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Effects of Demographic Change on Economic Growth: A Panel ARDL Approach for Selected OECD Countries

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Abstract

The changing population dynamics have substantial impact on economy. This paper investigates the effects of demographic change on economic growth. The share of working age population, child dependency ratio, old-age dependency ratio and age dependency ratio are used as demographic variables. The effects of these variables on the gross domestic product per capita growth rate are examined for the OECD countries covering the period 1970–2021. Four different models are estimated by using panel ARDL estimation method. The findings derived from the estimated models point out that the old-age dependency ratio and age dependency ratio have negative effects on economic growth. On the other hand, the share of working age population has a positive effect on economic growth. These results suggest that demographic change causing an increase in the dependency ratio and a decrease in the share of working age population will have adverse impacts on economic performance in the long run.

Keywords: demographic change, economic growth, panel ARDL

JEL Codes: J11, O47, C33

1. Introduction

The world population is growing more slowly than before and aging at an unusual speed. Today, the world's population is more than three times larger than it was in the mid-twentieth century. The global human population reached 8.0 billion in November 2022 from an estimated 2.5 billion people in 1950. Since the middle of the twentieth century, the rate of population growth has slowed by more than half because of the reduced levels of fertility. Today, the share of people aged 15 to 64 (the typical working age population) is starting to fall and the share of the elderly is increasing. The slower population growth and population aging have been formed by a certain decline in fertility rates and a rapid increase in life expectancy.

The demographic change is described as the transformation of societies from pre-industrial high fertility and mortality rates to post-industrial low fertility and mortality rates. Declines in mortality (especially infant and child mortality) have been observed at the first stages of demographic changes, and thus the age structure has been strongly affected. The increasing survivor rates for children have induced parents to reduce their fertility (Williamson, 2003). In addition, another factor that triggers the decline in fertility rates is social change, in other words, new lifestyles created by the modernization process. Decreases in mortality and morbidity rates increase life expectancy and this increases the share of the elderly in the total population.

Depending on the increase in the share of the elderly, the share of dependents also increases. The continued decline in fertility rates and the rapid improvement in life expectancy have led to slower population growth, which has caused population aging. Different countries and regions are placed at different stages of demographic change. The most developed countries have already begun to experience the aging process. Besides, many developing countries, e.g., in Southeast Asia, Central and Eastern Europe are expected to see population aging.

The relationship between population growth and the economy has long been the subject of debate among politicians and academics. Thomas Malthus, in his *Essay on the Principle of Population* published in 1798, argued that the rate of population growth was held in equilibrium by the pace of economic growth. According to Malthus, if population increased too fast, wages would fall. This, in turn, would cause famine or disease, increasing mortality rates, and marriage, and therefore, childbearing would be delayed. Then, a new economic expansion and consequent increase in welfare would increase fertility and the population would then rise rapidly to its new equilibrium. In the words of Malthus (1798):

"We will suppose the means of subsistence in any country just equal to the easy support of its inhabitants. The constant effort towards population, which is found to act even

in the most vicious societies, increases the number of people before the means of subsistence are increased. The food, therefore, which before supported eleven million, must now be divided among eleven million and a half. The poor consequently must live much worse, and many of them be reduced to severe distress. . . During this season of distress, the discouragements to marriage and the difficulty of rearing a family are so great that the progress of population is retarded."

Today, contrary to Malthus' theories, economic prosperity has increased all over the world, fertility rates have fallen, life expectancy keeps increasing, and thus, population growth has slowed down, causing population aging (IMF, 2004). Malthus was writing his book in a specific historical era. It was the time when a new revolution was taking place in England: the industrial revolution. For the first time in history, the living standards of a significant number of people had increased dramatically. Empirical studies in recent years have shown that increases in per capita income tend to decrease fertility, except in very poor countries and families. Although empirical studies do not confirm Malthus' predictions, these studies have presented significant relations between socio-economic variables (such as per capita income, wage rates, education levels of persons and urbanization) and fertility-mortality rates (Wahl, 1986; Behrman and Taubman, 1990; Schultz, 2007; Bilgin and Kaynar Bilgin, 2017). Therefore, it seems inappropriate to perceive the population growth as an exogenous factor to economic growth analysis.

Cross-country data reveal that there is a relation between fertility rates and economic growth rates. In many countries, the fertility rate tends to decline with increases in GDP per capita. Yet, the fertility rate in the poorest countries may increase with GDP per capita as Malthus predicted. On the other hand, the relations between education level and fertility have turned out to be stronger. Except in the most developed countries' experience, women's education level is negatively correlated with fertility rate and men's education level is positively correlated with fertility rate. As economy grows, over time the eventual effect of these factors would be a decreasing tendency of fertility rate and thus population growth rate. Hence, the assumption of exogenous population growth in economic growth analysis seems to contradict the applied studies (Barro and Sala-i-Martin, 2004).

