a given common support $T = [\lambda_1, \lambda_2]$ for f_t, f_t is transformed by $f_t^*(m) = f_t(\lambda_1 + (\lambda_2 - \lambda_1)m)$, such that f_t^* has common support [0,1]. The original response function g with respect to f_t can be recovered from the response function g^* with respect to f_t^* by the transformation $g(m) = g^*(\frac{m-\lambda_1}{\lambda_2-\lambda_1})$.

For this purpose, we employ the h-block cross-validation (CV) and the modified h-block CV criteria (MCV), as suggested by Burman, Chow, and Nolan (1994) and Racine (1997), as selection criteria for κ which denotes the number of functions in the approximation.[8] For a given block size (h), the h-block CV criterion can be expressed as:

$$CV_\kappa = N^{-1}\sum_{t=h}^{N-h}(reer_t - z_t'\hat{a_\kappa}(t,h))^2$$

where N is the number of observations, and $\hat{a_\kappa}(t,h)$ is the estimator for a_κ acquired by removing the t-th observations in $reer_t$ and z_t and the h observations preceding and following the t-th observations in both $reer_t$ and z_t. The modified h-block CV criterion, which is motivated by cases where κ is not negligible relative to N, can be written as follows:

$$MCV_\kappa = N^{-1}\sum_{t=h}^{N-h}(reer_t - z_t'\hat{a}_\kappa(t,h))^2 + N^{-2}\sum_{t=h}^{N-h}\sum_{n=1}^{N}(reer_n - z_n'\hat{a}_\kappa(t,h))^2$$
$$+N^{-1}\sum_{n=1}^{N}(reer_n - z_n'\hat{a}_\kappa)^2$$

The κ that minimizes the above CV_κ or MCV_κ criteria is then selected.

3. EMPIRICAL EVIDENCE

3.1. DATA

The Bank of International Settlements (BIS) provides various versions of the real effective exchange rate.[9] We choose the one that has the longest series for Korea. The series is based on the relative Consumer Price Indices and is set to 100 for 2010. The real exchange rate is provided by BIS at a monthly frequency, but the annual average is used in the analysis because the population data are available only at an annual frequency. The data are designed in a way in which higher values for the real exchange rate represent a greater appreciation.

The data of the Korean population structure data are taken from the Korean Statistical Information Service (KOSIS), which is managed by National Statistical Office in Korea.[10] We use population estimates by 17 five-year age groups

[8] We assume that the dependent variable (the real exchange rate) and regressors (population density functions) are stationary.

[9] The web address for BIS data section is http://www.bis.org/statistics/eer/index.htm.

[10] The website address for KOSIS is http://kosis.kr/statisticsList/statisticsList_01List.jsp?vwcd=MT_ZTITLE&parentId=A#SubCont.

(age 0 – 4, age 5 – 9, . . . , age 80 or above) to make the age distribution series as long as possible. The sample period begins at 1965 and ends at 2012.

3.2. ECONOMETRIC RESULTS

Since we cannot expand $g(m)$ with an infinite number of functions, it is of critical importance to determine the amount of series functions that should be included to achieve a good approximation for the empirical analysis. As discussed in the previous section, we use several series functions to compute CV_κ and MCV_κ with various values of κ. While computing CV_κ and MCV_κ, the block size, h, is set as the integer nearest to $N/6$, in accordance with the suggestion of Burman, Chow, and Nolan (1994). The results are shown in Table 1, where CV_κ is minimized with the quadratic form, among several alternative forms. MCV_κ is also minimized with the quadratic representation when polynomial and FFF series are considered. Therefore, $g(m)$ is estimated by using a constant term, m, and m^2 in the regression analysis.

Table 2 presents the results of the regression based on the selection of κ for Equation (2) in Table 1. All of the coefficients (μ, α_1, and α_2) are strongly significant, suggesting that the age distribution is tightly related to the real exchange rate. In order to determine whether or not the tight relation between the age distribution and the real exchange rate is in agreement with the implications of the life-cycle model, we plot the estimated age response function and the corresponding 95% confidence intervals in Figure 1. In Figure 2, we can note that different age groups have a heterogeneous impact on the movements of the real exchange rate. Specifically, an increase in the proportion of young individuals (roughly from age 0 to age 20) and/or older individuals (roughly age 50 or above) results in an appreciation in the real exchange rate. In contrast, the impact of the prime-working-age groups (roughly from age 20 to age 50) on the real exchange rate is insignificant. This U-shaped age response function is remarkably consistent with the implication of the life-cycle model presented in Rose, Supaat, and Braude (2009), where an increase in the fraction of young and/or old individuals raises the real exchange rate through a saving channel and a demand composition channel.

