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Population ageing, workers ageing and aggregate labour productivity in developing countries

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Abstract

Purpose – The ongoing demographic change has been changing the age structure of populations in developing countries, with far-reaching implications for economic growth and productivity. This study engages with the ongoing debate concerning whether an ageing population affects labour productivity, which is also a significant concern in changing workforce dynamics.

Design/methodology/approach – This study employs the cross-sectionally dependent autoregressive distributive lag (CS-ARDL) estimator on a dataset of 79 developing countries from 1991 to 2019.

Findings – Unlike previous studies, the results of this study show that older workers (aged 55–64) are still productive in increasing aggregate productivity. However, the ageing population (population aged 65 and above) has an adverse effect on aggregate productivity.

Originality/value – This study looks into the issue of population ageing in determining aggregate productivity in the context of developing countries, which has been given lesser attention. The estimation technique chosen for this study tackles prominent challenges in panel data research, such as cross-sectional dependency, slope heterogeneity, structural breaks, heteroskedasticity and serial correlation. The results give developing nations policy insights to manage demographic shifts and lessen the productivity issues brought on by population ageing.

Keywords Population ageing, Older workers, Productivity, Developing countries, CS-ARDL

Paper type Research article

1. Introduction

Population ageing refers to the demographic phenomenon characterised by an increase in the ratio of the population aged 65 and above. This change has stemmed from sustained reductions in fertility rates and also from mortality declines due to the advancements in medicine, leading to an extended average lifespan (Lee and Zhou, 2017). While population ageing is especially evident in economically advanced countries that have reached the final stage of demographic transition (Roy and Barua, 2023), it is an overarching global trend affecting economically developed and developing nations (Hu *et al.*, 2021).

The World Bank's (2023) statistics show a significant increase in the population aged 65 years and above, reaching 10% in 2022 from 6% in 1990. This trend is projected to reach 16% by 2050 (United Nations, 2022). Europe and North America have a higher ratio of older populations, followed by East Asia, Southeast Asia, Latin America and South Asia. The share of the population aged 65 years and above increased by 7.3% between 1990 and 2012 in East Asia and Pacific, 8.16% in Latin America and Caribbean, 1.9% in the Middle East and North Africa and 1.63% in South Asia and countries in the same period (World Bank, 2023).

The ageing population significantly impacts the working age population (age 15–64), causing a concentration of older individuals in the labour force, which leads to a rise in the

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proportion of aged workers in a country's workforce (Maddison, 2006; Börsch-Supan and Weiss, 2016). Additionally, the rising elderly population may cause shortages in labour and capital resources, necessitating increased government expenditure on healthcare and long-term care services (Ong and Mohd-Audi-Tye, 2022). The rise in the elderly population poses more challenges for societies as it increases the old-age dependency ratio. Population ageing has been reducing the potential support ratio [1], which is alarming for many countries' labour market, economic performance and financial burdens (United Nations, 2019).

The developing countries have entered into the demographic transition process much later than developed countries; however, due to the rapid decline in fertility and mortality rates, developing countries have entered into ageing in a shorter time. Very high birth rates and population expansion in the past have resulted in a significant elderly demographic in several developing countries (United Nations, 2022; Zhang and Schmid, 2023). The incidence and impact of ageing in developing countries may also differ from those in developed countries due to the differences in terms of health facilities, life expectancy and level of education and skills of the population (Cristea *et al.*, 2020). Moreover, population ageing leads to a drop in the support ratio towards the end, which results in a decline in the demographic window of opportunity [2]. Many developed countries have raised their retirement age over time to overcome the problem associated with the fall in support ratio. Therefore, there is also potential for developing countries to follow suit (United Nations, 2019). However, this step relies on what extent the older workers or elderly population in developing countries are productive.

The literature presents divergent perspectives on the influence of population ageing on economic performance and labour productivity, making it a contentious area of study. A negative effect is plausible if older individuals do not significantly contribute to the economy or retire, limiting the proportion of active, younger workers. However, a potentially positive effect may arise if the ageing workforce can be productive by being more experienced and knowledgeable. In addition, an ageing population continues to contribute to the economy by accumulating savings for investment, which is also called the second demographic dividend [3] (Lee and Zhou, 2017). Level of education, skills and technological advancement also affect labour productivity. However, there is disagreement about how these factors in productivity differ with different age levels. The answer to this question will be important regarding the employment of future old-age workers and reducing the burden by increasing social security payments and labour shortages.