Changes in the age structure of a population would have an impact on economic growth since labour supply and savings change with lifespan. An increase in life expectancy tends to raise labour supply levels and saving rates. Besides, any decline in fertility rates has the potential to increase female labour supply. Moreover, economic effects of individuals change with their phases of life. In the short term right after birth, an individual has a negative effect; it might be said that children are net "resource users". In the later stages of their lifespan,

they have a positive economic impact; working adults become "resource creators" (Kelley and Schmidt, 1995). Economic growth of countries with a high rate of children in general population would be slowing because they allocate a substantial amount of their resources to care for children. On the other hand, if the majority of a country's population is made of working age individuals, it generates additional productivity for the society. Selecting and imposing appropriate socio-economic policies together with this higher rate of productivity creates a "demographic dividend" in the process of economic growth. The collective effect of the bigger size of the working age population and proper policies regarding health, family, labour, finance and human capital generates productive cycles in wealth creation. However, if the share of the elderly in a country's population is large, the economic effect of this age structure would be very similar to the those in countries having a very young population. Being a relatively less productive group, the elderly are more likely to be resource users so that this situation would slow down economic growth (Bloom et al., 2001).

According to Lee and Mason (2006), countries experiencing falling fertility rates benefit from two types of demographic dividends. At the early phase of demographic change, a falling fertility rate implies fewer young individuals to care for. With lower mortality rates and fertility rates, this period makes the labour force increase substantially. In this case, there would be more resources to invest in economic development. Under these circumstances, the growth rate of income per capita increases. This is defined as the first dividend. This dividend period carries on for five decades or more, but eventually lower fertility rate and mortality rate slow down the growth rate of the labour force since the share of the elderly in the population is now growing. Thus, the income per capita growth rate decreases, and the first dividend becomes negative. A country having a higher working age and a lengthy retirement period induces people to amass assets if they are not sure that their needs will be provided for by families or governments. These added assets lead to rises in national income. This is the second demographic dividend. The first dividend has a transitory nature but the second one promotes sustainable development by supplying greater assets for the economy. According to Bloom and Canning (2004), increases in life expectancy rates lead people to save more under the conditions of a well-regulated and efficient financial sector. These savings must then be invested in a way that benefits the economy.

The positive effect of the "demographic dividend" on economy should not be taken for granted. In other words, economic growth is not a natural result of changes in the population age structure. If the demographic dividend is to be benefited from in economic terms, large labour supply is to be absorbed by labour demand. Otherwise, an excessive labour supply may occur if proper policies are not implemented. This situation might create political in-

stability. The crime rate can increase, and thus social capital might be destroyed. Whether a country benefits from demographic opportunity depends on the resilience of its economy and the country's capability of creating jobs to accommodate the increasing labour supply. Latin America has a demographic history that is similar to that of East Asia, but the East Asian region has experienced strong economic growth, while the Latin American region could not exhibit similar economic performance and it has stagnated for a long time (Bloom and Canning, 2004).

An increase in the share of the working age population can provide an opportunity for economic growth. Declining dependency rates cause more available resources, which can be used as new investments in education, health, employment, social protection or retirement plans. This improvement reinforces short and medium-term economic growth and promotes prosperity.

Projected demographic changes are expected to have a significant impact on the economies of developed and developing countries in near future. In advanced economies, the negative effect of population aging on savings will deteriorate their current account balances. When it comes to developing countries, demographic change is expected to improve the current account balances of countries in Africa and the Middle East, while it worsens the balances in Central and Eastern Europe. Besides, projections suggest that the demographic change in developed countries will decrease the growth rate of real GDP per capita by 0.6 percentage points while the demographic change in Africa will increase the growth rate of income per capita by 0.3 percentage points between 2000 and 2050 (IMF, 2004).

This paper analyses the effects of demographic change on economic growth for selected OECD countries covering the period 1970–2021. The share of working age population, child dependency ratio, old-age dependency ratio and age dependency ratio are used as demographic variables. We mainly examine the effects of these variables on the gross domestic product per capita growth rate. The economic variables such as trade openness and gross fixed capital formation are used as control variables in the estimated models. The definitions and properties of these variables are explained clearly in the next sections.

