A macroeconomic investigation into the impact of an ageing population and government health expenditure has on economic growth.

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Abstract

This paper investigates the impact that an ageing population and government health expenditure has on economic growth using a panel data set of 112 countries covering the period 2000-2021. A direct impact of people living longer and having fewer children is that the world's population is growing older. It is theorised that an ageing population will have an adverse impact on economic growth through losses in productivity and slower labour supply growth. To achieve their primary objective of economic growth, policymakers must explore what tools they can use to overcome the economic challenges that an ageing population presents. One tool that policymakers could use is government health expenditure. It is argued that an increase in health expenditure can bring sufficient gains in human capital to reduce some of the impact that an ageing population has on economic growth. This paper firstly explores the separate effects that an ageing population and government health expenditure both have on economic growth, before then investigating whether government health expenditure can moderate some of the impacts an ageing population has on economic growth. This study uses a two-stage least-squares (TSLS) model to deal with the potential endogeneity problem that both government health expenditure and an ageing population may have with economic growth. The results section of this study focuses on two subsets of data, one containing developed countries and the other developing countries. There are noticeable differences between developed and developing countries in where they are currently at in the stage of demographic transition and the speed that their populations will age. There is also a huge contrast in the resources available to countries at different levels of development to cope with the economic impact of an ageing population. Splitting the results between developed and developing countries allows policymakers to have a more detailed understanding of the policy implications specific to their country's development level. The empirical results indicate that, regardless of a country's development level, there is an inverted u-shaped relationship between an ageing population and economic growth. Effectively meaning that as the size of the older population rises, the initial positive effect of an ageing population on economic growth will diminish. Results also show that a 1 percentage point increase in government health expenditure led to a 0.13% increase in Gross Domestic Product (GDP) per capita in developed countries and a 0.22% increase in developing countries. Furthermore, in developed countries, government health expenditure can weaken the impact that an ageing population has on economic growth.

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1. Introduction

The emergence of a global ageing population represents an unprecedented challenge to policymakers. An ageing population is a result of two demographic shifts, longer life expectancy and declining fertility rates. Average life expectancy has increased significantly since the 1960's due to the huge advances that have been made in health and living standards across the globe. This has resulted in the average person born in 2021 living over 23 years longer than they would have if they were born in 1960 (Roser, et al., 2023). During this same period worldwide fertility rates have decreased by 50% (World Economic Forum, 2022). The combination of people living longer and having fewer children has a direct impact on the size of the older population. United Nations (UN) population data shows that in the last 70 years the global older population has almost doubled. This trend will only continue in the future with the global older population set to make up almost a quarter of the total population by the end of the century (United Nations, 2022).

A demographic shift of this magnitude is likely to impact the economic growth prospects of countries across the world. Economic growth is defined as "the increased capacity of an economy to produce goods and services, when comparing one period to another" (Alfano, 2014). It is a primary objective of governments and is a key priority for citizens as well. This is because growth can bring many benefits, including employment opportunities, a rise in living standards, greater income levels, technological advances and much more.

A major concern for policymakers is the impact that an ageing population will have on the labour market and the implications this could have on economic growth. Those who are entering the later stages of their life are far more likely to have ill health and/or a disability. Health is a component of human capital which according to endogenous growth theory is a key driver of economic growth (Bloom & Canning, 2003) (Lucas, 1988). When a person experiences ill health or disability it can lead to an increase in absenteeism, and it can be detrimental to their ability to perform specific skills in the workplace which can have an adverse effect on an individual's productive capacity. A population growing older means that human capital depreciation will increase and the ability for countries to grow will be hampered.

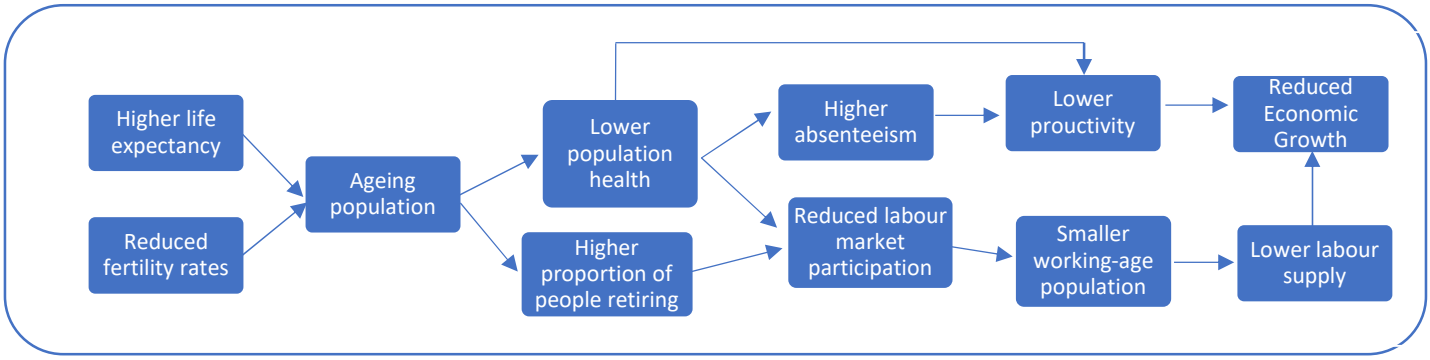
Research suggests that illness or disability will also lead to a reduction in labour market participation (Axelrad, 2018) (de Wind, et al., 2013) (Dwyer & Mitchell, 1999). Poor health can be a push factor for individuals to leave the labour market as it may not be possible for individuals to continue to do their job. As individuals grow older, they are also far more likely

to retire. Therefore, if the size of the older population is growing, there will be a greater proportion of the population leaving the labour market. This can cause the size of the working age population to decrease.

A declining working age population can cause strain to the economy as fewer workers will have to provide for a larger consumer base. If the burden of supporting the elderly increases, this could limit the working age population's labour supply time, which would further reduce the labour participation rate of society. This may cause supply shortages which can restrict the ability for firms to expand and invest. All of which can deter economic growth.

