



# Linkages between Economic Growth and Population Ageing with a Knowledge Spillover Effect

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## Abstract

Currently, the natural demographic process ageing becomes a worldwide phenomenon. The United Nations recognizes any country as “ageing” or “greying nation” if the share of the elderly in the total population of the concerned nation exceeds 7%. According to census 2001 and 2011, 7.47% and 8.60%, respectively, of Indians were elderly. Thus, the ageing process in India was initiated since 2001. Undoubtedly, it has a serious implication on the economic growth process. With this backdrop, the present study aims to investigate the linkages between population ageing and economic growth in India. In conjunction with this, the study also explores the ascendancy of the knowledge spillover on the footprint of population ageing on economic growth in India. The study is based on the “World Bank” data. The standard econometric tool of “Granger causality test” based “VECM” setting is utilized to scrutinize the unidirectional causality between ageing and economic growth. The empirical results divulge that population ageing is negatively related to economic growth. But interestingly, “knowledge spillover” can effectively marginalize the adverse consequences of population ageing on economic growth. The originality of the study is not only in orchestrating the problem but also propounding the potential solution to cope with the scar of ageing on the economy. Moreover, the study is unique in itself as it considers the globally recognized young economy, India, to find the connotation of population ageing on economic growth. Because of that, the furnished solution is applicable to all countries irrespective of their demographic and economic position.

**Keywords** Economic growth · Population ageing · Knowledge spillover effect · Granger causality and VECM

**JEL Classification** C5 · J1 · J14 · J18 · O4

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## An Overview

India has experienced more distinct economic growth in the last few decades. According to the World Bank (2018), India will continue to remain the fastest-growing major economy in the world in 2018–2019. During the ongoing financial year, 2018–2019, India's gross domestic product (GDP) is expected to grow at the rate of 7.3%, while China expects to register a much lower growth rate, viz., 6.3%. The Indian economy is regaining after a temporary slowdown due to demonetization and the implementation of “goods and services tax” (GST) (World Bank 2018). Both higher consumption and investment play as a catalyst for India's remarkable economic growth. Nevertheless, the issue of the impact of demographic age structure on India's economic growth gets less attention as India has not yet become an ageing society.

Population ageing is the worldwide phenomenon, and it escalates with the increasing life expectancy and declining fertility rate. The growing share of the elderly persons (60 and above for developing country and 65 and above for developed nations) in the total population contributes to population ageing (Ram 2016). Coulmas (2007) recognizes three types of veteran society, viz., “ageing society” if 7–13% of the population is 65 years or older; “aged society” if 14–20% of the population is 65 years or older; and “hyper-aged society” if 21% or more of the population is 65 years or older. The “United Nations Population Foundation (UNPF)” (2015) pinpoints that the elderly share in the total global population was 12.3% in 2015 and the “UNPF” prognosticates that by 2050, the figure will become almost 22%. Originally, population ageing was developed nations phenomenon. However, the process is now rapidly approaching to the developing world, and where India is not an exception. In India, the process of population ageing has started gradually (Bloom et al. 2010), and it is relatively faster in developed states than developing states due to irrelative variation in the level of economic development (Acharjee and Dutta 2013).

India is the second most populous country in the world, with 1.2 billion populations (Census of India 2011). The proportion of the elderly in the total population was 8.3% (Census of India 2011) and which is expected to reach 12.6% in 2025. The age profile of the Indian population indicates that most of the people are young in India. India is recognized as the largest contributor to the world demographic transition (Wilson 2001). But if you take into consideration the actual figure of the veteran population, the figure turns out 10 cores (Census of India 2011). This figure is much higher than the total population of many countries, viz., Portugal, Jordan and the United Arab Emirates. The increasing share of the aged population has a serious implication on the type of elderly living arrangements and health status (Rajan and Kumar 2003). Moreover, it also affects the economic growth of the country through changes in the pattern of saving and consumption, health expenditure and labour force participation (Bloom et al. 2010).