2. Literature Review

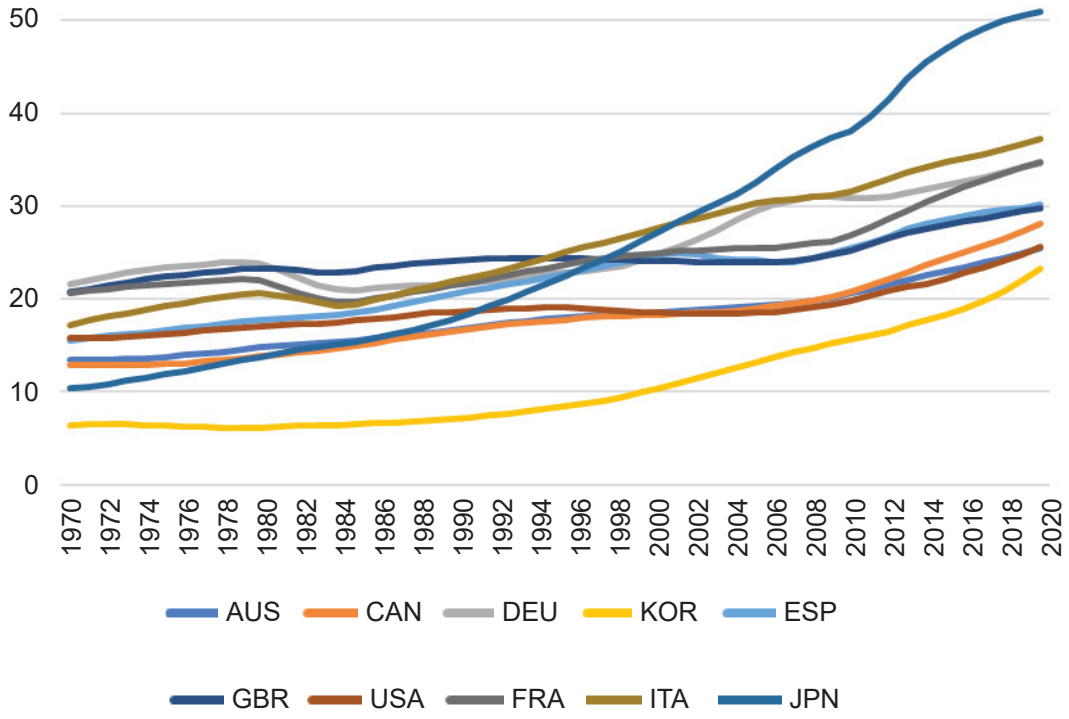
In examining the effects of demographic change on economic growth, there have been numerous studies attempting to derive empirical results to explain the relationship between demographic change and economic performance. One of them, Bloom and Williamson (1998) used sample data for 78 countries covering the period 1965–1990. The results of their analysis suggest that the growth of working age population has a powerful positive impact on GDP per

capita growth. In addition, the results put forward that the increase in the child dependency ratio decreases the per capita income. Bloom and Canning (2004) analysed the relation by using data covering the period 1870–1988 for a cross-section of countries. This study suggested that the steady-state level of income per capita is higher if the ratio of workers per capita is higher. The evidence derived from the analysis suggests that interactions among income levels, demographic changes and capital accumulation may be fairly strong. Kelley and Schmidt (2005) used data covering 86 countries and four growth periods (1960–70, 1970–80, 1980–90, 1990–95), resulting in a panel with 344 observations. They found that demographic change caused by declining birth and death rates has a positive effect on the GDP per capita growth rate. The impacts of demographic change account for 20% of the per capita output growth. The impacts are larger in Asia and Europe. Bloom et al. (2007) used cross-sectional country data for the period 1960–1980 and estimated the economic growth model parameters. They examined whether model forecasts for the new future are improved by including age structure. They found that the inclusion of age structure promotes forecasting. Cruz and Ahmed (2018) analysed how economic growth and poverty are affected by demographic change. The share of working age population and dependency ratios are important indicators of demographic change and were therefore selected for the analysis. Data for 180 countries for the period 1950–2010 were used in the estimation. They estimated the effects of changes in the share of working age population on the per capita income growth rate and poverty rate. Their findings point out that an increase in the working age population and a decrease in the child dependency ratio have a positive effect on the gross domestic product per capita growth and a negative effect on the poverty rate. Bawazir et al. (2020) analysed the effects of demographic change on economic growth in the Middle East countries. The working age population is separated by age and gender to explain the distinct impacts on economic growth. The paper imposed static linear panel data models for 10 Middle East countries covering the period 1996–2016. It was found that young workers, middle-aged workers, senior workers, population growth rate and old-age dependency ratio have positive effects on economic growth. On the other hand, the youth dependency ratio has a negative effect on economic growth.

