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Population Age Structure and Real Exchange Rate in OECD Countries: An Empirical Analysis



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Abstract This article examines the impact of population age structure on the real exchange rate. Data on a panel of 22 OECD (Organization of Economic Cooperation and Development) countries over 1980–2015 period are used to estimate the empirical model. Using fixed effect model the paper finds that different age cohorts have a significant influence on the real exchange rates in the sample countries. The results are mostly consistent with the theoretical framework discussed in the paper and also with the findings of previous studies in this area. These results have important policy implications given the fact that the population is ageing in almost all the OECD economies these days.

Keywords Population age structure, Real exchange rate, Saving, Investment, Panel data model

1. Introduction

The real exchange rate is an important consideration in open economy macroeconomics. It is commonly used as a measure of the competitiveness of the tradable goods sector and even as a measure of the standard of living in one country relative to another (Dwyer and Lowe 1993). It influences consumption and resource allocation decisions between tradable and non-tradable goods and also represents a country's comparative advantage. Different real (i.e., terms of trade [TOT], productivity) and nominal (i.e., money supply) shocks cause the real exchange rate to deviate from its equilibrium value, temporarily or permanently. There is an impressive body of empirical literature that examines the influence of real and nominal shocks on the real exchange rate. TOT, interest rate differential (INTDIFF), inflation differential, international capital flows, productivity differential, current account, etc. are found to have significant power to explain the movements in equilibrium real exchange rate in developing as well as developed countries. Recently, demography has been subjected to empirical research to examine its influence on the real exchange rate in a few studies¹. Although demography has been analyzed to explain the behaviour of savings, capital flows and current account (Besanger et al. 2000; Higgins 1997), the theoretical as well as empirical relation between the real exchange rate and demography is not so developed. Gente (2001) shows that in a two-sector, two-period overlapping generations model, a fall in the birth rate leads to a long-run real exchange rate appreciation. On the empirical side, Andersson and Österholm (2005) find that, in Sweden, the demographic structure has significant explanatory power in explaining the movements of the real exchange rate. These authors also find similar findings in their subsequent study in the context of Organization of Economic Cooperation and Development (OECD) countries (Andersson and Österholm 2006).

Previous studies in this area consider only age structures as the independent variables. So, a complete model of the real exchange rate incorporating population dynamics is warranted for understanding the impact of population age structure on the real exchange rate. Due to falling fertility, the population is ageing around the globe. However, the problem is more acute in developed countries. Tyers and Shi (2007) note that slower population growth and ageing in industrialized countries increase the aged dependency ratio. In 2010 the share of old aged people (65+) in the total population in major OECD countries was 16.36%, whereas, this share will rise to 27.80% in 2050 (see Appendix Table 4). Such an incredible increase (more than 11 percentage point) in the elderly population will put huge pressure on internal and external balance through their influence on

¹Some studies also examine the impact of population age structure on current account, for example, Zhou (2018) finds significant negative impact of elderly dependency ratio on China's current account.

domestic saving and investment. Hence, it is high time to examine the effect of population age structure on the real exchange rate, along with other usual determinants. Although the empirical studies on exchange rate determination are diverse, but there is no comprehensive study that incorporates most determinants, including population age structure in the same framework. This article intends to fill this gap and as such makes a contribution to the literature. The objective of this paper is to estimate a model of the real exchange rate with different cohorts of the population as additional independent variables and examine whether demographic variables have any significant influence on the movements of the real exchange rate. The novelty of this paper lies in the number of ways it is different from similar previous studies. First, unlike previous studies in this area, it considers not only saving effect but also an investment and consumption demand sides of population age structure. Second, the distinguishing feature of this paper is that it considers, in addition to the population age structure, other determinants of the real exchange rate. Third, this paper pays due to econometric attention in the analyses part to ensure justice to the data set used. Finally, the finding of this paper makes a significant addition to the Purchasing Power Parity (PPP) literature as well.

The rest of this paper is organized as follows. Section two contains a critical review of the related literature. Impact of population age structure on the real exchange rate is discussed in Section 3, followed by discussions of other determinants of the real exchange rate in Section 4. Section 5 deals with sample, data, estimation and analyses of results. The paper concludes in Section 6.

2. Review of the relevant literature

There is a large body of literature on the determinants of the real exchange rate. A wide range of factors has been identified in these studies as responsible for the equilibrium value of the real exchange rate. These factors include the TOT (Choudhri and Khan 2004; Chowdhury 2000; Mkenda 2001), capital inflow (Chowdhury 2000), real INTDIFF (Athukorala and Rajapatirana 2003; Chortareas and Driver 2001), relative productivity (Alexius 2000), government consumption (Chowdhury 2000; Mkenda 2001), labour productivity (Choudhri and Khan 2004) and oil price (Wang and Dunne 2000).

In addition to these factors, recently research attention has focused on the population age structure of an economy that has an important influence on the real exchange rate. One channel of influence is the impact the population structure on saving and consumption behaviour as postulated in the Life Cycle Hypothesis (LCH) of Modigliani and Brumberg (1954)². An economy's savings and thereby, capital formation partly depends on the size of different cohorts of the population. Working-age people save everywhere in the world. In a study on OECD countries, Lindh and Malmberg (2004) find that age effects on saving are similar across a world sample over the period 1960–1995. The age structure of the population also has an influence on the economies' investment through saving. Lindh and Malmberg (1999) find that investment behaviour displays different patterns of response to age structure across the sample of OECD countries. They find that young working-age people invest more in housing, whereas a middle-age working people invest in the business. The housing investment is rationalized by the tendency of population to settle down by the formation and acquisition of permanent shelter during youth; however, the latter investment behaviour is left without any solid explanation.