Figure 3 presents the fitted values of the non-parametric regression (2) along with the real exchange rate. The adjusted R^2 of the non-parametric regression is 0.7, and the fitted values track closely the actual real exchange rate, as if the fitted values are a long-run trend of the real exchange rate. Considering that appealing theories such as the purchasing power parity and the Balassa-Samuelson

Table 1: h-block and Modified h-block Cross-Validation Criteria

	h-block CV	Modified$h$-block CV
$1,\ m, m^2$	66.4979	290.5898
$1,\ m, m^2, m^3$	81.4608	310.7109
$1,\ m, m^2, m^3, m^4$	210.1641	453.1147
$1, m, m^2, \cos(m), \sin(m)$	209.9507	452.8739
$1, m, m^2, \cos(m), \sin(m), \cos(2m), \sin(2m)$	17058	32672

Notes: This table shows the h-block cross-validation (CV) and the modified h-block CV criteria (MCV), as suggested by Burman, Chow, and Nolan (1994) and Racine (1997). We select the number of series functions to approximate the age response function when either CV or MCV is minimized.

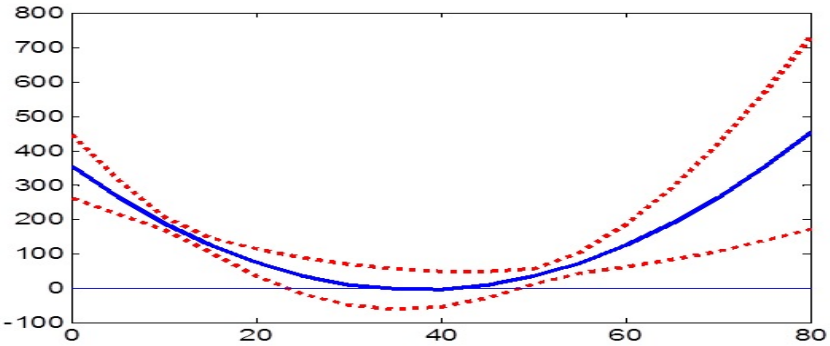
Table 2: Regression Results

μ	α_1	α_2
402.9***(58.82)	-1728.2***(434.30)	1834.1***(534.86)

Notes: This table shows the results from the regression based on the semi-nonparametric approach. $reer_t = \mu + \alpha_1 \int_T f_t(m) m dm + \alpha_2 \int_T f_t(m) m^2 dm + u_{\kappa,t}$. Robust standard errors are reported in parentheses, and '*', '**', and '***' denote the significance level at the 10%, 5%, and 1% level, respectively.

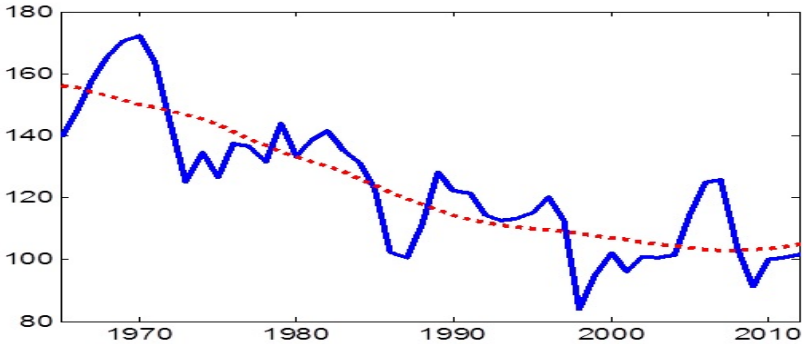
effect can provide very limited explanatory power for the real exchange rate, the connection herein proposed between the demographic structure and the real exchange is impressive. This result is also consistent with the empirical findings presented in Rose, Supaat, and Braude (2009) that the fertility rate (one aspect of the age distribution) is tightly related to the real exchange rate.