The working age population is a central concept in labour statistics. The working age population is defined as those aged 15 to 64. This indicator measures the share of the working age population in total population. Changes in the size of the working age population can significantly affect the labour market and economy. A growing working age population provides opportunities for economic growth, while a decrease can create problems for economic growth. Dependency ratios are defined as the ratios of the number of children (0–14 years old) and older persons (65 years or over) to the working age population (15–64 years

old). Changes in dependency ratios reflect the potential effects of changing age structures on social and economic development. According to OECD data, the oldest OECD country is Japan, which has an old-age dependency ratio of 52. By 2050, the old-age dependency ratio is expected to reach high values in Portugal (71.4), Korea (78.8), Greece (75.0), Japan (80.7), Spain (78.4) and Italy (74.4). Figure 1 shows the old-age dependency ratios of ten selected OECD countries. This graph indicates that from the 1970s to the 2020s, the old-age dependency ratios have substantially increased.

Figure 1: Old-age dependency ratios for selected countries (1970-2021)



Source: authors' calculations based on WDI database

The demographically youngest OECD countries are Mexico, Turkey, and Luxembourg, having old age to working age ratios of 13.2, 15.2 and 22.3 respectively. Still, these countries are also expected to age significantly by 2080. The old-age ratio is expected to rise to 50.9 in Mexico, 58.2 in Turkey and 50.1 Luxembourg (OECD, 2021). The ratio of children (under 15 years of age) to the total population in OECD countries has tended to decline since the second half of the 20th century. While the average child dependency rate in OECD countries was 46% in 1970, this rate dropped to 25% by 2021. As a result of falling fertility rates, child dependency rates are falling both within the household and within the population.

3. Data, Methodology and Model Specification

We use annual data for the OECD member countries covering 52 years from 1970 to 2021. 25 OECD countries are selected because of the data availability problems for the whole sample period. The countries are Australia, Austria, Belgium, Canada, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Italy, Japan, Luxembourg, the Netherlands, New Zealand, Norway, Portugal, the Republic of Korea, Spain, Sweden, Switzerland, Turkey, the United Kingdom and the United States of America. The economic variables are gathered from the World Development Indicators (WDI) and OECD databases, the demographic variables are derived from the United Nations Population Division database. Gross domestic product (GDP) per capita growth rate is defined as the dependent variable since it is considered one of the best measures of economic growth. The economic variables which are closely related to growth and so intended to be used as control variables in the models are the change in trade openness (TO), gross domestic saving growth rate (GDS) and foreign direct investment (FDI). The TO variable is the sum of exports and imports as a percentage share of GDP, and FDI is the net inflows of foreign investment as a share of GDP. Gross domestic savings in current prices are adjusted for the price changes so that gross domestic savings in real terms are obtained. Then, gross domestic saving growth rate is derived as a percentage change from these price-adjusted data. Studies on the determinants of economic growth have been examining the effects of TO and FDI on economic growth. The trade integration of countries into international markets is expected to have a positive effect on growth. FDI is also expected to stimulate growth by increasing physical capital stock and allowing technological transfer to host countries. Besides, economic growth is expected to be promoted by increasing saving rate, which supposedly stimulates investments. In fact, the main focus of the paper is to examine the effects of demographic change on economic growth. Therefore, the models include essential demographic indicators as explanatory variables: the child dependency ratio (CDR), the old-age dependency ratio (ODR), the age dependency ratio (ADR) and the working age population (WAP). All of these demographic variables directly reflect how and in which direction demographic structures of the countries change. The child dependency ratio (CDR) is the percentage ratio of the age group 0–14 to the age group 15–64. In other words, it is the ratio of the number of children to working age population in percentage terms. The second demographic variable is the old-age dependency ratio (ODR) and it is the percentage ratio of the age group 65+ to the age group 15–64, or the ratio of the number of old people to the number of working age persons. The third one is the age dependency ratio (ADR); it is the ratio of the sum of the age groups 0–14 and 65+ to the working age group (15–64). All of these demographic variables are theoretically expected to have negative effects on economic growth. The reason is that increases in the dependencies imply less productive workforce and thus

decrease in total product. The final demographic variable is the working age population (WAP); it is the percentage share of the age group 15–64 in general population. An increase in the WAP would be expected to have a positive effect on economic growth since it implies an increase in the share of productive population. Table 1 shows the descriptive statistics of the variables.