Moreover, past studies (Hu *et al.*, 2021; Nicole Maestas *et al.*, 2016; Huang *et al.*, 2019; Acemoglu and Restrepo, 2017) focused on the effect of ageing on economic growth while ignoring its effects on productivity, which is essential to sustain economic growth. Productivity per worker is crucial for sustaining economic growth in a country. The studies in the past also neglected the implications of ageing in developing countries, which are getting aged but not rich. Unlike previous studies, this study uses an updated form of the panel autoregressive distributed lag (ARDL) approach, the cross-sectionally dependent autoregressive distributive lag (CS-ARDL) method, whose estimates are corrected for many significant issues in panel data analysis, such as cross-section dependence and slope heterogeneity. Therefore, to fill the significant gap discussed above, this study aims to determine how population ageing affects aggregate productivity in developing countries. We present the literature review, methodology, results and discussion and conclusion in subsequent sections of this paper.

2. Literature review

Population ageing recently attracted significant research in various fields due to the challenges it poses to society and economies. However, the impact of population ageing on economic performance is still relatively unexplored, with only a limited body of research having inconclusive results. According to Hu *et al.* (2021), population ageing impedes economic growth, reducing the labour supply and slowing capital and technological development. Feyrer (2007) stated that workers' ageing leads to a decrease in productivity. He showed that the age structure of the labour force influences economic performance, which is mainly justified through changes in total factor productivity at different times. Nicole Maestas *et al.* (2016) tested the changes in ageing in US states for 1980–2010 to analyse the impact of ageing on economic growth and found a significant negative effect. Aiyar and Ebeke (2016) noted that the ageing of the labour force lowers productivity, particularly through its detrimental effect on total factor productivity growth in Europe. Lisenkova *et al.* (2013) used the data of Scotland from 2006 to 2016 to determine whether age-specific factors significantly affect output productivity. According to the findings, an ageing population leads to declining output per person. The author suggested that increasing the retirement age and having more elderly workers will have a negative impact on output productivity since physical strength reduces as people age.

In contrast, some studies found positive effects of workers ageing on economic performance (Malmberg *et al.*, 2008; Börsch-Supan and Weiss, 2016; Huang *et al.*, 2019). Huang *et al.* (2019) suggested that an ageing workforce increases economic growth and productivity in Taiwan, while an increase in old-age dependency has the opposite effect. Börsch-Supan and Weiss (2016) showed that the ageing of workers does not reduce their productivity. Using the data from Sweden's mining and manufacturing sector, Malmberg *et al.* (2008) demonstrated that the ageing of workers increases their productivity and, therefore, the elderly should be encouraged in the workforce. Lisenkova *et al.* (2013) discovered that although raising the retirement age will aid in overcoming a weakening labour market, workers of various ages are not exact replacements. Consequently, there would be a decrease in worker productivity. Narciso (2010) emphasised the detrimental effects of population ageing and the resulting decline in a nation's human capital stock, which had a negative impact on economic growth. As a result, the labour force would decline as the population ages.

Feyrer (2008) demonstrated the income gap between rich and poor countries in light of the age structure of labour. According to the author, poor countries have a higher ratio of young workers with lower productivity per person. This research also suggested that the innovative activity was age-related. The study by Acemoglu and Restrepo (2017) found that countries with increased population ageing have relied on robot technologies. Still, they acknowledged that these technologies do not fully compensate for the negative effect of population ageing on economic growth. They suggested that directed technological progress could address this issue and potentially lead to a positive relationship between population ageing and economic growth.

On the other hand, Ilmakunnas and Miyakoshi (2013) discovered that ageing among low-skilled individuals had an adverse effect on production. However, for highly skilled individuals, the case was the opposite. This study was done on the data from the manufacturing industry for thirteen Organisation for Economic Co-operation and Development (OECD). Ang and Madsen (2015) demonstrated that educated individuals aged 50–64 were more innovative than their younger colleagues. Bertschek and Meyer (2009), on panel data of German manufacturing and service sector data for 2004 and 2007, discovered that workers above the age of 49 do not significantly perform worse than individuals in their prime between the ages of 30 and 49. At the same time, they discovered that the share of older workers has no significant impact on the link between labour productivity and information technology use. Mahlberg *et al.* (2013) using panel data from 2002 to 2005 for Austrian businesses suggests that a company's production is not negatively correlated with the proportion of older workers it hires. A negative correlation between wages and labour productivity and the proportion of young workers was also discovered. According to the review by Robertson and Tracy (1998), a worker's ability to attain knowledge and skills is a remedy for coping with productivity decline in older age. In addition, the author concluded that job experience is more relevant to productivity regardless of a worker's age. Table 1 provides a summary of the research on the relationship between population ageing and labour productivity.