A simplified version of the mechanism of how an ageing population can impact economic growth through the labour market can be found in figure 1. It is critical that policymakers understand the impact of an ageing population on economic growth so that they can understand the extent of the challenge that an ageing population presents.

Figure 1 – Potential impact of an ageing population on economic growth through the labour market.



It is also crucial that policymakers are well equipped and have the tools to be able to deal with the economic impacts of an ageing population so that they can continue to promote economic growth. A potential solution is greater health investment. As previously stated, our health makes up part of our human capital, as humans need to be healthy to be productive. In the context of an ageing population, it is theorised that the decline in human capital accumulation through ageing could be minimised if greater resources were channelled into improving the health of a nation and its labour force. If individuals are getting older but are remaining in good health, then it is far more likely that an individual will stay in the labour market and be productive. This is because individuals will have the ability to continue to work at their productive capacity for a longer period of time. Under the assumption that health investment directly improves

health, this paper will focus on the state's role in promoting economic growth through health investment.

To study the macroeconomic relationship between these variables, this paper will bring economic growth, an ageing population and government health expenditure together under one analytical framework to investigate the following three questions:

1. What is the impact that an ageing population has on economic growth?
2. What is the impact that government health expenditure has on economic growth?
3. Can government health expenditure be used as a policy tool to moderate the impacts of an ageing population on economic growth?

To get a more valuable and detailed insight for policymakers, this research will also look at whether policy implications differ depending on how developed a country is. There are several noticeable differences between developed and developing countries that may affect the impact that an ageing population and government health expenditure has on economic growth. Currently, developed countries have a larger older population size; but developing countries are ageing at a quicker rate. Data suggests that in 2050, nearly 8 in 10 of the world's older population will be living in the developing regions (United Nations, 2017). It is also widely accepted that developed countries have greater resources and more advanced health care systems in place than developing countries, which could play a role in the ability for a country to cope with the effects of an ageing population. By separating the regression results out for developed and developing countries, this will ensure that policy implications are specific to countries who are at a comparable stage of their demographic transition and to countries experiencing similar challenges regarding their resource capacity.

2. Literature Review

2.1 Ageing Population and Economic Growth

Many researchers have attempted to understand and quantify the impact that an ageing population has on economic growth; however, the findings from these studies are not entirely consistent with each other.

The first group of studies found that an ageing population and economic growth have an inverse relationship. Maestas et al. derived using a production function that the relationship between growth in the older population share and economic growth depends on three elasticities: labour supply, labour force participation and labour productivity. The paper found using both ordinary

least squares (OLS) and instrumental variable methods that GDP per capita decreased by 5.5% in the United States (US) when there is a 10% growth in the population share aged 60 and older. Furthermore, two-thirds of the fall in GDP growth was driven by lower labour productivity, while one-third was due to decelerating labour force growth (Maestas, et al., 2023). These findings are supported by studies on a range of other countries. Lai & Yip found a negative relationship between an ageing population on economic growth when focusing on a panel dataset of 74 developing countries (Lai & Yip, 2021). Liu et al. conducted a further study on 30 provinces in China from 2000-2019 and found population ageing has a significant negative effect on economic growth (Liu, et al., 2023). Additionally, Lee & Shin focused on Organisation for Economic Co-operation and Development (OECD) countries and found ageing has negative effects on GDP growth per capita with lowered total factor productivity growth being the main channel of this negative effect (Lee & Shin, 2021).

This paper now turns to a body of literature that argues that an ageing population can have a positive effect on economic growth. Moving away from labour market theory, studies focusing primarily on the saving patterns of the older population have found that older individuals will save more (Aigner-Walder & Döring, 2012) (Lee & Mason, 2006). This could potentially create resources for investment which can drive growth. Using an endogenous growth model, Prettner identified that the overall effect of increasing longevity and decreasing birth rates, led to a rise in economic growth (Prettner, 2012). This positive effect was also captured by Zhao et al. who focused on the relationship using panel data from 31 Chinese provinces (Zhao, et al., 2018). Furthermore, Mamun et al. focused on Bangladesh and found that when using capital formation as an explanatory variable, there was a positive long-term relationship between an ageing population and economic growth (Mamun, et al., 2020). However, this study was limited by the fact that a variable capturing the human capital effect was not included due to a lack of data. This can cause omitted variable bias in the model specification.

The next section of this literature review establishes an inverted u-shaped relationship between an ageing population and economic growth. An & Jeon ran a cross-country regression on a group of OECD countries and found that demographic changes start off by increasing economic growth, but this positive effect diminishes as the proportion of the population aged 65 or over increases. These findings are largely explained by the amount of labour supply falling as a greater number of individuals become unable to work, which in turn hampers economic growth (An & Jeon, 2006). A separate study by Lee and Shin, focusing on a larger number of countries, also found a non-linear relationship using panel data methods (Lee & Shin, 2019).

2.2 Health Expenditure and Economic growth

It is also important for this study to look at the empirical evidence on the isolated impact government health expenditure has on economic growth to understand its appropriateness as a policy tool. Many studies find a positive relationship between the two variables. For example, Ozyilmaz et al. found that when focusing on EU countries, government health expenditure was the most important health expenditure variable for promoting economic growth (Ozyilmaz, et al., 2022). A positive relationship has also been found in other papers that use different econometric techniques and countries, for example Zhang et al. identified a significant positive relationship between government health expenditure and growth in China (Zhang, et al., 2020). Qehaja et al. also found a similar positive relationship when focusing on the western Balkan countries (Qehaja, et al., 2022). These papers support the health-led growth hypothesis that health is a form of capital, which if invested in, can bring benefits such as productivity gains. This will lead to increases in human capital accumulation which will promote economic growth (Mushkin, 1962).