The average economic growth rate for all the countries and for the whole sample period is 2.00% even though there is a big gap between the minimum and maximum values. The mean trade openness change is 0.949 and the mean saving growth is 9.87%. The average values of the child dependency ratio, old-age dependency ratio and age dependency ratio are 31.5%, 21.3% and 52.8% respectively. Regarding the maximum and minimum values and the standard deviation value, the CDR is the most fluctuating demographic variable. The mean and the median values of the working age population are almost the same and its standard deviation value is fairly low.

Table1: Descriptive statistics of variables

Variable	Mean	Median	Minimum	Maximum	Std. dev.
GDP	2.007	1.972	–11.407	23.223	2.992
TO	0.949	0.825	–28.68	34.909	5.206
GDS	9.870	6.941	–39.139	214.25	15.98
FDI	2.467	1.53	–36.14	86.479	6.541
CDR	31.506	29.060	16.643	81.981	9.620
ODR	21.334	21.261	6.150	50.971	6.244
ADR	52.840	51.891	36.479	90.818	7.036
WAP	65.557	65.836	52.405	73.271	2.845

Source: authors' calculations

Table 2 is a correlation matrix for the variables. The table shows that there is a strong relation between WAP and ADR and between WAP and CDR. The correlation coefficient between ADR and CDR is also quite high.

Table 2: Correlation matrix of variables

	GDP	TO	GDS	FDI	CDR	ODR	ADR	WAP
GDP	1.000							
TO	0.221	1.000						
GDS	0.429	0.113	1.000					
FDI	0.112	0.087	0.0011	1.000				
CDR	0.239	0.00003	0.532	−0.066	1.000			
ODR	−0.294	0.0003	−0.410	0.0054	−0.680	1.000		
ADR	0.059	0.0002	0.352	−0.085	0.745	−0.019	1.000	
WAP	−0.049	0.0001	−0.342	0.083	−0.720	−0.012	−0.995	1.000

Source: authors' calculations

This research mainly aims to identify the effects of demographic variables on economic growth. Economic growth is also affected by the trade integration level and the national investment level. Therefore, we included these variables into the models as control variables.

The first of the general functional formulas of the models is below.

$$GDP = f\left(CDR, TO, \text{FDI}, GDS\right) \tag{1}$$

$$GDP_{it} = \beta_0 + \beta_1\left(CDR_{it}\right) + \beta_2\left(TO_{it}\right) + \beta_3\left(FDI_{it}\right) + \beta_4\left(GDS_{it}\right) + u_{it} \tag{2}$$

Here, i denotes the cross-sectional unit and t denotes the time periods. In this equation, we focus on the effect of the child dependency ratio on economic growth. The second general formula is:

$$GDP = f\left(ODR, TO, \text{FDI}, GDS\right) \tag{3}$$

$$GDP_{it} = \beta_0 + \beta_1\left(ODR_{it}\right) + \beta_2\left(TO_{it}\right) + \beta_3\left(FDI_{it}\right) + \beta_4\left(GDS_{it}\right) + u_{it} \tag{4}$$

In this equation, we examine mainly the effect of the old-age dependency ratio on economic growth. It is expected that an increase in this ratio would have a negative effect on economic growth. The third formula is:

$$GDP = f\left(ADR, TO, \text{FDI}, GDS\right) \tag{5}$$

$$GDP_{it} = \beta_0 + \beta_1\left(ADR_{it}\right) + \beta_2\left(TO_{it}\right) + \beta_3\left(FDI_{it}\right) + \beta_4\left(GDS_{it}\right) + u_{it} \tag{6}$$

It is expected that the ADR has a negative effect on economic growth, since it is the sum of the child and old-age dependency ratios. As such, it is a more general dependency ratio reflecting the impact of demographic change on economic growth.

The final formula of the model is:

$$GDP = f\left(WAP, TO, \text{FDI}, GDS\right) \tag{7}$$

$$GDP_{it} = \beta_0 + \beta_1\left(WAP_{it}\right) + \beta_2\left(TO_{it}\right) + \beta_3\left(FDI_{it}\right) + \beta_4\left(GDS_{it}\right) + u_{it} \tag{8}$$

The sign of the coefficient of the WAP variable is expected to be positive. An increase in the number of working age people would have a positive effect on economic growth.

For all of these equations, the general autoregressive distributed lag (ARDL) model is below.

$$\Delta GDP_{it} = \sum_{j=1}^{p} a_{ij} GDP_{j,t-j} + \sum_{j=0}^{q} \delta_{ij}^{'} X_{i,t-j} + \mu_i + \varepsilon_{it} \tag{9}$$

In this ARDL model, i and t denote cross sectional units and time periods respectively and j refers to optimal lags. X_{it} refers to independent variables. The independent variables are CDR, TO, FDI, GDS in the first model, ODR, TO, FDI, GDS in the second model, ADR, TO, FDI, GDS in the third model and WAP, TO, FDI, GDS in the fourth model.