3. Methodology

3.1 Theoretical framework

This study rests on the premises of the Solow (1956) growth model, which uses a Cobb–Douglas production function by including physical capital, human capital and labour as inputs.

$$Y_{it} = AK_{it}^{\propto}\ H_{it}^{\beta} L_{it}^{1-\propto-\beta} \tag{1}$$

In equation (1), Y_{it} is total output, A is total factor productivity, K_{it} is capital stock, H_{it} is human capital and L_{it} is the labour force. Dividing equation (1) by labour (L_{it}), the per-worker production function can be shown as,

Table 1. Summary of the studies on the relationship between population ageing and labour productivity

Study	Data structure	Method	Conclusion
Feyrer (2007)	87 countries, 1960–1990	Instrumental variable	Workers' ageing leads to a decrease in productivity
Malmberg *et al.* (2008)	Sweden, 1985–1996	Instrumental variable	Ageing of workers increases their productivity
Bertschek and Meyer (2009)	German manufacturing and service sector, 2001,2003,2006	Instrumental variable	The share of older workers has no significant impact on the link between labour productivity and information technology use
Lisenkova *et al.* (2013)	Scotland, 2006	OLG-CGE model	The ageing population leads to a decrease in output per person
Ilmakunnas and Miyakoshi (2013)	OECD countries (manufacturing industries) 1970–2005	Fixed effect	Ageing among low-skilled individuals adversely affects production
Mahlberg *et al.* (2013)	Austrian firms, 2002–2005	GMM	The firm's production is not negatively correlated with the proportion of older workers
Ang and Madsen (2015)	OECD counties, 1870–2009	System GMM	Educated individuals 50 to 64 were more innovative than younger ones
Aiyar and Ebeke (2016)	28 European countries, 1950–2014	Instrumental variable	Ageing of the labour force lowers productivity
Nicole Maestas *et al.* (2016)	United States, 1980–2010	Instrumental variable	The negative impact of ageing on economic growth
Börsch-Supan and Weiss (2016)	Sweden, 3,824 works, 973 days	Fixed effect model	The ageing of workers does not reduce their productivity
Acemoglu and Restrepo (2017)	169 countries, 1965–2015	Instrumental variable	Technological improvements do not fully compensate for the negative effect of population ageing on economic growth
Huang *et al.* (2019)	Taiwan, 1981–2017	OLS	ageing workforce increases economic growth and productivity in Taiwan
Hu *et al.* (2021)	172 countries, 1960–2019	Fixed effect model	Population ageing impedes economic growth

$$\frac{Y_i}{L_{it}} = A\left(\frac{K_{it}}{L_{it}}\right)^{\propto}\left(\frac{H_{it}}{L_{it}}\right)^{\beta} \tag{2}$$

$$y_{it} = A\, k_{it}^{\propto}\, h_{it}{}^{\beta} \tag{3}$$

where y_{it} is output, k_{it}^{α} is capital per worker, h_{it} is human capital per worker and A represents productivity.

The physical capital and human capital change rates are as follows:

$$\dot{k} = S_k y - (n + g - \delta)k \tag{4}$$

$$\dot{H} = S_h y - (n + g - \delta)h \tag{5}$$

where S_k is the fraction of income invested in physical capital, S_h is the portion invested in human capital and is expected to remain constant over time and δ is the proportional depreciation for both types of capital. Mankiw Gregory *et al.* (1992) used the steady-state income equation to solve the steady-state solutions $\dot{k}$ and $\dot{H}$.

$$\ln\left(\frac{\mathrm{Y}}{\mathrm{L}}\right) = \ln \mathrm{A}_0 + \mathrm{g}_{\mathrm{t}} - \left(\frac{\propto + \beta}{1 - \propto - \beta}\right)\ln(\mathrm{n} + \mathrm{g} + \delta) + \left(\frac{\propto}{1 - \propto - \beta}\right)\ln \mathrm{S}_{\mathrm{k}} + \left(\frac{\beta}{1 - \propto - \beta}\right)\ln S_h \tag{6}$$

The equation demonstrates the relationship between population change, the accumulation of human and physical capital and income per worker.