2.3 Health, an Ageing Population and Economic Growth

The final part of this literature review focuses specifically on research that has investigated the combined economic effects of health and ageing. There has been a recent flurry of research focusing on this. For example, a Japanese study used a fixed effects model and found that functional limitations have a positive association with retirement and greater health spending. The study also identified that health interventions can prevent labour market exits and reduce medical and long-term care costs (Okamoto, et al., 2023). Other economic benefits have been identified; one study quantified the non-market impact of health improvements of those in later life in the United Kingdom (UK). This study found that if 10% of older people in self-perceived "very bad" health were to transition to "very good" health, it could generate up to £278 million through the production of non-market activities (Santos & Cylus, 2024). Non-market activities are not typically captured in GDP data; however, this paper highlights the wider economic benefits that can arise from healthy ageing.

Tang et al. explored the impact that the health care burden for the elderly population has on economic growth. Using various panel data techniques on a sample of 111 countries, this study found that poor health can limit economic growth as the increased burden of family caregiving can potentially crowd out labour inputs that are needed for production. The paper found that a 1% increase in the health care burden led to a 0.083% decrease in the GDP growth rate (Tang,

et al., 2022). Therefore, suggesting a wider economic benefit of health investment could be the reduced crowding out effect on labour supply for the working-age population.

The following two studies focus specifically on whether a reduction in disability levels of the older working age population could moderate the impact an ageing labour force has on economic growth. Cylus et al. applied a fixed effects model to data across 180 countries from 1990 to 2017. They found the statistically negative association between an ageing labour force and economic growth can be moderated through greater productivity and labour market participation when disability in the older working age population is lower (Cylus & Tayara, 2021). In 2022, a similar study focused on Mongolia and found that a 5% decrease in disability rates among the older labour force could have added around 0.2% to annual per-person GDP growth in 2020 (Williams, et al., 2022).

To this paper's knowledge, the only previous study to integrate the impact of health expenditure and an ageing population on economic growth is a paper produced by Yang et al. This study used both a least-squares dummy variable and a TSLS model on a panel data set of 186 countries from 2000-2016. The paper outlines that the TSLS model is used to overcome the endogeneity problem, hence why this paper will focus on this model specification. This study found an inverted U-shaped relationship between population ageing and economic growth, a positive effect of health investment on economic growth and that the effects of health investment and an ageing population weaken each other out (Yang, et al., 2021).

This paper expands on Yang et al.'s paper in three key ways:

- Firstly, Yang et al.'s paper uses health expenditure as a proportion of GDP as its variable to explore the mitigating effect health investment has on an ageing population. Instead of focusing on all the health expenditure spent in an economy, this paper will focus on government health expenditure as this will better capture health expenditure that policymakers and the state have more control over. This allows for a greater understanding of the role that the state can play in dealing with the ageing population problem.
- Secondly, this paper investigates and compares findings for developed and developing countries. This is not covered in Yang et al.'s paper and will allow for a greater understanding of whether the findings and subsequent policy implications differ due to a country's development level.

- Thirdly, this paper extends the timespan of data to 2021 to allow for a more current and accurate understanding of this paper's findings. By including Covid-19 pandemic years, this will test whether the relationships still hold whilst accounting for the pandemic. In 2020, government spending on health rose to a new high of approximately 11% of global GDP whilst GDP growth fell by 4.4% (International Monetary Fund, 2020) (World Health Organisation, 2022). If findings still show health expenditure promotes economic growth, even when including pandemic years, then this would further support the robustness of Yang et al.'s paper.

3. Data

To conduct this investigation data has been collected for 112 countries. Data was collected for as many countries as possible to ensure that enough observations were included in the regression analysis. Countries containing missing data were dropped from the final dataset to ensure the panel was balanced. A balanced panel data set ensures consistency in the number of observations per country. The data set covers the period 2000-2021. At the time of this research, 2021 is the most current year that data has been collected for many of these variables. To allow for a comparative analysis between developed and developing countries, the dataset has been further split into two subsets, the first subset of data contains 77 developing countries and the other contains 35 developed countries.

Similarly, to Yang et al.'s paper, this study is based on an extended version of the Mankiw–Romer–Weil model where health capital is identified separately to education capital (Knowles & Owen, 1995). Yang et al.'s study uses a Cobb-Douglas production function (figure 2) where it is derived that output (y) is produced as a function of population ageing (φ), physical capital (k), human education capital (e) and human health capital (h) (Yang, et al., 2021). This function is useful to help identify the variables that should be included in this research.

Figure 2 – Cobb-Douglas production function

$$y_{it} = \varphi_{it} k_{it}^{\alpha} e_{it}^{\beta} h_{it}^{\psi}$$

The dependent variable in this regression, representing economic growth, is GDP per capita. A per capita variable is chosen as this considers differences in population sizes which allows for comparisons across countries to be made. Real GDP was chosen as opposed to nominal GDP as this removes the impact of changes in inflation. This makes it easier to compare growth

across countries and time. To further aid comparison across countries, GDP has been converted to constant 2015 US dollars prices.

To help inform the choice for an ageing population variable, this paper uses the OECD definition of an elderly population which is defined as people aged 65 or over (OECD, 2019). Therefore, to measure the size of the older population, the proportion of the population aged 65 or above is used as the independent variable. This variable is used in previous studies investigating the impact of an ageing population (Lai & Yip, 2021) (An & Jeon, 2006).

For the health capital variable, this study focuses solely on the role that the state has in impacting economic growth through health expenditure, the variable domestic government health expenditure as a proportion of GDP is chosen as the secondary explanatory variable. This variable narrows the scope of health expenditure to focus on the amount of resources channelled to health by the government relative to their GDP. This variable was used in Ozyilmaz's paper to represent government health expenditure (Ozyilmaz, et al., 2022).