A more formal and direct link between age structure and investment can be found from the standard production function, which implies that a fall in the number of workers raises the wage and the decreases return to capital by raising the marginal product of labour and decreasing the marginal product of capital, respectively. Ludwig et al. (2007) find that due to the aging population, the productivity of capital in major industrialized countries will fall and wage will rise. Their simulation results show that the rate of return on capital can be expected to fall by about 80 to 90 basis points until 2050 with a corresponding increase of wage. As in the world of free capital mobility, capital flows from low-return to high-return locations (Chatterjee and Naknoi 2007); fall in return on capital would cause capital outflow and the real exchange rate to depreciate.

Research work on population dynamics and the real exchange rate is very limited. So far, a few studies have been conducted in the context of developed countries. Andersson and Österholm (2005) use Swedish age structure data over the period 1960–2002 to forecast the real exchange rate. The authors find that the age structure has significant explanatory power on the real exchange rate and their out-of-sample, medium-term forecasts of the real exchange rate perform well. Findings of this paper indicate that in an ageing economy population growth has appreciating effect on the real exchange rate.

²Over the last couple of decades, population growth rates in developed countries have slowed down. During 1950–1955 population growth rate in the developed countries was 1.20 percent, whereas this growth rate declined to 0.36% during 2000–2005. A projection by the United Nations shows that over the period 2005–2050, the share of the population aged 15–59 will decline from 62.9 percent of the total population of the developed countries to 52.2 percent (World Population Prospect: The 2006 Revision).

Latter, Andersson and Österholm (2006) estimate a reduced-form equation where the real exchange rate is regressed on different cohorts of the population of 20 OECD countries over the period 1971–2002. They divide the total population into six groups: children (0–14), young adults (15–24), prime-aged (25–49), middle aged (50–64), young retirees (65–74) and old retirees (75–and above). Their results show that different age groups affect the real exchange rate differently. The prime and middle age group (25–49 and 50–64 years respectively) have a depreciating impact, as they are productive and save for their retirement, which causes capital outflow. On the other hand, the study finds that young adults and retirees (15–24 and 65–above years respectively) have an appreciating effect. This is because these groups are not productive, they are dependent and they dissave, so they seem to cause capital inflow and depreciation. The authors, however, do not include other factors in their regression model.

Aloy and Gente (2009) also find the significant appreciating impact of falling population growth in Japan on Yen/US dollar bi-lateral real exchange rate. This paper employs an overlapping generations (OLG) model linking the population growth to the real exchange rate. However, they do not consider the USA-Japan bi-lateral trade balance, which has been identified as one of the major factors for yen's real appreciation against the US dollar (Rahman et al. 1997). Hassan et al. (2015) show that Australia's real exchange rate is cointegrated with its productivity differential and the relative share of young dependents (0–14 years) in the population. These authors also demonstrate that young cohort has an appreciating influence on the real exchange rate in the long-run.

Ross et al. (2009) analyze the link between demography and the real exchange rate from a different viewpoint. They argue that a drop in fertility is associated with lower child-rearing cost, which increases saving. A smaller populace due to lower fertility causes investment to fall. Thus higher saving and lower investment improve the current account and depreciate the real exchange rate. Using panel data covering 87 countries over 1975–2005, they find empirical support in favour of their hypothesis. However, their hypothesized link between fertility, saving and investment needs careful attention. A fall in investment due to a fall in fertility could take a longer time than a rise in saving. If the changes in saving and investment are not contemporaneous, then the proposed changes in the current account, and hence the real exchange rate, may not follow.

Very recently Du and Wei (2011) relate sex ratios to the real exchange rate. Higher sex ratio creates current account surplus and capital outflow, which causes real exchange rate depreciation. They argue that countries with higher sex ratios appear to have a low value of the real exchange rate and current account surplus. Their study focuses on the Chinese economy and finds that sex ratio and other factors, such as dependency ratio, Balassa-Samuelson effect, exchange rate regime, and financial underdevelopment contribute to the undervaluation of Chinese real exchange rate by 2%–8%. For a detailed review on population dynamics, savings, investment, exchange rate, and capital flow readers can consult Hassan et al. (2011).

From the above discussion, it is clear that the relationship between population age structure and the real exchange rate has mostly been examined in terms of the saving effects of different cohorts of the population. However, different cohorts of the population also place demand for tradable and non-tradable goods at varying degrees. Besides, changes in population age structure have significant implication for labour supply and hence marginal productivity of labour and capital (Ludwig et al. 2007). These factors have not been considered in previous studies, which creates a huge gap in this area of research. Moreover, the number of studies addressing this issue is quite insufficient. Thus, it remains an unexplored area of research to examine the impact of population age structure on the real exchange rate. The present paper makes an effort to accomplish this task.

3. Population age structure and the real exchange rate

The theoretical linkage between the real exchange rate and demography comes from the relation between age structure of population and the resultant consumption and saving pattern in an economy as postulated in the LCH³. According to the LCH, people smooth their consumption by saving during their working life and dissaving in the rest of their life until death (Modigliani and Brumberg 1954). So in an economy, where the proportion of the working population is greater than the proportion of the young or old dependents, the saving will be greater than dissaving. If aggregate saving does not exactly match domestic investments, there will be international capital flows, which will affect the current account (Andersson and Österholm 2005). This, in turn, will influence the real exchange rate.

“In the early stage of demographic transition per capita income growth is diminished by large youth dependency burdens and small working-age adult shares. There are relatively few workers and savers. As the transition proceeds, per capita income growth is promoted by smaller youth dependency burdens and larger working-age adult shares. There are relatively many

³Recently Lv (2018) analyses the impact of population age structure and urbanization in terms of Balassa-Samuelson, factor endowment and demand structure effect and conclude that aging population in G20 countries reduces working age population with adverse effect on productivity.

workers and savers. The early burden of having few workers and savers becomes a potential gift later on: a disproportionately high share of working-age adults. Still later on, the economic gift evaporates, perhaps becoming a burden again, as elderly share rises” (Williamson 2001: 263). Thus a country, having a larger share of elderly people in the population, lacks capital for investment, imports foreign capital and cause the real exchange rate to appreciate. In addition to saving, demography can also work through the investment channel.