3.2 Empirical specification

To analyse how population ageing affects output per worker, we start with the following criteria:

$$LGDPW_{it} = \beta_0 + \beta_1 LOAP_{it} + \beta_2 LOLDW_{it} + \beta_3 LCPW_{it} + \beta_4 LHCI_{it} + \beta_5 LTRD_{it} + \beta_6 LSSE_{it} + \varepsilon_{it} \tag{7}$$

Dependent variable $LGDPW_{it}$ is labour productivity measured as GDP per-worker. The independent variables are, $LOAP_{it}$ the ratio of the population aged 65 years and above to the total population of age 15–64 and $LOLDW_{it}$ and the ratios of the age 55–64 population to the population of age 15–64. The control variables are, $LHCI_{it}$ representing human capital, which measures educational attainments and years of schooling (human capital index). CPW_{it} is the physical capital stock per worker. $LTRD_{it}$ is trade openness measured as the sum of exports and imports as the ratio of GDP. Trade openness is a control variable included in growth and productivity studies (Lai and Yip, 2021). $LSSE_{it}$ is the sectorial share in employment, measured as the share of employment in services, industries and agriculture. We use sectorial share in employment as control variables because a significant variation in productivity resulted from changes in sectoral employment (Golley and Wei, 2015; Mao *et al.*, 2018). All variables were transformed into logarithms.

Table 2 summarises the information on variables and the data source. The dataset for this study is composed of a long panel including 79 developing countries in the period from 1991 to 2019. We selected developing countries since, compared with developed countries in Western Europe, North America, and East Asia, these countries entered a demographic transition later. Although the countries under consideration are currently in the middle of a demographic transition, the ratio of the elderly population in these nations is also increasing, which is a challenge for the developing countries. We cannot cover all developing countries in this

Table 2. Description of variables

Variable	Measure	Source
GDP per worker (GDPW)	GDP per person employed	PWT 10
Old-age population (OAP)	Population age 65 years and above as ratio total population	WDI
Older workers (OLDW)	Population age 55–64 years as ratio of total employed labour	WDI
Capital per worker (CPW)	Real capital stock divided by total employed labour	PWT 10
Human capital (HCI)	Human capital index	PWT 10
Trade openness (TRD)	Export plus import as GDP ratio	PWT 10
Employment in services sector (WSS)	Employed labour in services sectors as the ratio of total employed labour	WDI
Employment in industrial sector (EIS)	Employed labour in industrial sectors as the ratio of total employed labour	WDI
Employment in agriculture sector (EAS)	Employed labour in agriculture sectors as the ratio of total employed labour	WDI

analysis and have excluded many countries due to the unavailability of the data. The data for employment shares in services, industries and agriculture comes from the World Development Indicator (WDI), while data on the remaining variables were drawn from Penn World Table 10th version (PWT 10) by Feenstra *et al.* (2015). The list of countries analysed for this study is shown in the appendix section.

3.3 Estimation method

This study conducts a cross-section dependence (CSD) test before the main data analysis because nations may have interdependency due to globalisation and economic cooperation. If cross-section dependence is overruled during the research, the panel estimates become biased (Ali *et al.*, 2021; Nathaniel *et al.*, 2021). The CSD issue may also prevail due to large panel data (Ditzen, 2019). This study employs Pesaran (2004) to confirm country interdependence. In addition to that, this study applies the slope homogeneity test by Hashem Pesaran and Yamagata (2008). Following the results of the above tests, we apply cross-sectionally dependent Im, Pesaran and Shin (CIPS) unit root tests by Pesaran (2007) to check for unit root since traditional unit root tests do not cover CSD. Accordingly, we apply the cointegration approach by Westerlund (2007) as an augmented cointegration for CSD.