Many studies have been undertaken to understand the association between population ageing and economic growth. Most of the literature argued that there is a negative relationship between population ageing and economic growth (Walker 1990; Guest 2008; Narciso 2010; Bloom et al. 2010; Daniele et al. 2019). On the contrary, some researchers like Fougère and Mérette (1999), Lee et al. (2011) and Prettnner (2012) claimed the existence of a positive effect. According to them, older people tend to save more, and so there is a possibility of more resources available for investment, which impacts the growth positively. The footprint of ageing on income is dynamic and heterogeneous

across nations (Cuaresma et al. 2014). The impoverished economies are more vulnerable to the greying process compared with the developed nation (Cuaresma et al. 2014). Nagarajan et al. (2016) pursued a comprehensive literature survey on the consortium between population ageing and economic growth and conceded dichotomous outcomes. The complex relationship between population ageing and economic growth largely depends on the nature and the mechanics of the specified variables. For example, the studies that focus on the “public social expenditure” convey a negative impact of ageing, while the studies that focus on the “human capital” and “consumption and saving patterns” mechanism experience an insignificant and positive impact of ageing respectively (Nagarajan et al. 2016). Recently, Acemoglu and Restrepo (2019) scrutinize the aftermath of population ageing on economic growth and conclude no negative relationship between population ageing and growth of GDP per capita. The authors pinpoint that in the epoch of automation, the negative footprint of ageing would be counterpoised.

In aggregates, earlier researches on the evaluation of population ageing footprint on economic growth mainly concentrate on theoretical perspectives and fail to draw any ubiquitous conclusion. The relationship varies across countries and also varies with the selected mechanism. In fact, there is a dearth of an empirical study to examine the specific issue of the aftermath of ageing on economic growth. In addition, the issue of whether the knowledge spillover can take care of the footprint of population ageing on economic growth is also not probed properly in India. Thus, this study is the first of its kind to explore the linkages between population ageing and economic growth with a knowledge spillover effect in India. This backdrop motivates us to concentrate on probing the research question that whether the knowledge spillover can take care of the footprint of population ageing on economic growth in India. Thus, the objective of this paper is twofold, initially, to find out the impact of population ageing on economic growth in India and then to incorporate the consequence of the knowledge spillover on the linkages between economic growth and population ageing in India.

The paper is organized as follows: the “[Conceptual Framework](#)” section analysed the conceptual framework of the study. The “[Data and Econometric Model](#)” section enlists the data source and outlines the adopted methodologies of this study. The research objectives are investigated in the “[Results](#)” section. The “[Discussion](#)” section presents the discussion of the results, and the “[Conclusion and Policy Prescription](#)” section concludes the study and suggests the induced policy measures.

## Conceptual Framework

The relationship between population ageing and economic growth is a critical one. There is no consensus among the authors regarding the direction of this relationship. Most of the literature advocates in favour of the existence of a negative relationship between population ageing and economic growth (Narciso 2010; Bloom et al. 2010). According to them, an increase in the share of the aged population in the total population affects both government’s earnings and expenditures. With a greater share of retired persons obviously, the government’s revenue earning from direct taxes will become low. On the contrary, the government needs to pay attention to the veteran healthcare, pension system and other old age-related benefits. This action will increase government expenditures. It also impacts economic growth negatively by decreasing the number of labour force.

In contrast, some authors, such as Prettner (2012) and Lee et al. (2011), advocate an alternative thought. They claim the existence of a positive relationship between population ageing and economic growth. They argue that elderly individuals used to save more and thus create more resources available for investment. Patently this will positively influence the economic growth rate. A longer life span will further enable investment in research and development (R&D). Therefore, the savings as well as the time span of savings will increase with an increase in longevity. The increase in savings will positively influence investment, particularly in R&D. The investment in R&D is consensually recognized as the engine of economic growth (Aghion and Howitt 1990).