The study also employs a range of control variables to control for other factors that may impact economic growth. These variables have been chosen based off existing literature and from the remaining inputs of the Cobb-Douglas function in the Mankiw–Romer–Weil model. From the Cobb-Douglas function, gross fixed capital formation as a proportion of GDP is selected to represent physical capital. Data has also been collected to represent human education capital, but this is only included in the robustness tests due to missing data observations and the desire for the dataset to be balanced. Control variables inspired by other literature include the annual growth rate of both inflation and the population, the proportion of trade and foreign direct investment as a proportion of GDP and the labour force participation rate. The inclusion of control variables helps to reduce omitted variable bias which strengthens the robustness of the results. Table 1 provides an overview of the variables included in the regression analysis.

Table 1 – Variables and summary statistics

Variable	Notation	Summary statistics					Data Source
		No.Obs	Mean	Max	Min	SD	
Log GDP per capita (constant 2015 US$	GDP	2,464	8.7	11.41	5.57	1.44	World bank
Proportion of the population aged 65+ (%)	AGE	2,464	9.23	29.79	1.52	6.13	UN – World Population Prospects
Domestic general government health expenditure (% of GDP)	GOVHEA	2,464	3.45	10.69	0.14	2.31	World Health Organisation
Inflation, consumer prices (annual %)	INF	2,464	5.47	359.09	-8.97	13.09	World Bank
Population growth rate (%)	POP	2,464	1.21	8.18	3.09	1.23	UN-World Population Prospects
Trade (% of GDP)	TRADE	2,464	82.72	437.33	4.13	49.69	World Bank
Gross fixed capital formation (% of GDP)	INV	2,464	22.88	81.02	2.78	6.45	World Bank
Foreign direct investment, net inflows (% of GDP)	FDI	2,464	5.35	449.08	113.14	19.54	World Bank
Labour Force Participation Rate (%)	LFP	2,464	68.1	89.45	41.6	9.65	World Bank

Before performing any econometric analysis, two scatter plots were constructed using the full dataset to allow for a better understanding of the separate relationship an ageing population and government health expenditure has with economic growth. This exercise provides valuable information of what tools may be needed for the econometric analysis. Figure 3 illustrates a non-linear relationship between an ageing population and economic growth. This suggests that a quadratic ageing population term should be included in the model's final specification.

Figure 3 – Scatter plot (Ageing population)

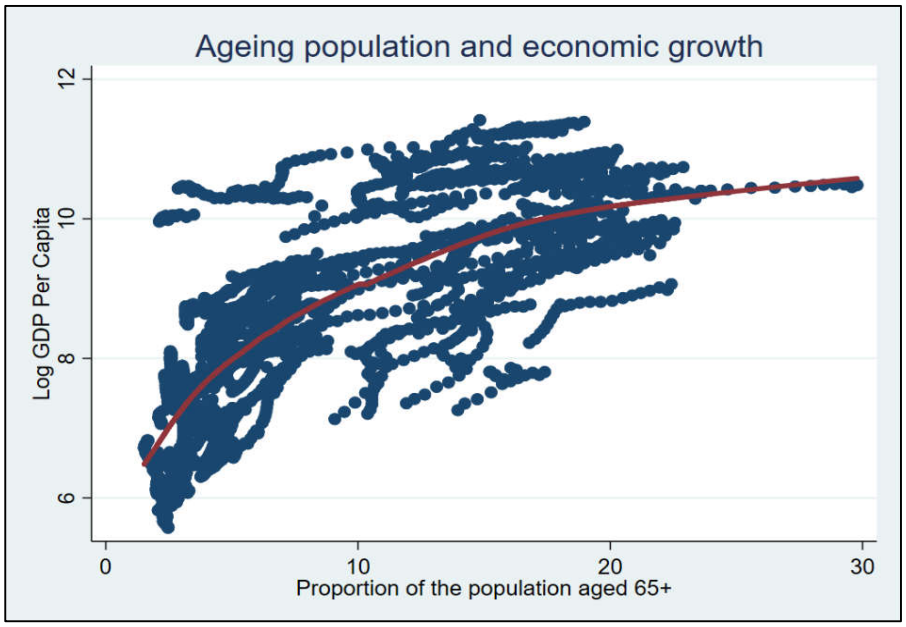
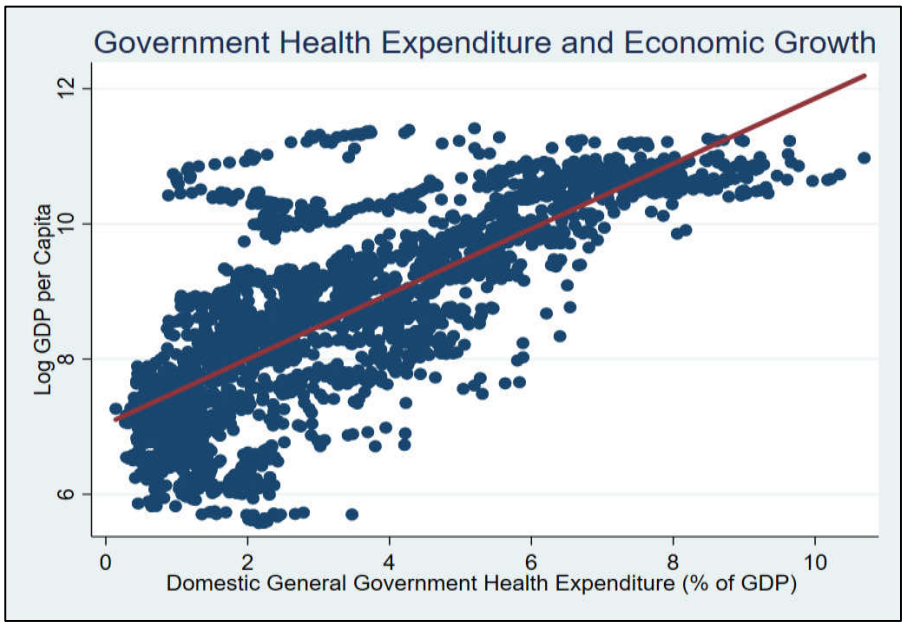


Figure 4 shows a positive relationship between government health expenditure and economic growth. The scatter plot is backed up by the results of the correlation matrix which produced a significant correlation value of 0.77. It is important that these initial results are taken with caution. It is well known that correlation does not mean that there is a causal relationship. The next step for this paper is to focus on looking at what methods and econometric techniques can be used to prove a potential causal relationship.