This study applied the CS-ARDL estimator for regression analysis. The CS-ARDL estimator can be used regardless of the order of integration and accounts for cross-sectional dependency and has valid estimates even if the slope coefficients are heterogeneous. The mean group version of the CS-ARDL technique relies on incorporating cross-sectional averages, which serve as a measure for unobserved common components and their lags, to the ARDL estimations of each cross-section (Chudik *et al.*, 2017). The problem of weak exogeneity that comes when the lagged dependent variable is included in the model may also be successfully solved using this estimator. Inserting the lagged cross-section averages into the specification can overcome the endogeneity issue (Okumus *et al.*, 2021). The following regression is the foundation for the CS-ARDL estimation.

$$y_{it} = \propto_i + \sum_{l=1}^{p_y} \varphi_i y x_{it-1} + \sum_{l=0}^{p_x} \beta_i x_{it-1} \sum_{l=0}^{P} \delta_1 \bar{z}_{t-1} + e_{it} \tag{9}$$

Lagged cross-sectional averages $\bar{y}_{t-1}x$, are referred to as $\bar{z}_{t-1}$. The mean group estimations' long-run coefficient is

$$\widehat{\theta}_{CS-ARDL,i=\frac{\sum_{l=0}^{px}\widehat{\beta}_{li}}{\sum_{l=0}^{py}\varphi_i}} \qquad (10)$$

where $\widehat{\theta}_i$ stands for each cross-individual section's estimates. The CS-ARDL method's error correcting form is,

$$\Delta y_{it} = \alpha_i + \varnothing_i \left[y_{it-1} - \widehat{\theta i}\, x_{it} \right] + \sum_{l=0}^{p_{y-1}} \delta_{l,i}\, \Delta_i\, y_{it-1} + \sum_{l=0}^{p_x} \beta_i x_{it-1} \sum_{l=0}^{P} \delta_1 \bar{z}_{t-1} + u_{it} \qquad (11)$$

Where $\varnothing_i$ stands for the rate of adjustment for error correction.

4. Results and discussions

Table 3 presents the descriptive statistics on variables, which include mean, standard deviation maximum, minimum and total number of observations. Productivity averages 21,304 USD per worker employed per year over the observed period. The ratio of older workers is 0.075 on average, which makes up 7.5% of the total workforce. The mean of the ratio of the old-age population is 0.084, which forms 8.4% of the population working age (population aged 15–64). The observations on capital per worker are relatively more scattered. The trade openness has the lowest value, and capital per worker has the largest value in the data.

Table 4 shows the results of the CSD test. The table provides the t-statistics of the Pesaran (2004) CSD test, Pesaran LM test and biased-corrected Scaled LM test for CSD and corresponding *p*-values. Table 4 confirms the presence of strong cross-sectional dependency among the cross-section units, as the t-statistics of the three tests and their corresponding *p*-value *p*-values of all t-statistics are significant at 1% in the case of all variables. Based on this evidence, it is necessary to apply unit root tests, cointegration test and regression method, which consider the effect of CSD; otherwise, the results may be questionable. In light of this evidence, the application of the CIPS unit root test, Westerlund (2007) cointegration and CS-ARDL estimator are relevant.

This study employed cross-sectionally dependent Im, Pesaran and Shin's (CIPS) unit root test. The results of the second-generation unit root test are shown in Table 5. The variables GDP per worker, old-age population, old workers, capital per worker, human capital, trade openness and employment in services are stationary. The variables employment in industries and employment in agriculture have a unit root. We, therefore, take the first difference of all variables and conduct the CIPS unit root test. Now the variables, employment in industries and

Table 3. Descriptive statistics

Variable	Mean	Std. dev.	Min	Max	Obs
GDP per worker	21304.43	21007.91	973.392	163188	2,289
Old-age population	0.08448	0.022545	0.037057	0.194	2,291
Older worker	0.075215	0.029385	0.035937	0.233307	2,291
Capita per worker	74938.89	76364.22	1169.713	531377.4	2,262
Human capital	2.013864	0.522821	1.03352	3.61277	2,291
Trade openness	0.382653	0.288046	1.30E−06	1.8606	2,291
Employment in services sector	42.10811	16.82855	5.20472	78.2054	2,291
Employment in industrial sector	17.1047	7.733436	1.0679	40.0362	2,291
Employment in agriculture sector	40.78719	22.58508	3.05227	92.5917	2,291