It is unanimously accepted that “ageing” is the natural process of demographic transition. The indispensable question is that within the ageing environment, how can we sustain the economic growth process? Here also, no single solution is furnished by the earlier researchers. Bloom et al. (2010) recommend the postponing of the retirement age and legalization of immigration to overcome the decrease in the labour force. Another view is that countries can sustain economic growth despite the ageing problem through technological innovation. For instance, Elgin and Tumen (2010) state that with a decline in human capital, the economy will switch from traditional production (that uses young workers) to new human capital oriented production (that uses old-age workers). Therefore, in this line of argumentation, an ageing population will affect neither the production nor the growth dynamics. Furthermore, Elgin and Tumen (2010) also argue that modern economies rely more on machines than labour force. Therefore, a fall in the labour force will not affect productivity. The lack of uniformity in the conclusion of the relationship between population ageing and economic growth as well as the solution to the ageing problem motivates us to conduct this study for India. We consider India, as it is the “largest individual contributor to the global demographic transition” (Demographic Dividend, Wikipedia 2019). The uniqueness of the study is that we have considered a not so old economy; rather, India is globally recognized as the young and developing economy. Again, in this paper, we have furnished the solution of the ageing problem applicable to all countries irrespective of their demographic and economic position.

The complex relationship between population ageing and economic growth can only be understood through three mechanisms: consumption and saving patterns, public social expenditure and human capital. Based on the various literatures, the relationship between population ageing and economic growth are depicted by a flow chart in Fig. 1.

Figure 1 discloses that there is a two-way relationship between population ageing and economic growth. Firstly, with the process of economic growth, the literacy rate and health facilities improve, which results in a decline in fertility rate and an increase in life expectancy. This ultimately increases the share of older adults in the total population. Secondly, population ageing impacts economic growth through three mechanisms: consumption and saving patterns, public social expenditure and human capital. First of all, the ageing population will prompt changes in saving and consumption patterns such as higher demand for health services and lower demand for luxury goods. Such changes in the demand for goods and services will influence the economic growth of a country. Again, the rise in the ageing population will affect government revenue from taxes and leads to an increase in government expenditure, especially on healthcare, for supporting the pension system and other old age-related benefits. Finally, an increase in the share of the aged population in the total population decreases the number of working adults (within the age group 15–59). This reduction in the labour force will influence economic growth negatively.