Young dependents place investment demand, mainly through consumption of non-traded goods (such as education and health care) without making any contribution to saving. This may give rise to two opposite effects on the real exchange rate. On the one hand, young dependents reduce saving leading to capital inflow and real appreciation. On the other hand, higher demand for non-traded goods may result in their higher prices relative to traded goods leading to real depreciation. The net effect depends on the relative magnitudes of saving effect and consumption effect.

The impact of old dependents on the real exchange rate is not so clear-cut. This is because, although they do not participate in the current production, they have the savings that they accumulated during their working-age period of life. Therefore, their consumption does not have any impact on the saving behaviour of the working-age people. However, as their saving is a part of private saving, the pattern of the use of their saving for consumption may affect total saving.

Although the life-cycle hypothesis predicts that aged people use up their saving to finance their consumption, empirical evidence suggests to the contrary. For example, Mirer (1979) uses data from 1968 survey of the Demographic and Economic Characteristics of the Aged in the USA to examine the saving behaviour of the aged people and finds that the wealth of the elderly rarely declines. In a similar study with 1972–73 Consumer Expenditure Survey data in the USA, Danziger et al. (1982) conclude that elderly people spend less than the nonelderly at the same level of income and the oldest people have the lowest average propensity to consume.

Several explanations are forwarded for this observed puzzling saving behaviour of the aged people. A bequest motive may be one plausible explanation for this behaviour. When the bequest motive dominates the consumption motive, people continue to save because the marginal utility of the aged people of leaving a dollar for their children is greater than the marginal utility of dollar used for their own consumption (Danziger et al. 1982). However, empirical studies suggest that the dissaving pattern is mostly influenced by the concern over health condition in the old age. Palumbo (1999) finds that during the retirement period consumption of the elderly people is largely influenced by the potential future shocks to their wealth level, the shock being the out-of-pocket expenses to finance health care. The possibility of a person living past her/his life expectancy also affects consumption behaviour. De Nardi et al. (2006 & 2009) also find that longevity and the risk of high medical expenses during the old age significantly explain why the elderly people run down their wealth so slowly.

The above empirical studies suggest that the old dependents are unlikely to exert a negative effect on saving. They may even have a positive effect on saving and thereby capital flow instead. If this is the case, then the old dependents will have a depreciating effect on the real exchange rate. The size of the working age cohort of population should also have significant effect on the real exchange rate. This is the cohort that mainly contributes to the private saving in an economy. If the share of working age people in total population increases total private saving will rise. This will lead to capital outflow and real depreciation. Conversely, a declining share of working-age people will cause private saving to fall, which will cause capital inflow and real appreciation.

There is another channel through which the working-age population can affect the real exchange rate. Higher working-age population or higher labour force raises the marginal product of capital and hence attracts investment. It will cause capital inflow and real appreciation. However, it also lowers the marginal product of labour and hence wage and saving. In this case, too, capital inflow will take place to fill the gap and the real exchange rate will appreciate. Existing studies on demography and the real exchange rate do not take this channel of influence into consideration. Developed countries are passing through notable changes in their demographic composition, which make these countries likely candidates for a study on demography and the real exchange rate. From the above discussion, it is clear that the demographic structure should have a significant effect on the real exchange rate, however, the direction of this effect is not clear *a priori*.

4. Other determinants of the real exchange rate

The main focus of this paper is to examine the effect of population age structure on the real exchange rate. However, only the population age structure cannot be the sole determinant of the real exchange rate. Other factors that have frequently been suggested in the literature as the determinants of the real exchange rate include productivity differential, TOT, net foreign assets (NFA), government expenditure (GOVEX), and INTDIFF. The rationales of including these factors are briefly discussed below.

Productivity differential: Balassa (1964) and Samuelson (1964) provide convincing explanation of the long-run behaviour of the real exchange rate. According to Balassa-Samuelson (BS), hypothesis productivity differential between traded and non-traded goods sector can significantly explain the long-run movements of the real exchange rate. They argue that higher productivity in the traded goods sector relative to non-traded goods sector tends to cause real appreciation. A number of studies have found empirical evidence of this productivity effect on the real exchange rate. Due to the difficulty of drawing a distinct line between traded and non-traded goods, different proxies for the BS effect have been used in the literature. For example, Edison and Klován (1987) and Mark (1996) use relative per capita Gross Domestic Product(GDP) as a proxy for the BS effect. De Gregorio, Giovannini, and Wolf (1994) and Chinn and Johnston (1996) use total factor productivity in 20 sectors. Canzoneri et al. (1996) use the average labour productivity in six sectors, two of which are considered tradable. To capture the BS effect we use four productivity measures, such as real GDP growth rate (GDPGR), per capita real GDP growth rate, the growth rate of real GDP per person employed and growth rate of GDP per hour worked.

Terms of trade: TOT is an important determinant of the real exchange rate. However, the effect of TOT on the movement of the real exchange rate is ambiguous (Amano 1995). As the price of tradable is a weighted average of the prices of exportables and importables, the effect of TOT on the real exchange rate cannot be determined *a priori* (Elbadawi and Soto 1994). This is because of two contrary effects, namely, *income effect* and *substitution effect*, work in opposite directions. An improvement in TOT, either through higher exportable prices or lower importable prices, raises the income of the economy. This *income effect* increases the demand for non-tradables and their prices, which in turn, reduces the relative price of tradables and appreciates the real exchange rate. Thus the final effect of TOT improvement/deterioration hinges upon the relative strength of these two effects. For example, Elbadawi and Soto (1994) study seven developing countries and find that for three of the TOT improvements lead to the real exchange rate appreciation, while for the four others, it leads to real depreciation.