Figure 4 – Scatter plot (Government Health Expenditure)



4. Methodology and Specification

Before selecting a model, several tests were conducted on the collected variables. The first test was a Levin-Lin-Chu test for stationarity. It is important that all the variables included in the final model are stationary. This ensures that the regression is not spurious and that the interpretation of the results are accurate. For all variables, the null hypothesis that the data is non-stationary was rejected meaning that detrending the variables was not necessary.

The next step was to ensure that the variables were normally distributed. After creating a histogram on GDP per capita it was clear that the data was positively skewed. To reduce the skewness of the data, a common step is to log transform the data. This approach has been taken in several other studies (Maestas, et al., 2023) (An & Jeon, 2006) (Yang, et al., 2021). After taking the log of GDP per capita, a histogram was recreated, and this shown much more normalised data. This is important for the accurate interpretation of results.

Following this, a test for multicollinearity was conducted. This is where two or more variables are highly correlated with one another causing the variance to become large and the coefficients difficult to interpret. To test for multicollinearity, variance inflation factors were calculated. All the variance inflation factors were less than 10 which suggests that multicollinearity is not a problem for this specification.

Following these initial steps, a pooled OLS regression model was created which produced some basic regression results. This is a useful starting point in the specification process as this helps establish some suggestive results. At this stage, a quadratic term of the ageing population variable was added to the model to test whether the relationship between an ageing population and economic growth was non-linear. The quadratic variable was significant and had a negative coefficient whilst the original ageing population variable was positive and significant. This supports the findings from figure 3 that an ageing population has a non-linear relationship with economic growth. The quadratic variable (SQAGE) was included in regressions from this point forward.

The pooled OLS model is limited by the fact that it cannot address the significant challenge of endogeneity. Endogeneity is where an explanatory term is correlated with the error term. In this instance, this is largely due to the bidirectional nature of the relationship that both health and an ageing population has with economic growth. This paper so far has set out how health and an ageing population may impact economic growth but is yet to consider the reverse causal impact economic growth may have. It is theorised that economic growth can have a causal

positive impact on health as growth allows individuals to spend more income on their health and have access to better living conditions. Better health outcomes may lead to life expectancy gains which can increase the size of the older population. The reverse causality relationship is explained in more detail by Fumagalli et al. (Fumagalli, et al., 2024).

The findings from a recent meta-regression analysis study found that a failure to account for endogeneity can cause an upward bias in result estimation for papers focusing on health and economic growth (Ridhwan, et al., 2022). To help inform whether endogeneity is present, a granger-causality test was conducted to assess whether there is a reverse causal relationship between an ageing population and economic growth, the same test was conducted on government health expenditure and economic growth. Both tests identified that reverse causality was present further supporting the need for this paper to address endogeneity.

To account for endogeneity, an instrumental variable method was employed. An instrumental variable is uncorrelated with the error term and correlated with the endogenous variable (Wooldridge, 2013). In Yang et al.'s study, the lag of both the ageing population and health expenditure variable is used as their instrumental variables. This is replicated in this model but with a lag of government health expenditure being taken instead. These instrumental variables are taken forward and used in a TSLS regression specification which is shown below in figure 5.

To explain the TSLS method, the specification is split into two stages. The first stage is used to estimate the impact that the control variables have on the endogenous variables. In this case there were two endogenous variables therefore two regressions were run. The first regression obtains the fitted values of the ageing population variable after using the lag of the ageing population as the instrumental variable and the second regression does the same but for government health expenditure.

The second stage of the regression regresses the log of GDP per capita against the fitted values from both equations along with the additional control variables. Both a time trend (T) and unit index variable (I) are included in the model to control for unobserved heterogeneity across units and time. The model specification also includes the interaction between an ageing population and government health expenditure (GOVAGE). This inclusion allows for further study of the combined effect both variables have on economic growth which is important in allowing this paper to investigate whether government health expenditure can be an appropriate policy tool to deal with an ageing population.

Figure 5 – Model Specification

First-stage:

(1) $\mathbf{AGE} = B_1\mathbf{AGE}_{-1}+B_2\,\mathbf{SQUAGE}+B_3\mathbf{INF}+B_4\mathbf{POP}+B_5\mathbf{TRADE}+B_6\mathbf{INV}+B_7\mathbf{FDI}+B_8\mathbf{LFP}+B_9\mathbf{GOVAGE}+B_{10}\mathbf{I}+B_{11}\mathbf{T}+\boldsymbol{\varepsilon}_1$

(2) $\mathbf{GOVHEA} = B_1\mathbf{GOVHEA}_{-1}+B_2\,\mathbf{SQAGE}+B_3\mathbf{INF}+B_4\mathbf{POP}+B_5\mathbf{TRADE}+B_6\mathbf{INV}+B_7\mathbf{FDI}+B_8\mathbf{LFP}+B_9\mathbf{GOVAGE}+B_{10}\mathbf{I}+B_{11}\mathbf{T}+\boldsymbol{\varepsilon}_2$

Second stage:

(3) $\mathbf{LNGDP}=\hat{}B_1\mathbf{GOVHEA}+\hat{}B_2\mathbf{AGE}+B_3\mathbf{SQAGE}+B_4\mathbf{INF}+B_5\mathbf{POP}+B_6\mathbf{TRADE}+B_7\mathbf{INV}+B_8\mathbf{FDI}+B_9\mathbf{LFP}+B_{10}\mathbf{GOVAGE}+B_{11}\mathbf{I}+B_{12}\mathbf{T}+\mathbf{u}$

After running the TSLS model, several tests were conducted to check the robustness of results. The first test was a Durbin-Wu-Hausman test for endogeneity. The null hypothesis is that the regressor is exogenous and that an OLS is the correct specification to be using. In all cases the null hypothesis was rejected at the 5% confidence level. This confirmed that the TSLS model is the correct specification to take forward. The second test was the Cragg-Donald F-test which measured the strength of the instrumental variables. In all selected models the F-statistic was greater than 10 which indicated that the instruments are strong.