The error correction formula of the model is below.

$$\Delta GDP_{it} = \varphi_i\left(GDP_{i,t-1} - \beta_i^{'} X_{it}\right) + \sum_{j=1}^{p-1} \Delta GDP_{i,t-j} + \sum_{j=0}^{q-1} \delta_{ij'}^{*} \Delta X_{i,t-j} + \mu_i + \varepsilon_{it} \tag{10}$$

In this equation, φ_i is the speed of adjustment and it measures how much of the deviations from the equilibrium are corrected in one period. This coefficient implies a long-run equilibrium between the dependent variable and the independent variables if it is negative and sta-

tistically significant. The long-run relation within this model is indicated by ($GDP_{i,t-1} - \beta_i^{'} X_{it}$) and it is called the error correction term. The vector $\beta_i^{'}$ within this ECT includes the long-run coefficients of the independent variables.

4. Empirical Results

A panel ARDL model is applied in the case of a mixture of *I*(1) and *I*(0) variables (Khan et al., 2020). In other words, some of the variables are stationary at level while others are stationary at difference. Therefore, the unit root tests are imposed for each variable used in the models. The unit root test results are indicated in Table 3.

The variables GDP, TO, FDI, GDS and CDR are stationary at level; they are *I*(0) variables. The variables of ODR, ADR and WAP are not stationary at level but they are stationary at first difference; they are *I*(1) variables.

Table 3: Unit root test results

Variable name	Levin, Lind and Chu	Im, Pesaran and Shin	ADF-Fisher
GDP per capita growth (GDP)	–24.30***	–22.97***	–20.13***
Change in trade openness (TO)	–34.29***	–31.74***	–25.42***
Foreign direct investment (FDI)	–10.88***	–10.40***	–9.974***
Gross domestic saving growth (GDS)	–21.84***	–20.03****	–18.01***
Child dependency ratio (CDR)	–29.58***	–23.99***	–17.63***
Old-age dependency ratio (ODR) **First difference of ODR**	11.17 –1.70**	4.95 –3.29***	6.18 –3.08***
Age dependency ratio (ADR) **First difference of ADR**	–2.15* –2.718***	–0.14 –2.71***	0.70 –6.50***
Working age population (WAP) **First difference of WAP**	–1.41* –2.38***	0.057 –2.52***	0.96 –2.42***

Notes: *, ** and *** refer to the rejection of the unit root hypothesis at the 10%, 5% and 1% significance levels respectively

Source: authors' calculations

The panel least squares estimation procedure does not seem to be a proper method since not all of the variables are stationary. Pesaran and Smith (1995) and Pesaran et al. (1999) suggested to use a panel ARDL model if the variables are not all *I(0)* but are *I(1)*.

Table 4 indicates the panel ARDL estimation results. We estimated four different models. For each model, the different types of demographic variables are used. Namely, Model 1 includes CDR, Model 2 includes ODR, Model 3 includes ADR and Model 4 includes WAP as an explanatory demographic variable. CDR, ODR, ADR and WAP are not used together within one model since they are population-based demographic indicators and there are strong correlations among them. Otherwise, we would face a multicollinearity problem in an estimation using all of them in one model. Therefore, the four distinct models are estimated separately, including these different demographic variables one by one.

Table 4 indicates the estimated long-run coefficients and short-run coefficients. ECT denotes the error correction term. Its estimated coefficients for each model are negative and statistically significant at 1%. This proves that there is a long-run equilibrium between the dependent variable and the independent variables for each model.

In Model 1, the estimated coefficient of ECT is −0.602 and its p-value is much less than 0.01. Thus, the ECT is statistically significant at 1%, suggesting that there is a long-run relationship between the dependent variable (GDP) and the independent variables (CDR, TO, FDI, GDS). As the speed of adjustment, approximately 60% of the deviation from the long-run equilibrium is corrected within one-period, proving cointegration between the variables. The estimated long-run coefficient for the variable CDR is −0.007, its sign is negative as we expected, but it is not statistically significant; the child dependency ratio does not seem to have any effect on economic growth.

The estimated long-run coefficients for the variables TO and GDS are statistically significant at 1% since the p-values for each coefficient are less than 0.01. Thus, we reject the null hypotheses which suggest that there is no effect of TO and GDS on economic growth at this level. The estimated coefficient of the variable TO is 0.067; a one-percentage point increase in TO leads a 0.06 percentage point increase in GDP per capita growth. Economic integration in global trade promotes economic growth in these 25 countries for the period 1970−2021. The estimated coefficient of GDS is 0.212; a one-percentage point increase in GDS growth increases GDP per capita growth by 0.21 percentage points. Increases in saving growth positively affect economic growth as we expected. The estimated coefficient of FDI is 0.026 and it is statistically significant at 5%. A one-percentage point increase in FDI share causes GDP per capita growth to increase by 0.02 percentage points.