Net foreign assets: The effect of NFA on the real exchange rate can be analyzed in terms of the *wealth effect*. An improvement in NFA raises a national wealth of an economy, thereby inducing larger expenditure on and therefore, the price of non-tradable goods, which, in turn, appreciates the real exchange rate (MacDonald and Ricci 2003). Wealth effect may also work by changing the labor supply. Higher wealth may reduce labour supply to the non-tradable sector, leading to an increase in the relative price of non-tradables and the result is appreciated real exchange rate (Lane and Milesi-Ferretti 2004). It is therefore, expected that NFA will have an appreciating effect on the real exchange rate.

Interest rate differential: The role of the real INTDIFF is highlighted in many exchange rate models, for example, Dornbusch (1976); Grilli and Roubini (1992); Mussa (1984). INTDIFF works through its effect on capital flows. When the world interest rate is higher than the domestic interest rate, capital will flow out until they are equalized and the vice versa. This link is robust in the business cycle domain, instead of lower frequencies (Baxter 1994; Edison and Pauls 1993). When the world interest rate is higher than the domestic interest rate, capital will flow out and the real exchange rate will be depreciated and it will appreciate when the domestic interest rate is higher than the world interest rate.

Government expenditures: Government consumption on non-tradables is another fundamental variable that affects the movements of the real exchange rate. Higher GOVEX on non-tradables bid up their prices and appreciates the real exchange rate. However, as the precise estimate of non-tradable consumption by the government is not available, it is proxied by the ratio of government total consumption expenditure to GDP. Edward (1988) notes that this is a poor proxy, as it is possible, for the total GOVEX to increase with the share of actual consumption of non-tradables going down. In this case, a larger share of GOVEX will fall on tradables and the real exchange rate may depreciate. This depreciation does not come through changes in tradable prices, as that is determined in the world market and a small open economy cannot affect that. When a larger share of GOVEX falls on tradable goods, demand for non-tradable goods falls and hence their prices, which depreciate the real exchange rate. So, the effect of this variable may be positive or negative.

Based on the above analyses an empirical model of the real exchange rate is specified as follows:

$$RER = f\left(\underset{+}{PRODUCTIVITY}, \underset{+}{TOT}, \underset{+}{NFA}, \underset{-}{INTDIFF}, \underset{+/-}{GOVEX}, \underset{+/-}{POP}\right) \quad (1)$$

where, PRODUCTIVITY = productivity differential variable to capture BS effect, TOT_t = terms of trade, NFA = net foreign assets, INTDIFF = interest rate differential, GOVEX = government expenditure, and POP = population age structure variables. The following section empirically estimates and analyses the model.

5. Sample, data and estimation

A panel of 23 OECD countries⁴ is selected based on the availability of data. The study covers a period of 30 years, from 1980 to 2015⁵. However, some observations on some variables are missing and as such we estimate an unbalanced panel data model. Two measures of productivity are used to proxy for productivity differential: GDPGR and per capita GDP growth rate (PCGDPGR). TOT is the net barter or commodity TOT, which is the ratio of the export price index to the import price index. Log of real effective exchange rate index (LNRER) and terms of trade index (LNTOT) are used in the analyses. Difficulty arises in selecting INTDIFF variable. As there is no unique interest rate that can be termed as world interest rate, the variable poses a problem as to what rate should be taken as a proxy for it. Theoretically, the world interest rate is given for a small open economy, that is, a small open economy cannot influence this rate. All small open economies are affected by a change in the world interest rate. From this point of view, the real interest rate of the USA is taken as a proxy for the world interest rate, because any change/shock in the US economy affects other countries in the world. For this reason, the USA economy is used in the analysis of the large open economy textbook model (for example Mankiw 2007). NFA and GOVEX are measured as a percentage of GDP.

With regard to population structure, the following demographic variables are used:

- i. YDEP: young dependency ratio (% of working-age population)
- ii. ODEP: old dependency ratio (% of working-age population)
- iii. OAPOP: old age population (65 years and above) as a percentage of the total population
- iv. YAPOP: young age population (0–14 years old) as a percentage of the total population
- v. WAPOP: working-age population (15–65 years) as a percentage of total population

Before estimating the regression, careful attention is given to identify all possible time-series properties of the data set. First of all, we examine whether there is any cross-sectional dependence (CD) in the data set. It is possible that a common shock affects all the cross-section units in the sample. Presence of CD reduces the reliability of panel unit root tests. We employ the general diagnostic test for CD in panels proposed by Pesaran (2004). Appendix Table 5 reports CD test results. The results reject the null of cross-sectional independence at 1% significance level.

Having being confirmed the CD, the analysis next proceeds to check the stationarity properties of the variables. Several methods have been proposed to test stationarity in panel data among which three methods are widely used: Im et al. (2003) [hereafter IPS], Levin et al. (2002) [hereafter LLC] and Maddala and Wu (1999) [hereafter MW]. However, both IPS and LLC require cross-sectional independence. Maddala and Wu (1999) find that the MW test is more robust than LLC and IPS tests to the violation of this assumption. However, MW test is not designed to directly address this problem. Pesaran (2007) proposed a new panel unit root test that allows the presence of cross-section dependence. We employ both MW and Pesaran (2007) tests. Before performing a panel unit root test, we make a visual inspection of the data to see if any series experiences an abrupt change in intercept or trend or both. We find that except Poland, variables in other countries do not exhibit any sign of significant structural change in intercept or trend or both. We, therefore, exclude this country from panel unit root tests and report the results for 22 countries in Table 1 below. Since we are using annual data, one lag is used in the test procedure.