Tests for heteroskedasticity and autocorrelation highlighted that both were present in the final models. This meant that the error term does not have constant variance and that the errors are correlated with each other, both of which violate the classical OLS assumptions. To correct for this and to ensure robust results, panel-corrected standard errors (PCSE) was applied. PCSE standard errors are robust to both unit heteroskedasticity and possible contemporaneous correlation across the units (Bailey & Katz, 2011). All these steps ensure that the final model is BLUE (Best, linear, unbiased estimator).

5. Results

The conclusions from the methodology section are that the most robust specification to use is a log-linear TSLS model. This model contains a unit index variable and a time trend to factor in unobserved heterogeneity and includes robust standard errors. Table 2 outlines the outputs of six models that use the preferred specification to test causality. There are two models for each dataset, one model that includes an interaction variable and one that does not. These two

models are run on the full sample of countries, a subset of developed countries and a subset of developing countries.

Table 2 – TSLS Regression results[1] [2]

	Full Sample		Developed countries		Developing countries	
	Model 1	**Model 2**	**Model 3**	**Model 4**	**Model 5**	**Model 6**
GOVHEA	**0.277****	**0.284*****	**0.129*****	**0.343*****	**0.218*****	**0.195*****
	(0.016)	**(0.024)**	**(0.009)**	**(0.085)**	**(0.017)**	**(0.046)**
AGE	**0.357*****	**0.356*****	**0.091*****	**0.073*****	**0.651*****	**0.649*****
	(0.193)	**(0.020)**	**(0.024)**	**(0.028)**	**(0.041)**	**(0.041)**
SQAGE	**-0.011*****	**-0.011*****	**-0.002*****	**0.001**	**-0.030*****	**-0.030*****
	(0.001)	**(0.001)**	**(0.001)**	**(0.001)**	**(0.002)**	**(0.002)**
INF	**-0.003***	**-0.003***	**-0.038*****	**-0.037*****	**0.000**	**0.000**
	(0.002)	**(0.002)**	**(0.007)**	**(0.007)**	**(0.002)**	**(0.002)**
POP	**0.244*****	**0.246*****	**0.372*****	**0.387*****	**0.249*****	**0.245*****
	(0.036)	**(0.037)**	**(0.035)**	**(0.033)**	**(0.045)**	**(0.047)**
TRADE	**0.004*****	**0.004*****	**-0.001*****	**-0.001*****	**0.007*****	**0.007*****
	(0.000)	**(0.000)**	**(0.000)**	**(0.000)**	**(0.000)**	**(0.000)**
INV	**0.008*****	**0.008*****	**0.004**	**0.006**	**0.003**	**0.003**
	(0.002)	**(0.002)**	**(0.004)**	**(0.004)**	**(0.002)**	**(0.002)**
FDI	**-0.001**	**-0.001**	**0.001****	**0.001****	**-0.016*****	**-0.016*****
	(0.001)	**(0.001)**	**(0.000)**	**(0.001)**	**(0.004)**	**(0.003)**
LFP	**0.000**	**0.000**	**0.041*****	**0.039*****	**-0.004*****	**-0.004*****
	(0.016)	**(0.001)**	**(0.002)**	**(0.002)**	**(0.001)**	**(0.001)**
GOVAGE		**-0.000**		**-0.013*****		**0.004**
		(0.024)		**(0.005)**		**(0.007)**
TIME	**-0.002**	**-0.002**	**-0.012*****	**-0.012*****	**0.005*****	**0.005*****
	(0.001)	**(0.001)**	**(0.002)**	**(0.002)**	**(0.001)**	**(0.001)**
UNIT	**-0.003*****	**-0.003*****	**0.000***	**0.000****	**-0.005*****	**-0.005*****
	(0.000)	**(0.000)**	**(0.000)**	**(0.000)**	**(0.000)**	**(0.000)**
Constant	**5.148*****	**5.139*****	**5.554*****	**5.079*****	**4.651*****	**4.678*****
	(0.115)	**(0.114)**	**(0.293)**	**(0.265)**	**(0.255)**	**(0.248)**

[1] Significance levels are * p<0.1, ** p<0.05, *** p<0.01.
[2] Standard errors are in parenthesis.

Observations	2,352	2,352	735	735	1,617	1,617
F stat	5144.80	5099.87	532.31	542.33	3022.78	2810.30
R^2	0.73	0.73	0.76	0.76	0.57	0.57
Durbin-Wu-Hausman p-value	0.00	0.00	0.03	0.04	0.00	0.00
Cragg-Donald F-test	16,967	3,550	3,358	170	9,679	1,987

5.1 Ageing population

To isolate the impact an ageing population has on economic growth, this paper now focuses on the results from models 1,3 and 5 where no interaction term is included. These models show a consistent significant inverted u-shaped relationship between an ageing population and economic growth at the 1% level. This is evidenced by the positive sign of the ageing population variable and the negative sign of the quadratic ageing population variable. The non-linear relationship means that at first, a rise in the size of the older population has a promoting impact on economic growth, but as the size of the older population increases, the positive impact of an ageing population on economic growth diminishes. This supports the hypothesis that as the size of the older population increases, the working-age population will shrink causing labour supply shortages and a loss of human capital. This can be detrimental to economic growth. These findings are in line with several studies, including Yang et al.'s paper who found a similar inverted u-shaped relationship (An & Jeon, 2006) (Yang, et al., 2021) (Lee & Shin, 2019).