Table 4: Estimated panel ARDL models

Model 1				Model 2			
Long-run equation				**Long-run equation**			
Variable	**Coefficient**	***t*-statistic**	***p*-value**	**Variable**	**Coefficient**	***t*-statistic**	***p*-value**
CDR	−0.007	0.37	0.707	ODR	−0.051	−3.02	0.002
TO	0.067	3.26	0.001	TO	0.074	3.39	0.000
FDI	0.026	2.23	0.025	FDI	0.030	2.49	0.012
GDS	0.212	14.7	0.000	GDS	0.189	14.3	0.000
Short-run equation				**Short-run equation**			
ECT	−0.602	−10.7	0.000	ECT	−0.592	−11.7	0.000
ΔGDP(−1)	−0.067	−2.09	0.036	ΔGDP(−1)	−0.066	−2.18	0.029
ΔCDR	0.049	0.28	0.777	ΔODR	0.751	2.88	0.004
ΔTO	0.075	3.48	0.000	ΔTO	0.074	3.55	0.000
ΔFDI	0.046	0.74	0.454	ΔFDI	0.046	0.75	0.449
ΔGDS	0.042	4.45	0.000	ΔGDS	0.051	5.46	0.000
C	0.236	2.13	0.033	C	0.646	3.32	0.000
Model 3				**Model 4**			
Long-run equation				**Long-run equation**			
Variable	**Coefficient**	***t*-statistic**	***p*-value**	**Variable**	**Coefficient**	***t*-statistic**	***p*-value**
ADR	−0.052	−3.21	0.001	WAP	0.125	3.42	0.000
TO	0.072	3.32	0.000	TO	0.074	3.37	0.000
FDI	0.024	1.95	0.050	FDI	0.023	1.89	0.058
GDS	0.206	15.3	0.000	GDS	0.201	15.1	0.000
Short-run equation				**Short-run equation**			
ECT	−0.596	−12.8	0.000	ECT	−0.597	−12.2	0.000
ΔGDP(−1)	−0.069	−2.27	0.022	ΔGDP(−1)	−0.066	−2.19	0.028
ΔADR	0.128	1.42	0.153	ΔWAP	−0.214	−0.98	0.325
ΔTO	0.074	3.51	0.000	ΔTO	0.074	3.49	0.000
ΔFDI	0.058	1.08	0.280	ΔFDI	0.059	1.10	0.270
ΔGDS	0.045	5.05	0.000	ΔGDS	0.046	5.17	0.000
C	1.709	8.28	0.000	C	−4.851	−13.9	0.000

Source: authors' calculations

In Model 2, the estimated coefficient of ECT is −0.592 and it is statistically significant at 1%. It is proved that there is a cointegration between the variables (GDP and ODR, TO, FDI, GDS). The estimated coefficients of ODR, TO and GDS are statistically significant at 1%, and the estimated coefficient of FDI is statically significant at 5%. The estimated coefficient of ODR is −0.051, suggesting that a one-percentage point increase in ODR causes a 0.05 percentage point decrease in GDP per capita growth. Increases in the old-age dependency ratio have a negative impact on economic growth since population aging leads to some loss in productive workforce. The other estimated long-run coefficients imply that trade openness, foreign direct investment and saving growth have a positive effect on economic growth.

Model 3 gives the estimated speed of adjustment as −0.596 and it is statistically significant at 1%. The result implies that there is a long-run relationship between the variables (GDP and ADR, TO, FDI, GDS). In Model 3, we take the age dependency ratio as the demographic variable. The estimated long-run coefficient for ADR is −0.052; a one-percentage point increase in ADR causes a 0.05 percentage point decrease in GDP per capita growth. This estimated coefficient is statistically significant at 1%. As expected theoretically, increases in the age dependency rate have a negative effect on economic growth. The other estimated long-run coefficients have similar properties: increases in TO, FDI and GDS have positive effects on GDP.