The results show that all series, except GOVEX and NFA, are $I(0)$ under both tests. GOVEX is $I(1)$ under Pesaran (2007) and $I(0)$ under the MW test, while NFA is $I(1)$ under both the tests⁶. As Pesaran's (2007) test directly addresses the cross-section dependence issue, we accept the results given by this test and exclude GOVEX and NFA from the model as they are integrated to a different order.

Before we proceed further some observations are in order. Both Pesaran (2007) and the MW test indicate that the real exchange rate is $I(0)$. This result bears significant relevance to the PPP literature. The PPP theory states that the real exchange rate is mean-reverting, that is, any shock to it is temporary. However, Balassa (1964) and Samuelson (1964) note that differential in the relative productivity of tradable over non-tradable sector between countries induces the real exchange rate to deviate permanently from its equilibrium value. According to this BS effect the real exchange rate series should be a random walk. Table 1 shows that the real exchange rate is stationary, which implies productivity differential does not have any impact on it.

⁴Country list is given in Appendix Table 1.

⁵Data sources and definition of variables are given in Appendix 2 and descriptive statistics are given in Appendix Table 3.

⁶Unit root tests of GOVEX and NFA in their first differences are reported in Appendix Table 6.

Table 1. Panel unit root test

Variables	Pesaran (2007) panel unit root test		Maddala and Wu (1999) panel unit root test	
	Without trend	With trend	Without trend	With trend
LNRRER	-2.599*** (0.005)	-2.406*** (0.008)	63.918** (0.041)	61.420* (0.064)
LNTOT	-1.511* (0.065)	-2.419*** (0.008)	77.195*** (0.003)	64.267** (0.039)
GOVEX	2.054 (0.980)	2.532 (0.994)	65.561** (0.031)	58.996* (0.095)
NFA	0.249 (0.598)	0.740 (0.770)	39.830 (0.727)	43.103 (0.594)
INTDIFF	-3.009*** (0.001)	-6.337*** (0.000)	111.398*** (0.000)	77.762*** (0.002)
GDPGR	-4.566*** (0.000)	-3.558*** (0.000)	129.668*** (0.000)	97.164*** (0.000)
PCGDPGR	-3.804*** (0.000)	-3.139*** (0.001)	183.004*** (0.000)	138.757*** (0.000)
WAPOP	-16.793*** (0.000)	-14.662*** (0.000)	763.340*** (0.000)	956.974*** (0.000)
OAPOP	-6.261*** (0.000)	-6.610*** (0.000)	27.035 (0.979)	293.669*** (0.000)
OYPOP	-9.449*** (0.000)	-6.665*** (0.000)	120.534*** (0.000)	214.805*** (0.000)
ODEP	-12.131* (0.000)	-11.156* (0.000)	238.151* (0.000)	670.368* (0.000)
YDEP	-11.431* (0.000)	-11.156* (0.000)	790.363* (0.000)	851.325*** (0.000)

*** and ** indicate significant at 1%, 5%, and 10% levels.

LNRRER, log of real effective exchange rate index; LNTOT, terms of trade index; GOVEX, government expenditure; NFA, net foreign assets; INTDIFF, interest rate differential; GDPGR, real GDP growth rate; PCGDPGR, per capita GDP growth rate.

Our proxies for productivity are also $I(0)$, which implies the absence of any long-run cointegrating relation between the real exchange rate and productivity. This finding supports the PPP hypothesis and cast doubt on the BS effect on the real exchange rate. Based on unit root test results Eq (1) is re-specified as follows:

$$RER = f\left(\underset{+}{PRODUCTIVITY}, \underset{+}{TOT}, \underset{-}{INTDIFF}, \underset{+/-}{POP}\right) \quad (2)$$

With these unit root test results, we next proceed to estimate panel regression as specified in Eq (2) above. A panel regression equation may be specified as follows:

$$y_{it} = \mathbf{x}_{it}\beta_k + \mathbf{z}_i\delta + u_i + \varepsilon_{it} \quad (3)$$

In this equation i , t , and k represent cross-section unit identifier, time period and number of independent variables respectively, y is a dependent variable. x_{it} is a $1 \times k$ vector of independent variables and β is the associated vector of coefficients. z is the vector of factors that vary over the individual; however, remain constant over time and δ is the vector of coefficients on z . Finally, u_i is the cross-section unit level effect and ε_{it} is the error term. If the u_i are correlated with the regressor in x_{it} , then the above panel equation is called FE model; however, if the u_i are uncorrelated with the regressor, then the equation is called random effect (RE) model. A practical problem that we encounter at this stage is to decide whether we should estimate FE or RE model. To resolve this issue we perform specification test proposed by Hausman (1978).

The null hypothesis of Hausman test states that the RE is the appropriate model, which implies the u_i and the regressors in x_{it} are uncorrelated, that is, $Cov(u_i, x_{it})=0$. The alternative hypothesis of the test is that the FE model is the appropriate model, which implies the u_i and the regressor in x_{it} are correlated, that is, $Cov(u_i, x_{it}) \neq 0$.

The formula to calculate the Hausman test statistic is as follows:

$$H = (\hat{\beta}^{RE} - \hat{\beta}^{FE})' [Var(\hat{\beta}^{RE}) - Var(\hat{\beta}^{FE})]^{-1} (\hat{\beta}^{RE} - \hat{\beta}^{FE}) \quad (4)$$

where $\hat{\beta}^{RE}$ and $\hat{\beta}^{FE}$ are vectors of estimated coefficients on x from RE and FE model. Under the null hypothesis, the test statistic is distributed as $\chi^2(k)$, where k is the number of independent variables. Hausman test conducted with our data turns out to be highly significant rejecting the null of the RE model⁷. Accordingly, we estimate the FE model and report the results in Table 2.