Table 4. Cross-section dependence test

Variables	Pesaran CSD	Pesaran scaled LM	Bias-corrected scaled LM	*p*-values
GDP per worker	133.3850***	615.3899***	613.9792***	0.000
Old-age population	19.3354***	588.0686***	586.6578***	0.000
Older workers	74.8534***	550.7074***	549.2967***	0.000
Capital per worker	77.3757***	484.1216***	482.7288***	0.000
Human capital	257.5915***	869.5200***	868.0736***	0.000
Trade openness	136.2182***	669.9170***	665.4885***	0.000
Employment in services sector	213.9641***	715.2348***	713.8241***	0.000
Employment in industrial sector	12.68654***	350.8632***	349.4525***	0.000
Employment in agriculture sector	191.8108***	687.6287***	686.2180***	0.000

Note(s): (***), (**) and (*) are significance levels at 1, 5 and 10%

Table 5. Panel unit root test (CIPS)

Variable	Level Constant and trend	First difference Constant and trend
GDP per worker	−2.6569**	−4.6591***
Old-age population	−3.2411***	−3.6141***
Older workers	−3.2905***	−3.5162***
Capital per worker	−2.9704***	−3.7723***
Human capital	−3.4114***	−4.3470***
Trade openness	−3.3530***	−2.9590***
Employment in services sector	−2.6624**	−3.7412***
Employment in industries sector	−2.2497	−3.7108***
Employment in agriculture sector	−2.1110	−3.8935***

Note(s): (***), (**) and (*) are significance levels at 1, 5 and 10%

agriculture, are also stationary. Hence, we confirm that the variables GDP per worker, old-age population, old workers, capital per worker, HCI, trade openness and employment in services are stationary at level *I*(0) and the variables, employment in industries and employment in agriculture are stationary at first difference *I*(0).

A cointegration test is aimed at determining the long-run relationship among variables. To that end, the current study applied Westerlund (2007). Results of the Westerlund (2007) cointegration test are shown in Table 6. Four statistics, Gt, Ga, Pt and Pa, represent the cointegration tests for a group with the trend, a group without the trend, a panel with the trend

Table 6. Panel cointegration test (Westerlund (2007) cointegration)

Specification	Gt	Ga	Pt	Pa
LGDPW = f (LOAP, LOLDW, LCPW, LHC, LTRD)	−2.937***	−2.857	−15.256	−2.026
LGDPW = f (LOAP, LOLDW, LCPW, LHC, LTRD, LESS)	−3.080**	−5.899	−19.442	−5.091
LGDPW = f (LOAP, LOLDW, LCPW, LHC, LTRD, LEIS)	−3.147***	−2.178	−18.005	−1.555
LGDPW = f (LOAP, LOLDW, LCPW, LHC, LTRD, LEAS)	−3.133***	−6.035	−23.506	−5.787

Note(s): (***), (**) and (*) are significance levels at 1, 5 and 10%, H0: no cointegration and a panel without trending, respectively. The Gt test from Westerlund's (2007) cointegration test for all four models is significant at one per cent. We reject the null hypothesis of no cointegration and confirm long-run cointegration among the variables in all four specifications.

We provide the results of slope homogeneity in Table 7 by using the Hashem Pesaran and Yamagata (2008) slope homogeneity test. For the null hypothesis, we state that the slope coefficients are homogenous, which is against the alternative hypothesis of heterogeneous slope coefficients. The t-statistics of the slope homogeneity test Δ and the biased-adjusted slope homogeneity test coefficient Δ_{adj} are significant at one per cent in the case of all specifications, and we, therefore, reject the null hypothesis.

Table 8 provides CS-ARDL results. The upper portion of the table presents the long run, while the lower portion presents the short-run results. The first specification is the baseline regression model; the subsequent specifications control for the ratio of employment in services, industry and agriculture accordingly. The adjustment coefficient is the variable L.GDP per worker, as shown in Table 7, which is an important feature of ARDL models. The coefficient of the adjustment term is negative and significant, which fulfils its theoretical justifications. We can observe a negative coefficient for the old-age population in both the short run and long run. This evidence is in line with many studies. However, in this study, we find the insignificant effect of the older population on productivity, which means that the developing countries have not yet entered the severe ageing phase. Nevertheless, the negative effect of ageing demonstrated in this study is alarming for the policymakers in developing countries soon.