Finally, Model 4 uses working age population as the demographic variable. The estimated coefficient of ECT is −0.597, its p-value is 0.0000, which is less than 0.01. Thus, the coefficient is statistically significant at 1% and has a negative sign, once again suggesting that there is a cointegration between the variables (GDP and WAP, TO, FDI, GDS). The estimated long-run coefficient for WAP is 0.125; a one-percentage point increase in WAP causes a 0.12 percentage point increase in GDP per capita growth rate. Its p-value being less than 0.01, the coefficient is statistically significant at 1%. An increase in the working age population ratio has a positive effect on economic growth since the productive workforce rises. The other long-run estimated coefficients for the variables TO and GDS are 0.074 and 0.201 respectively and they are both statistically significant at 1%. Trade openness and saving growth rate have statistically significant positive effects on economic growth. The estimated coefficient of FDI is 0.023 and it is significant at 10%; there is a positive effect foreign direct investment on economic growth.

Finally, we examine the effects of economic growth on demographic variables. Four different panel ARDL equations are estimated by using four demographic variables as dependent variables in each model. The log of GDP per capita is defined as the explanatory variable for each model. We do not provide the full statistical tables for the estimated models since the main focus of this paper is the search for the effects of demographic variables on economic growth. The estimated long-run coefficients of GDP on CDR, ODR, ADR and WAP are −5.11, 1.51, 2.20, −0.87

and they are all statistically significant at 1%. For the period 1970–2021 and within the framework of the data for 25 countries, the results indicate that an increase in GDP per capita causes a decrease in CDR and WAP. A higher income level leads to lower fertility rate and so a lower child dependency. As the theory of demographic change argues, economic growth makes countries richer. With higher income, fertility rate decreases and life expectancy rate increases, causing population aging. A decrease in the working age share is accompanied by population aging. Thus, it can be said that aging populations in higher-income countries would generate increases in the age and old-age dependency rates and decreases in the share of working age people.

5. Conclusion

The world population growth rate is slowing down, and the population is aging. Declines in fertility rates and improvements in life expectancy are the causes of this lower growth and aging. Under these circumstances, working age population decreases and the old age dependency ratio increases. The resulting loss of productive workforce would have substantial effects on economic performance. This study attempted to examine the impacts of changes in age structure on economic performance.

The main purpose of the study was to examine the effects of demographic change on economic growth in the OECD countries. The share of working age population, child dependency ratio, old-age dependency ratio and age dependency ratio were used as demographic variables. We mainly examined the effects of these variables on the growth rate of gross domestic product per capita. For this purpose, four distinct models were estimated. Each model included one specific demographic variable separately.

The first of the estimated models, Model 1, included the child dependency ratio as the demographic variable. The old-age dependency ratio is used as the demographic variable in the Model 2 and the estimated model suggests that the old-age dependency ratio has a negative effect on economic growth. Model 3, using the age dependency ratio as the explanatory variable, gives a similar result, suggesting that the age dependency ratio negatively affects economic growth. The findings derived from the estimations point out that the old-age and age dependency ratios have negative impacts on economic performance. Increases in the dependency ratios imply decreases in productive workforce, leading to deteriorating effects on the economy. The demographic transition from higher fertility and mortality rates to lower fertility and mortality rates seems to have an adverse effect on economic performance in the long run.

On the one hand, Model 1 indicated that the child dependency ratio does not have any effect on economic growth. On the other hand, Models 2 and 3 give us nearly similar estimated

coefficient values for the variables of the old-age dependency ratio and the age dependency ratio. These coefficients are statistically significant and they have negative signs, implying their adverse effects on economic growth. This result implies that age dependency is dominated by old-age dependency. Therefore, it can be said that the OECD countries face challenges of aging populations in terms of stagnant economic growth rates. In other words, these countries have been experiencing the adverse effects of population aging on economic growth. The results of Model 4 point out that the working age population has a positive effect on economic growth. It should be noted that the working age share of the population is deemed to decrease in aging countries, causing slowdowns in economic growth rates. The findings suggest that countries which try to combat stagnant economic growth rates should find ways of overcoming population aging. For this purpose, the authorities need to impose necessary social and economic policies before the adverse effects of this demographic change become more serious. Within the context of increasing life expectancy, the retirement age is supposed to be raised and savings for longer periods of time should be encouraged. Thus, work duration would be extended and the needed funds for the long run would be generated. Besides, policies that increase women's labour force participation rates would mitigate the decrease in labour supply; in this case, the productive population share would be kept at a plausible level. For the increasing need for qualified workforce, it is essential to enhance education conditions for young generations. As a result, longer working time, plausible level of labour supply and qualified workforce, all in all, would promote economic growth under the negative conditions of population aging. In addition, the derived results from all of the estimated models reveal that trade openness, foreign direct investment and domestic savings have positive effects on economic growth. Increasing economic integration in global trade has a positive impact on the economies. As we expected, increases in the saving rate and foreign direct investment have a substantial positive effect on the economies.

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