The magnitude of the negative coefficient for the SQAGE variable is larger for developing countries, relative to developed countries, which suggests that as the size of the older population rises the diminishing returns effect will be greater. A plausible reason for this finding is that developing countries may not have the resources, like sufficient health care systems, to cope with the impacts that an ageing population has. Linked to this problem is the fact that developing countries are ageing at a much quicker rate than developed countries. This means developing countries have less time to adjust to changes in their demographic transition. A 2016 study found evidence to support this. When studying the impact of how quickly countries age, the study found that the speed of ageing diminishes the least developed economies growth

prospects more than that of developed countries (Teixeira, et al., 2016). In developing countries there are also differences in culture such as the reliance on family systems to look after the elderly (Shetty, 2012). This may cause a greater economic strain on individuals and a worsened impact of an ageing population on economic growth in developing countries. All of which support the findings from the regression results.

5.2 Government Health Expenditure

Continuing with models 1, 3 and 5, the results show that government health expenditure has a significant positive causal relationship with economic growth across these models. The results state that a 1 percentage point increase in government health expenditure as a proportion of GDP leads to a rise in per capita of GDP of 0.13% in developed countries and 0.22% in developing countries. There are three main takeaways from these results. The first is that an increase in government health expenditure has a greater impact on economic growth than what Yang et al. found for general health expenditure. This highlights the importance of the state's role in promoting economic growth through health expenditure. The second takeaway is that even when including pandemic years, a significant positive relationship between health expenditure and economic growth remains. These findings strengthen the results from pre-pandemic studies that have found a positive relationship between government health expenditure and economic growth (Ozyilmaz, et al., 2022) (Qehaja, et al., 2022). Under the assumption that greater health expenditure leads to better health, the results also support human capital theory, whereby investment in health leads to greater human capital in the form of higher productivity, lower absenteeism, and higher participation in the labour market.

The third takeaway is that the economic returns of government health expenditure is greater for developing countries. This finding can be explained by marginal benefit theory, whereby the marginal benefit of spending on health is greater in countries where the population's health is poorer. This is because developing countries have a lower starting point in terms of health which means there are greater returns that can be made with each pound of investment. This is explained in Ozyilmaz's paper from the perspective of developed countries (Ozyilmaz, et al., 2022).

5.3 Interaction Variable

When it comes to looking at the moderating impact that government health expenditure has on an ageing population the results are less conclusive. To focus on this, this paper turns its

attention to models 2,4 and 6. The interaction variable in model 4 is significant and negative. This shows that when the effects of government health expenditure and an ageing population are combined there is a slight decrease in their impact on economic growth in developed countries. In other words, the two effects weaken each other. A possible reason for this finding is that when an ageing population positively effects growth, the returns of government health expenditure are small. Therefore, additional health investment may crowd out alternative investments that yields greater returns. The return on health investment increases as the size of the older population gets larger and the impact of an ageing population on economic growth becomes negative. At this stage, government health expenditure can help weaken this negative impact through the human capital accumulation effect. This is theorised by Yang et al. who found a similar relationship (Yang, et al., 2021). However, what makes this result less clear is that the SQAGE variable become slightly positive and insignificant in model 4. This suggests that more work is needed to be done to assess the robustness of the non-linear relationship between an ageing population and economic growth in developed countries.

These outputs also suggest that an ageing population weakens the positive impact of government health expenditure on economic growth. A credible reason for this finding is that population ageing means more health investment spent on older individuals with greater health needs. It is much more likely that these individuals will not be in the workplace; therefore, the positive impact on economic growth from this health investment is smaller.

For developing countries, the interaction term's coefficient is close to zero and insignificant suggesting that the two effects do not affect each other. This indicates that the weakening effect found in model 4 and Yang et al.'s paper does not currently apply for developing countries. This result may be a consequence of developing countries being at an earlier stage of population ageing, therefore the effects they have on each other are not defined yet. Further work is needed to be done to understand the interaction effect, this could be done using more complex econometric tools such as interaction and marginal effect plots.

5.4 Robustness Tests

Several tests were conducted to test the robustness of the results of the model. The first test used a 5-year average of log GDP per capita as opposed to annual log GDP per capita to test whether the findings remained the same when accounting for short-term fluctuation in GDP. The model outputs were consistent with the final specification.

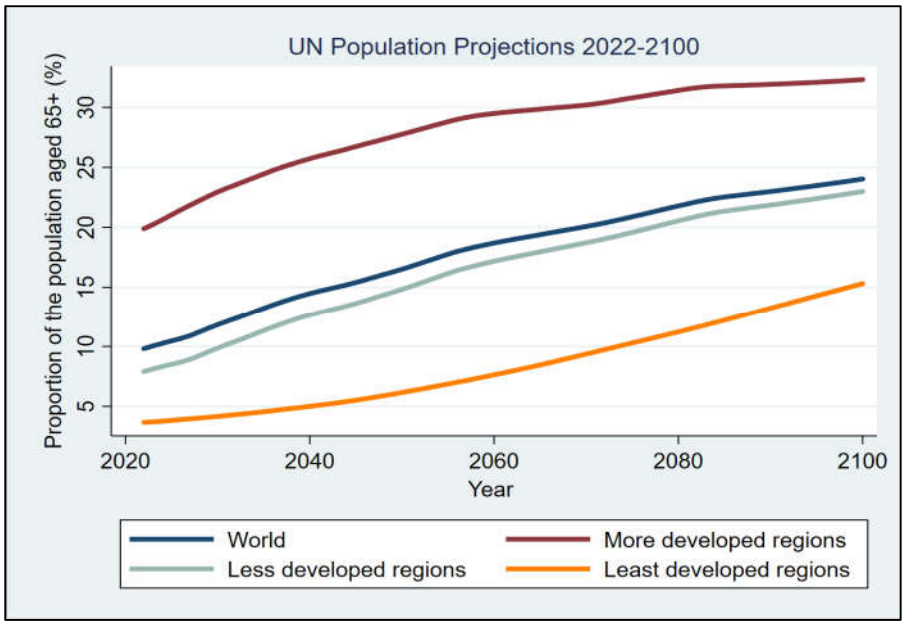
A second test replaced the ageing population variable with the old age dependency ratio. This acts as another proxy for measuring the ageing population. When running these models, a significant inverted u-shaped relationship was also found between an ageing population and economic growth. Interestingly, for the full sample of countries the interaction variable between old age dependency and government health expenditure became significant and slightly negative supporting the results from model 4.