In the estimation process, we incorporate demographic variables in two different phases. First, we incorporate old and young dependents as a percentage of the working-age population (Model 1). In the second phase, we incorporate old and working-age population as a percentage of total population (Model 3)⁸. Results in Model 1 shows that young dependents have a significant depreciating impact on the real exchange rate, while the impact of old dependents is not significant. However, the Durbin-Watson statistic (0.7520) indicates that this model suffers from significant serial correlation. This is removed by adding two autoregressive terms as indicated by the Durbin-Watson test statistic of 2.04 in Model 2. Similarly, two autoregressive terms are added in Model 3 to get rid of serial correlation.

Estimation results of Model 2 show that young dependents have a depreciating effect on the real exchange rate. Consumption of non-traded goods by this group, such as, education, health care etc. results in higher prices of non-traded relative to traded goods, which causes the real exchange rate to depreciate. This finding is in contrast with Andersson and Österholm (2006), who document appreciating effect of the young cohort. However, Andersson and Österholm (2006) consider the population

Table 2. Estimation results of the fixed effect model

	Model 1	Model 2	Model 3
LNRER ₁		0.89915*** (0.07095)	0.89646*** (0.0709)
LNRER ₂		-0.30746*** (0.06856)	-0.30907*** (0.06847)
GDPGR	0.00032 (0.00111)	0.00058 (0.00076)	0.000584 (0.00076)
LNTOT	0.41872*** (0.05627)	0.15321*** (0.04346)	0.15531*** (0.04306)
INTDIFF	-0.00538*** (0.00089)	-0.00243*** (0.00064)	-0.00243*** (0.00064)
ODEP	0.00163 (0.00137)	0.00031 (0.00094)	
YDEP	-0.01402*** (0.00264)	-0.00563*** (0.00189)	
OAPOP			0.00923*** (0.00281)
WAPOP			0.01029*** (0.00353)
Constant	1.43287*** (0.17922)	0.63689*** (0.13667)	-0.33075 (0.23045)
Adjusted R^2	0.67	0.85	0.85
F-stat (p -value)	17.1860 (0.000)	42.6336 (0.000)	42.8077 (0.000)
Durbin-Watson statistic	0.7510	2.03	2.03

***, ** and * indicate significant at 1%, 5% and 10% levels

LNRER, log of real effective exchange rate index; GDPGR, real GDP growth rate; LNTOT, terms of trade index; INTDIFF, interest rate differential.

⁷Results are not reported to save space; however, available upon request.

⁸Three population cohorts add up to unity, so we cannot include all three in one regression. Adding all three will create the problem of perfect multi-collinearity. So we add only two based on least pair-wise correlation. Appendix Table 7 reports pair-wise correlation among these three cohorts.

aged between 15 to 24 years as young, while we consider a dependency ratio of 0 to 15 years aged population. Clearly, young population considered in our sample consume more non-tradeable than those considered in Andersson and Österholm (2006). Impact of old dependents is statistically zero. This may be due to a couple of reasons. As discussed above, older population may have either depreciating or appreciating effect, so this insignificant impact may result from the workings of those two opposite channels. Since old dependents variable in Model 2 is the size of the older population relative to the working-age population, another possibility is that the magnitude of the impact of older population may be quite small relative to the working-age population. We find some support for this view in the estimation results of Model 3, where the impact of the working-age population on the real exchange rate is much higher than that of the old age population.

In Model 3, both working age and old age population cohort exhibit significant appreciating effects on the real exchange rate. Our finding with regard to old age cohort is consistent with Andersson and Österholm (2005 & 2006). This cohort is not productive and run down saving, leading to capital inflow and exchange rate appreciation. However, our finding does not support Mirer (1979), Danziger et al. (1982), Palumbo (1999) and De Nardi et al. (2006 & 2009), who argue that older people are likely to increase saving.

Among other determinants of the real exchange rate, TOT and INTDIFF have a significant impact, while the GDP growth rate is found to have no significant impact. TOT have appreciating effect on the real exchange rate, which indicates that the income effect is stronger than the substitution effect. This result is in line with Elbadawi and Soto (1994). INTDIFF has a significant depreciating impact on the real exchange rate. Higher INTDIFF (i.e., world rate–domestic rate) causes capital to flow out and real exchange rate to depreciate.

Finally, we estimate the FE model incorporating initially excluded GOVEX and net foreign asset variables. The results (reported in Appendix Table 8) show that GOVEX has a depreciating effect on the real exchange rate, while net foreign asset does not have any effect. Inclusion of these variables does not affect previous estimations results (Model 2 & 3) significantly.

6. Conclusion

The objective of this paper has been to examine the impact of population age structure on the real exchange rate in 22 OECD countries. Four demographic variables are used, namely, young dependents, old dependents, the old population as a percentage of the total population and working-age population as a percentage of the total population. Other control variables included are GDP growth rate, trade (percentage of GDP), the log of TOT, and INTDIFF. Based on the Hausman test we estimate a fixed-effect model. Estimation results show that young dependents, through their demand for non-traded goods, exert a depreciating effect on the real exchange rate. Increase in the share of older people in the population put negative pressure on domestic saving, leading to capital inflow and real appreciation. Share of the working-age population is found to have an appreciating effect on the real exchange rate. This is because an increase in the working-age population raises the marginal product of capital, which attracts investment causing capital inflow and real appreciation. Among control variables, TOT and INTDIFF are found to have significant and expected effects on the real exchange rate.