The coefficients of older workers (aged 55–64) are positive and significant. This result means that the increase in the ratio of elderly workers does not have an adverse impact on aggregated productivity in developing countries. This finding contradicts many studies' results (Aiyar and Ebeke, 2016; Nicole Maestas *et al.*, 2016; Siddiqui, 2018; Calvo-Sotomayor *et al.*, 2019), which demonstrated a negative coefficient for the older workforce corresponding to productivity. These studies believe that productivity declines after age 55 because people are less healthy and energetic at this stage of life. In addition, people in the old working-age cohort are less aware of modern technology use in their workplace. The positive effect of older workers on productivity is due to an increase in life expectancy. As a result, people are getting healthier and more energetic. Besides, workers aged 55–64 mostly occupy top-level positions in an organisation or business and are responsible for policymaking and decisions and have acquired much experience and are more productive than younger workers (Huang *et al.*, 2019). In comparison, few studies observed the positive effect of the elderly workforce (Malmberg *et al.*, 2008; Börsch-Supan and Weiss, 2016; Huang *et al.*, 2019).

The coefficient of capital per worker is positive and significant in all specifications, meaning that capital stock per worker is an important factor of production and essential for increasing developing countries' labour productivity. In addition, we failed to capture human capital's substantial role in increasing productivity. The human capital is negative in the first specification, positive in the remaining three specifications and nonsignificant in the long run, while in the short run, it is negative in the first and third specifications. The insignificance of

Table 7. Slope homogeneity test

Specification	Δ	Δ_{adj}
LGDPW = f (LOAP, LOLDW, LCPW, LHC, LTRD)	48.995 ***	56.260***
LGDPW = f (LOAP, LOLDW, LCPW, LHC, LTRD, LESS)	43.912 ***	51.611***
LGDPW = f (LOAP, LOLDW, LCPW, LHC, LTRD, LEIS)	45.267 ***	53.203***
LGDPW = f (LOAP, LOLDW, LCPW, LHC, LTRD, LEAS)	44.205 ***	51.956***

Note(s): (***), (**) and (*) are significance levels at 1, 5 and 10%, H0: Slope coefficients are homogenous

Table 8. CS-ARDL estimates

Long-run coefficients	(I)	(II)	(III)	(IV)
L.GDP per worker	−0.7814*** (0.0397)	−0.87397*** (0.0385)	−0.8848*** (0.0422)	−0.8463*** (0.0373)
Old-age population	−0.1902 (0.3217)	−0.0078 (0.1989)	−0.3804 (0.2551)	−0.2327 (0.2304)
Older worker	0.5124** (0.2587)	0.5939*** (0.2286)	0.5900** (0.2775)	0.3050 (0.2720)
Capital per worker	0.3168** (0.1413)	0.2476** (0.0984)	0.3109*** (0.1141)	0.2635** (0.1251)
Human capital	−2.9530 (3.3599)	0.4777 (0.7766)	0.0601 (1.0111)	0.4664 (0.9564)
Trade openness	0.0653*** (0.0219)	0.0132 (0.0105)	0.0471*** (0.0168)	0.0551*** (0.0248)
Services employment		0.9383** (0.3907)		
Industry employment			0.5542*** (0.200)	
Agriculture employment				−1.5555*** (0.3929)
Short-run coefficients				
Old-age population	−0.1991 (0.2277)	0.02422 (0.2070)	−0.3173 (0.2056)	−0.0226 (0.1487)
Older worker	0.2893** (0.1991)	0.3668* (0.2110)	0.3626** (0.2204)	0.1767 (0.2067)
Capital per worker	0.3254** (0.1061)	0.2476** (0.1038)	0.3552*** (0.1054)	0.2392*** (0.0773)
Human capital	−0.7007 (0.9123)	1.1480 (0.9550)	−0.0339 (0.7360)	0.0023 (0.8154)
Trade openness	0.0307*** (0.0111)	0.0089 (0.0108)	0.0322*** (0.0103)	0.0315*** (0.0106)
Services employment		1.0032** (0.4099)		
Industry employment			0.5791*** (0.2485)	
Agriculture employment				−1.2315*** (0.2937)
No of groups	78	78	78	78
No of observations	2,104	2,104	2,104	2,104

Note(s): (***), (**) and (*) are significance level at 1, 5 and 10%. The values in the parenthesis are standard errors

human capital can be attributed to low-quality education, fast-growing education levels with decreasing benefits or market failures in finding profitable jobs for educated employees (Pritchett, 2001; Bloom *et al.*, 2010). The coefficient of trade openness becomes positive and significant in three specifications. This finding means that productivity per worker increases as the countries are more open to international trade. The results also show that increasing employment ratios in services and industrial sections greatly contributes to increasing aggregate labour productivity, while employment in agriculture significantly reduces productivity. According to Hu *et al.* (2021), population ageing results in an increase in services demand, which necessitates the growth of the services sector.