The final test added a proxy for education to the model. The variable collected was government education expenditure as a proportion of GDP. Although there is a proportion of missing observations for this variable making the dataset unbalanced, this test was conducted to try and control for all the main components of human capital as stated in the extended Mankiw–Romer–Weil model. When including the education variable in the model, government health expenditure still had a positive and significant effect on economic growth and the coefficients remained relatively constant across the models. This suggests that even when controlling for other forms of human capital, government health expenditure still plays a key role in promoting economic growth.

6. Policy Implications

These results are of real importance to policymakers tasked with understanding the economic impacts of an ageing population. To put these findings into greater context, figure 6 illustrates using UN projections, that the size of the older population is expected to rise significantly over the next 80 years (United Nations, 2022). This suggests that countries will start to move closer to where the positive impact of an ageing population on growth diminishes and even becomes negative, highlighting the need for action from policymakers sooner rather than later.

Figure 6 – Projected estimates of the proportion of the population aged 65+



In the context of an ageing population, the results for developed countries show that extra government health expenditure could be a valuable tool to counterbalance some of the negative impacts of an ageing population. The results for developing countries are less conclusive. As the size of the older population grows, there are several other policies that could be explored to help alleviate some of the negative impacts of an ageing population. For example, a rise in immigration levels could help to mitigate the fall in labour supply that countries are facing through ageing. Another intervention could be to raise the retirement age (and access to a state pension) of the population to try and prevent older people exiting the labour market. Furthermore, greater investments in education could also soften the fall in human capital accumulation caused by ageing as could other government expenditure that indirectly improves health, an example being investment in improving working conditions. The success of these policies is dependent on the government having the correct information to target interventions to areas where population ageing is having the greatest economic impact.

Irrespective of the ageing population problem, it is important that policymakers also take note of the consistent significant positive relationship found between government health expenditure and economic growth. This highlights to policymakers that they can promote growth from investing more in the health of its population. Particularly for developing countries where the payoff from government health expenditure has been found to be greater.

7. Further Research and Limitations of Analysis

It is important with all pieces of research that the limitations of the study are acknowledged. As mentioned briefly, further work should be done to test the robustness of the non-linearity of the relationship between an ageing population and economic growth, particularly with the non-significant finding of the SQAGE variable in model 4. This can be done by looking at other econometric model specifications, such as a generalised additive model which can model non-linear relationships. Further work on non-linearity could also aim to identify at what point in the population ageing process does the impact of an ageing population become negative. This will allow policymakers to understand in more detail when government health expenditure would be useful as a policy tool in the context of an ageing population.

Another limitation is that this paper assumes that the definition of the older population is constant. Due to medical advances over the last 20 years, the average 65-year-old is healthier in 2021 than they were in 2000 meaning that their contribution to the economy is greater too. This improvement in productive capacity is not captured in this paper. In future research, one way this limitation could be addressed is by using a prospective approach to the ageing population variable based on expected years of life. This has begun to be explored by scholars (Bloom & Kotschy, 2023).

A further limitation is that the model does not capture what type of government health expenditure is most beneficial to economic growth. The choice of variable sums all government health expenditure. Therefore, it is important that further research disaggregates health spend to allow for a more detailed understanding. Though cross-country data is currently limited, a useful starting point is the OECD health system of accounts which splits health spend by both provider and category (OECD, 2013).

Finally, this research does not consider that countries have different types of health systems in place. This could impact the paper's findings. For example, the UK has a tax-based system whereas the US system is insurance-based. Research suggests tax-based systems lead to higher health expenditure relative to GDP (Ivankova, et al., 2022). Therefore, further studies splitting out countries by health system would allow policymakers to see whether different health systems cope better with the economic impacts of an ageing population.

8. Conclusion

This paper has attempted to give policymakers a better understanding of the relationship that both an ageing population and government health expenditure has with economic growth. To do this, a TSLS model was employed to test causality and to answer the three fundamental questions that were set out at the start of this paper:

1. What is the impact that an ageing population has on economic growth?
2. What is the impact that government health expenditure has on economic growth?
3. Can government health expenditure be used as a policy tool to moderate the impacts of an ageing population on economic growth?

Unlike previous literature in this area, this paper has focused on findings for both developed and developing countries and has extended the time period of the data to give a current and accurate assessment.

This paper found that the relationship between an ageing population and economic growth is an inverted u-shape whereby there is an original positive effect of an ageing population on economic growth. However, this positive effect diminishes as the size of the older population increases. With the pattern of population ageing set to continue, these findings indicate that the future effect of an ageing population is likely to harm economic growth prospects regardless of a country's development level.

In answer to the second question, this paper found that government health expenditure has a significant positive effect on economic growth. This finding supports the idea that investment in health can be a useful tool in promoting economic development. The results show that the payoff of investing in health for developing countries are greater than developed countries, thus providing strong rationale and incentives for developing countries to adopt a health-led growth strategy.

In respect of the third question on whether government health expenditure could weaken the impact of an ageing population, the answer is less clear. The significant negative findings of the interaction variable for developed countries indicate that government health expenditure weakens the impact an ageing population has. This is insightful for policymakers as it indicates in developed countries that government health expenditure could be a useful policy tool. Though this tool should be used carefully given the risk of crowding out other investment whilst the impact of an ageing population on economic growth is still positive. More work is

needed to understand when the right time in the population ageing process would be to employ this policy tool. For developing countries, a non-significant interaction effect suggests that the joint impact of an ageing population and government health expenditure on economic growth is currently not apparent. Further work should test the robustness of this finding further.

Although more work is still needed to be done to fully understand the relationship between these variables, this paper provides useful findings that can aid policymakers in understanding and navigating through the economic challenges that an ageing population presents.

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