Our findings have significant policy implications for the developed economies, which are experiencing rapid population ageing. An ageing population will have an adverse effect on the international competitiveness of OECD countries through its appreciating effect on the real exchange rate. To face this adverse effect of population ageing governments may adopt a policy to save more for the future, such as, by reducing/increasing budget deficit/surplus, reducing tax-free threshold income level, or increasing the effective retirement age.

We find that ageing causes a real appreciation of the exchange rate in the OECD countries. However, in many non-OECD countries where population growth is significant, and ageing is not a major issue of concern, for example, developing or emerging countries. Thus, the limitation of this paper is non-inclusion of those non-OECD countries where ageing may lead to a real depreciation, and this limitation is expected to overcome in future research.

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Appendix

Appendix Table 1. Country list

1. Australia	13. Japan
2. Belgium	14. Korea Republic
3. Canada	15. Netherlands
4. Czech Republic	16. New Zealand
5. Denmark	17. Norway
6. Finland	18. Poland
7. France	19. Portugal
8. Germany	20. Spain
9. Greece	21. Sweden
10. Hungary	22. Switzerland
11. Ireland	23. United Kingdom
12. Italy	

Appendix 2. Data sources and definition of variables

Sources of data

The prime source of data is *World Development Indicators (WDI)-2016*, published by the World Bank. Where data are not available in WDI-2016, other sources have also been used such as *Thomson Datastream*, *OECD.Stat*. Variable specific sources of data are discussed below:

(i) Real effective exchange rate (REER): Real effective exchange rate data are collected from WDI-2016. The base year for the nominal exchange rate (NER) is 2000 and weights for other currencies are given on the basis of trade in manufacturing goods. REER index is calculated from the NER and a cost indicator of relative normalized unit labour cost in manufacturing. An increase in the REER index represents an appreciation of the local currency.

REER data for Korea republic are not available in WDI. REER for Korea is calculated using data from *OECD.Stat*. In calculating REER from NEER, consumer price index and producer price index for manufacturing are used as a proxy for domestic and foreign price levels respectively.

(ii) Terms of trade (TOT): Terms of trade data on the sample countries (except the Czech Republic, Finland and Switzerland) are taken from WDI-2016. It is net barter or commodity terms of trade, which is the ratio of the export price index to the import price index. For the Czech Republic, Finland and Switzerland, TOT data have been collected from Thomson Datastream, however, the original source of these data is *Economist Intelligent Unit* as reported in Datastream.

(iii) Net Foreign Assets (NFA): Net foreign assets data on all countries are collected from WDI-2016. NFA is the sum of foreign assets held by monetary authorities and deposit money banks, less their foreign liabilities. NFA is reported in local currencies. In the estimation procedure, it has been measured as a percentage of Gross Domestic Product (GDP). The benefits of this conversion are twofold: first, the NFA data are uniform across countries, as all are measured as a percentage of GDP; second, conversion of national currency into Euro in 1999 in some of the OECD countries changes the NFA figures to a great extent. This problem has been eliminated by converting them into a percentage of GDP form.

(iv) Government Expenditure (GOVEX): Government expenditure data are also taken from WDI-2016 and expressed as a percentage of GDP. General government final consumption expenditure includes all government current expenditures for purchases of goods and services (including compensation of employees). It also includes most expenditure on national defence and security but excludes government military expenditures that are part of government capital formation.

(v) Interest rate differential (INTDIFF): Interest rate differential is calculated as the difference between the US and individual country's real lending interest rate. These are collected from WDI-2016. To get the real lending interest rate, the nominal lending interest rate is adjusted for inflation as measured by the GDP deflator.

(vi) Demographic variables: Data on demographic variables are also collected from WDI-2016.

Appendix Table 3. Descriptive statistics

Variables		Mean	Standard deviation	Observations
GDPGR	Overall	2.3079	2.6978	768
	Between		1.1116	
	Within		2.4522	
PCGDPGR	Overall	1.7652	2.6313	768
	Between		0.9600	
	Within		2.4531	
LNRER	Overall	1.9799	0.0629	735
	Between		0.0452	
	Within		0.0471	
LNTOT	Overall	2.0012	0.0797	350
	Between		0.0544	
	Within		0.0605	
WAPOP	Overall	66.6475	2.0878	792
	Between		1.3516	
	Within		1.6165	
OAPOP	Overall	14.5701	3.8618	792
	Between		2.4227	
	Within		2.1209	
YAPOP	Overall	18.7823	3.3766	792
	Between		2.2368	
	Within		2.5728	
YDEP	Overall	28.2756	5.6344	792
	Between		3.5996	
	Within		4.4002	
ODEP	Overall	21.9156	4.9981	792
	Between		3.8091	
	Within		3.3346	

GDPGR, real GDP growth rate; PCGDPGR, per capita GDP growth rate; LNRER, log of real effective exchange rate index; LNTOT, terms of trade index.