Figure 2: Estimated Age Response Function



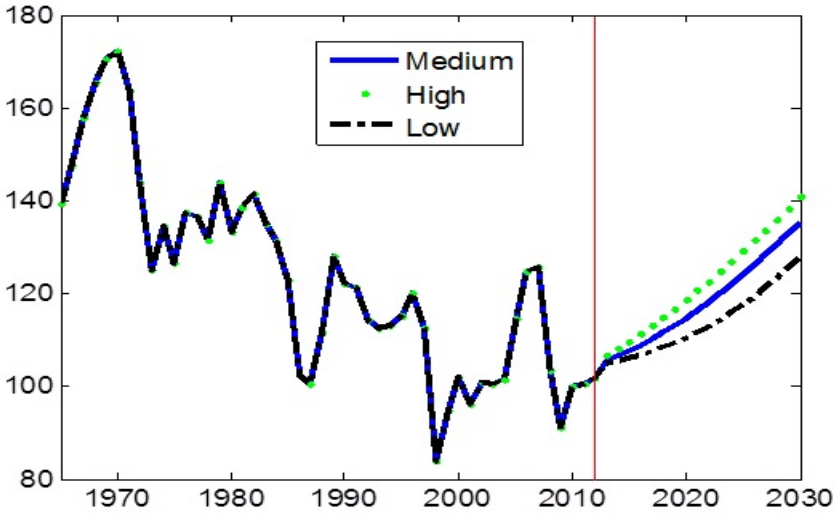
Notes: This figure shows the age response function and its 95% confidence intervals, as estimated from Equation (2). The horizontal axis denotes ages.

Figure 3: Real Effective Exchange Rate and Fitted Value based on the Age Distribution



Notes: This figure shows the fitted values from the nonparametric regression in Equation (2).

Figure 4: Projections for the Real Effective Exchange Rate



Notes: This figure shows the real exchange rate predicted for the period of from 2013 to 2030 (after the vertical line) when the nonparametric regression results in Table 2 and the projections in the Korean age distribution are combined. Three types of projections are provided by KOSIS for the growth of Korean population: optimistic, medium, or pessimistic senario on the growth of Korean population.

3.3. FORECASTING THE REAL EXCHANGE RATE BASED ON PROJECTED AGE DISTRIBUTION

Two prominent characteristics of the demographic structure of Korea are the extremely low fertility rate and the drastically growing proportion of the older population. According to the life-cycle model, the low fertility rate in Korea reduces the demand for eductation (non-tradeable goods), and lowers consumption and investment, which results in a depreciation in the real exchange rate. However, the rapid rise in the proportion of the older population due to the development of medical science has the opposite effect on the real exchange rate. An increase in the fraction of older individuals inreases demand for healthcare (another type of non-tradeable goods), and stimulates consumption and invest-

ment, which results in an appreciation in the real exchange rate. As a result of these features of the demographic structure in Korea and the implications of the life-cycle model, one natural question is whether the real exchange rate will appreciate or depreciate in the future in response to the dynamics of the age distribution.

This question is particularly important in Korea, which has actively engaged in international trade. Hence, we address this concern using estimates of the parameters in the nonparametric regression of Table 2 and the population projections provided by KOSIS. Three types of population projections are provided by KOSIS, and these are based on an optimistic, neutral, or pessimistic senario of the growth of the Korean population. Irrespective of the senarios of the population growth in Korea, we can see in Figure 4 that the effect of the rapid rise in the old population becomes more dominant than the low fertility rate, which in turn forecasts a gradual appreciation of the real exchange rate until 2030. The real exchange rate is expected to show a more rapid appreciation under more optimistic senarios for the population growth. However, this projection based on the age distribution should not be used to forecast short-run fluctuations in the real exchange rate because a myriad of other factors (economic growth, macroeconomic risk, monetary policy, etc.) are not considered.

4. CONCLUSION

Although it is hard to explain the movement of the real exchange rate, we have found that demographic structure is an important factor to understand such movement in Korea. Our results are similar but complementary to those presented by Rose, Supaat, and Braude (2009), who uncovered that the fertility rate (one aspect of the demographic structure) has a significant relation with the real exchange rate, because the entire age distribution is shown to have a strong impact on the real exchange rate. When the evolution of the entire age distribution in Korea is taken into account, the real exchange rate is expected to appreciate in the future, which implies that the increase in the elderly population will be a more dominant factor than the decrease in younger population.

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