5. Conclusion

This research is based on the ongoing debate on whether the ageing population affects labour productivity. This study used GDP per worker as a proxy for labour productivity and the ratio of the population aged 55–64 to the total working-age population for the older workforce and the population aged 65 and above as the old-age population while considering the effect of capital per-worker, human capital, trade openness and sectorial shares of employment. This analysis used a balanced panel dataset that included 79 developing countries, and the time dimension of the dataset was stretched from 1991 to 2019. The results of this study show that older workers (55–64) are still productive in increasing aggregate output, which contrasts with the findings of previous studies. However, the ageing population (population aged 65+) has an adverse effect on aggregate productivity, although this effect is not substantial. The coefficient of capital per worker is positive and significant, indicating that capital stock is essential for increasing labour productivity in developing countries. However, human capital's substantial role in increasing productivity is not captured. The trade openness plays a positive and significant part, indicating that productivity increases as countries are more open to international trade. The results also show that employment in the services and industrial sectors significantly contributes to increased aggregate labour productivity, while the agriculture sector significantly reduces productivity. As shown in Table 3, the mean value of agriculture employment is 40%. A transition from agriculture to the secondary and tertiary sectors can boost aggregate productivity.

There are some important implications in light of the results obtained from this study, which can help to cope with challenges caused by population ageing in developing countries. Although this study finds an insignificant impact of ageing on productivity, its negative impact is an alarming sign for the future since population ageing is also rapidly increasing in developing countries. Secondly, the positive effect of older workers in developing countries will provide hope to raise the retirement age to 65 to overcome labour shortages and fiscal burdens. In most developing countries, the retirement age is below 65. This policy implication is also consistent with the achievement of Sustainable Development Goal 8 (SDG-8), which aims to promote economic growth, productivity and employment for all. Thirdly, although not significantly impacted by the research, human capital can contribute to productivity growth through policies promoting education and skills development. This policy implication aligns with meeting Sustainable Development Goal 4 (SDG-4). Lastly, governments should pursue policies that encourage international trade and the transformation of employment from agriculture to industry and service to boost aggregate productivity.

This study also introduces new research directions. This study covers developing countries that have initiated their demographic transition phase later than developed countries, facing common economic challenges while considering heterogeneity. The future studies may be conducted by examining distinct income groups, specifically low-income and upper-middle-income developing countries. Moreover, future studies may consider individual studies.

Appendix

List of countries included

Algeria, Angola, Argentina, Bangladesh, Belize, Benin, Bolivia, Botswana, Brazil, Burkina Faso, Burundi, Cambodia, Cameroon, Central African Republic, Chile, China, Colombia, Congo, Dem. Rep., Congo, Rep., Costa Rica, Cote d'Ivoire, Dominican Republic, Ecuador, Egypt, Arab Rep., El Salvador, Ethiopia, Fiji, Gabon, Gambia, The, Ghana, Guatemala, Guyana, Haiti, Honduras, India, Indonesia, Iran, Islamic Rep., Iraq, Jamaica, Jordan, Kenya, Lao PDR, Lesotho, Malawi, Malaysia, Mali, Mauritania, Mauritius, Mexico, Morocco, Mozambique, Myanmar, Namibia, Nepal, Nicaragua, Niger, Nigeria, Pakistan, Panama, Paraguay, Peru, the Philippines, Rwanda, Senegal, Sierra Leone, South Africa, Sri Lanka, Sudan, Thailand, Togo, Trinidad and Tobago, Tunisia, Turkey, Uganda, Uruguay, Zambia and Zimbabwe.

Notes

1. Support ratio is the population aged 15–64 divided by population aged 65 or older.
2. Window of opportunity is the period in which a country's active population grows faster than its dependent population.
3. Demographic dividend means when a change in a country's demographics favours its economic expansion.

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