Appendix Table 4. Percentage of population aged 65 and over

Country	Year									Percentage points change from 2010 to 2050
	2010	2015	2020	2025	2030	2035	2040	2045	2050	
Australia	13.9	15.7	17.3	19.1	20.7	21.9	22.9	23.3	23.8	9.9
Belgium	17.4	18.8	20.3	22.2	24.1	25.5	26.3	26.5	26.6	9.2
Canada	14.1	16	18.1	20.5	22.7	23.8	24.5	25	25.5	11.4
Czech Repub	15.3	17.5	19.5	20.5	21.4	22.3	24.4	26.7	27.6	12.3
Denmark	16.7	18.8	20.1	21.3	22.7	23.9	24.7	24.6	23.8	7.1
Finland	17.2	20.2	22.3	23.9	25.1	25.7	25.5	25.6	25.9	8.7
France	17	19.1	20.9	22.6	24.3	25.5	26.5	26.6	26.9	9.9
Germany	20.5	21.3	23	25.1	28.2	31	31.8	32.1	32.5	12
Greece	18.3	19.5	20.7	22.4	24	26.2	28.3	30.2	31.3	13
Hungary	16.4	17.4	19.3	20.3	20.4	21.2	22.8	25.1	26.1	9.7
Ireland	11.4	12.5	13.8	15.1	16.7	18.3	20.3	22.6	24.2	12.8
Italy	20.4	21.9	23	24.4	26.8	29.4	31.8	33.1	33.3	12.9
Japan	22.6	26.3	28.5	29.7	30.8	32.5	35.1	36.8	37.8	15.2
Korea Repub	11	13	15.4	19.3	23.2	26.8	30.2	32.2	34.2	23.2
Netherlands	15.4	17.8	19.7	21.7	23.8	25.6	26.3	26	25.6	10.2
New Zealand	13	14.5	16	18.1	20.3	21.8	22.5	22.7	23.2	10.2
Norway	15	16.6	18	19.4	20.7	22.3	23.4	23.7	23.8	8.8
Poland	13.5	15.4	18.3	21	22.4	23	24.5	26.9	29.9	16.4
Portugal	17.8	19.1	20.6	22.3	24.5	26.4	28.8	30.9	32.1	14.3
Spain	17.2	17.8	18.7	20.4	22.7	25.4	28.1	30.7	31.8	14.6
Sweden	18.3	20.1	21	21.7	22.6	23.6	24.1	24.1	24.1	5.8
Switzerland	17.3	18.8	20.2	21.9	24.1	25.7	26.3	26.2	26	8.7
UK	16.6	17.9	18.5	19.4	20.9	22.1	22.6	22.6	22.9	6.3
Average	16.36	18.08	19.70	21.40	23.20	24.78	26.16	27.14	27.80	11.44

Source: World Population Prospect: 2008 Revision, United Nations (last column and last row are the authors' own calculations).

Appendix Table 5. Pesaran's (2004) cross-sectional dependence (CD) test

Series	CD test statistic	Correlation	Series	CD test statistic	Correlation
LNRER	14.06* (0.000)	0.427	GDPGR	16.53* (0.000)	0.382
LNTOT	3.65* (0.000)	0.577	PCGDPGR	17.55* (0.000)	0.397
GOVEX	6.57* (0.000)	0.437	INTDIFF	30.23* (0.000)	0.531
NFA	3.63* (0.000)	0.483			

LNRER, log of real effective exchange rate index; LNTOT, terms of trade index; GOVEX, government expenditure; NFA, net foreign assets; GDPGR, real GDP growth rate; PCGDPGR, per capita GDP growth rate; INTDIFF, interest rate differential.

Appendix Table 6. Panel unit root test for $\Delta govex$ and Δnfa

Variables	Pesaran (2007) panel unit root test		Maddala and Wu (1999) Panel Unit Root test	
	Without trend	With trend	Without trend	With trend
$\Delta GOVEX$	-4.384* (0.000)	-4.108* (0.000)		
ΔNFA	-3.909* (0.000)	-2.378* (0.003)	163.221* (0.000)	127.243* (0.000)

* Indicates significant at 1% levels.

GOVEX, government expenditure; NFA, net foreign assets.

Appendix Table 7. Correlations among the independent variables

	<i>WAPOP</i>	<i>OAPOP</i>	<i>YAPOP</i>
<i>WAPOP</i>	1		
<i>OAPOP</i>	-20.84	1	
<i>YAPOP</i>	-42.35	-79.77	1

Appendix Table 8. Estimation results of fixed effect model with government expenditures (GOVEX) and net foreign assets (NFA)

	Model 1	Model 2	Model 3
LNRER ₋₁		0.8481*** (0.0713)	0.8469*** (0.0712)
LNRER ₋₂		-0.3073*** (0.0662)	-0.3108*** (0.0663)
GDPGR	-0.00030 (0.00116)	0.000417 (0.0008)	0.000431 (0.0008)
LNTOT	0.3864*** (0.06261)	0.1538*** (0.04711)	0.1563*** (0.0468)
INTDIFF	-0.0068*** (0.00093)	-0.00333*** (0.00069)	-0.000333*** (0.00069)
GOVEX	-0.00931*** (0.00254)	-0.00553** (0.00179)	-0.00551*** (0.00178)
NFA	-0.00045 (0.00035)	-0.00027 (0.00024)	-0.00029 (0.00024)
ODEP	0.00258** (0.00138)	0.00094 (0.0010)	
YDEP	-0.01777*** (0.00271)	-0.00812*** (0.00204)	
OAPOP			0.01387*** (0.00032)
WAPOP			0.01443*** (0.0038)
Constant	1.7626*** (0.20531)	0.8888*** (0.1639)	-0.4795** (0.2391)
Adjusted R ²	0.7145	0.8854	0.8857
F-stat (<i>p</i> -value)	18.42 (0.000)	42.37 (0.000)	42.51 (0.000)
Durbin-Watson statistic	0.8940	2.13	2.13

Source: Authors' calculation.

We estimate a fixed effect model incorporating all variables⁹ and the results are reported in the above Table. However, we did not report this in the text of the manuscript. As we can see from the above table that government expenditure has a depreciating effect on the real exchange rate, while net foreign asset does not have any effect. Inclusion of these variables does not affect previous estimations results (Model 2 & 3) significantly. Therefore, we may argue that there is no omitting variable bias in our reported results in the manuscript.

LNRER, log of real effective exchange rate index; GDPGR, real GDP growth rate; LNTOT, terms of trade index; INTDIFF, interest rate differential; GOVEX, government expenditure; NFA, net foreign assets

⁹ We excluded government expenditure and net foreign asset variables from our initial estimation and the reasons for exclusion are explained in the manuscript.