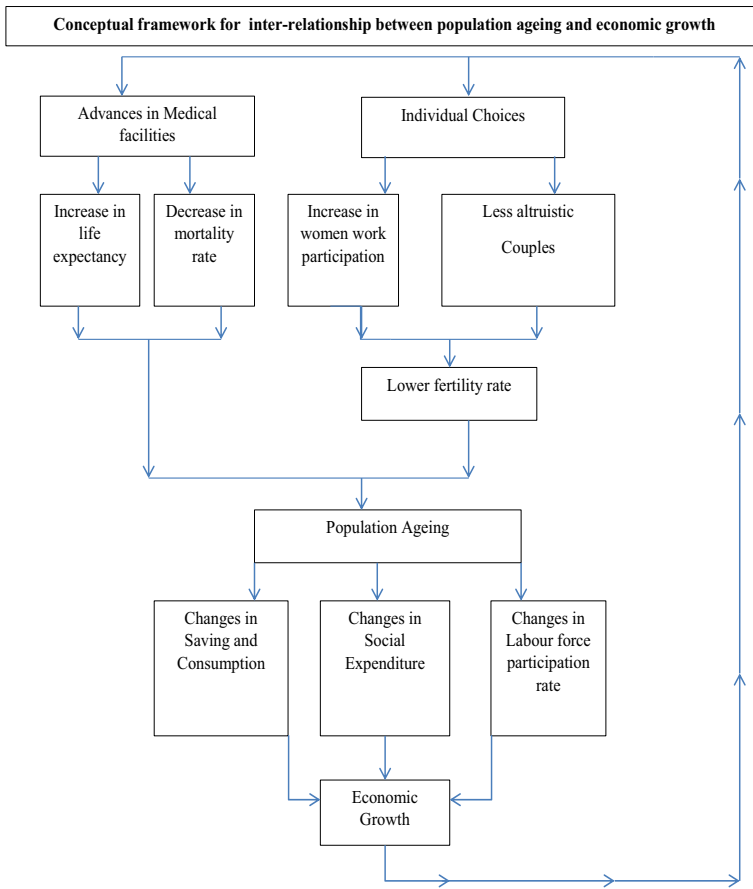


Fig. 1 Conceptual framework for inter-relationship between population ageing and economic growth

If we believe in the conventional view of the negative linkages between population ageing and economic growth, then our immediate concern is how to contrive with such situation. As population ageing is a natural demographic phenomenon and we cannot compromise with economic growth also, then we are compelled to find out a solution. Earlier literature on “economic growth with human capital” (Harrod 1948; Uzawa 1965; Rosen 1976; Romer 1986, 1990; Lucas Jr 1988) anticipate some solutions to the problem through “knowledge spillover”. However, the issue of whether the “knowledge spillover” can take care of the footprint of population ageing on economic growth does not receive more attention, particularly in the case of India. An attempt has been made to fulfil the mentioned research gap in the present paper.

### Data and Econometric Model

In this section, we are going to discuss the data sources, descriptions of the concerned variables and econometric model to address the said objectives.

## Data

This empirical study exclusively relies on secondary data sources. The study period of the present paper is from 1988 to 2016, both inclusive. The availability of data restricts the time span of the current study. The data on age and sex of the population are compiled from the World Bank and Census of India. The main interest variable, viz., the proportion of the elderly population is retrieved from the World Bank Development Indicators. The World Bank provides three categories of data based on the age groups, scilicet, 0–14 years, 15–64 years and 65 and above years. According to the United Nations for India and other developing countries, the age group 60 and above are considered elderly population, unlike developed countries where 65 and above aged population are contemplated as senior citizens. As the definition of ageing is different in India (proportion of 60 and above) we have re-calculated the data for the age groups 0–14 years, 15–59 years and 60 and above years separately. The population of 60 and above years is calculated simply by adding the population of 60–64, 65–69, 70–74, 75–79 and 80 and above years of the information provided by World Bank. Subsequently, to get the proportion of the aged population, we divide 60 and above years population to total population. The data on real GDP (constant) as a proxy of economic growth is compiled from the World Bank. The control variables, viz., urbanization, manufacturing export and medium and high tech export, are also compiled from the World Bank. Finally, data on social expenditure and per capita deposit bank account are collected from the Reserve Bank of India (RBI). Thus, the lists of the secondary data sources utilized for this study are as follows:

1. Census of India
2. World Bank
3. Reserve Bank of India (RBI)

## Variables

For the inquiry into the first objective, we have considered “real GDP (RGDP)” and “population ageing (AGE)” as the effect and cause variables, respectively. Again, the growth rate of “real GDP (RGDP)” also depends on several other variables. Hence, along with cause variables, to capture these effects, we have considered various control variables, viz., “openness index (OI)”, “per capita deposit bank account (PDBAC)”, “per capita social expenditure (PSE)”, “urbanization (URBA)” and “manufacturing export (MANFEX)” (see Table 2 for details) for the first model.

However, this is not the sole objective of this study. Along with this, our aim in this paper is to scrutinize the consequence of the knowledge spillover on the linkages between economic growth and population ageing in India. Thus, a variable representing “knowledge spillover” is highly required. In this model following Romer (1989), we have assumed that knowledge has two components, viz., human capital and technology. The supply of human capital or skilled labour is fixed (Romer 1989). The available technology is not fixed, and technological innovation can be achieved by engaging human capital in research over the existing technology (Romer 1989). Because of the lack of data on human capital, we consider the “medium and high technology export” as an indicator and/or proxy of knowledge of the country. Again,

we assume that technology is non-rival so that the discoverer of new technology will not be the sole beneficiary of that discovery. There will be knowledge spillovers, and others will also use the new technology (Romer 1989). Hence, by engaging skilled labour or human capital one country can achieve an enhancement in the existing technology or through “knowledge spillover” the country can manoeuvre the refining technology. In both cases, the application of the new sophisticated technology necessitates skilled labour or human capital. Thus, we can use the “medium and high technology export” as a proxy of “knowledge spillover” of any country including India. Accordingly, we have considered “medium and high tech export (MHTECH)” as an added control variable in the original model and call it “model 2”. The elucidation of the variables including cause, effect and control variables is presented in Table 1.

### Econometric Model

The investigation of the impact of population ageing on economic growth means the interrogation of the unidirectional and/or bidirectional causal relationship between population ageing and economic growth in India. The most appropriate technique, in this case, is the “Granger causality test (Granger 1969)”. In brief, this test comprehends us that if past values of  $x$  statistically improve the prediction of  $y$ , then we can conclude that  $x$  Granger causes  $y$  and vice versa (Granger 1969). The available control variables authorize us to explore unidirectional causality between economic growth and population ageing. Thus, we specify our model as follows:

$$\text{GDP}_t = \alpha + \sum_{i=1}^n \beta_i \text{GDP}_{t-i} + \sum_{j=1}^m \gamma_j \text{PA}_{t-j} + u_t \quad \forall t = 1, 2, \dots, T \quad (1)$$

where GDP stands for “gross domestic product”, PA means “population ageing” and the white noise error component is presented by  $u_t$ . As the paper is exploring twin objectives, viz., first, scrutinizing the causal relationship between economic growth and population ageing and then uncovers the effect of “knowledge spillover” on the causal relationship between economic growth and population ageing, hence, we have used two “Granger Causality Model”. In model 1, we drop “medium and high tech export (MHTECH)” as one of the controls variables, and the impact of knowledge spillover is executed in the second model by considering “medium and high tech export (MHTECH)” as an added control variable. The technological progress is assumed to be neutral in the “Harrod” sense (Harrod 1948).

### Results

In this section, we are going to discuss the empirical results of the study.

#### Age-Wise Distribution of Population in India

Population ageing is one of the serious issues in the recent period. “Many developed countries are approaching an era of ageing populations due to an increase in longevity, a decrease in mortality rates and a decrease in fertility rates” (Harper and Leeson 2009).

Table 1 Lists of variables

Variables	Definition	Variable type	Model 1: Causal relation between economic growth and population ageing	Model 2: Causal relation between economic growth and ageing with knowledge spill over effect
Real GDP (RGDP)	GDP at purchaser's prices is the sum of gross value added by all resident producers in the economy plus any product taxes and minus any subsidies not included in the value of the products. It is calculated without making deductions for depreciation of fabricated assets or for depletion and degradation of natural resources. Data are in constant 2010 US dollars	Effect		
Population ageing (AGE)	Population ages 65 and above as a percentage of the total population	Cause		
Openness Index (OI)	It shows the extent of trade openness. The index is defined as: export + import/real GDP. It is an indicator of globalization and liberalization	Control		
Per capita Deposit bank A/C (PDBAC)	It shows number bank A/C per person	Control		
Per capita social expenditure (PSE)	Share of GDP spent on social sector like education and health divided by total number population	Control		
Urbanization (URBA)	Percent of population live in the urban areas	Control		
Manufacturing export (MANFEX)	Manufactures exports (% of merchandize exports). It comprises commodities in SITC sections 5 (chemicals), 6 (basic manufactures), 7 (machinery and transport equipment) and 8 (miscellaneous manufactured goods), excluding division 68 (non-ferrous metals)	Control		
Medium and high tech export (MHTECH)	Share of medium and high tech manufactured exports in total manufactured exports. High technology exports are products with high R&D intensity, such as in aerospace, computers, pharmaceuticals, scientific instruments and electrical machinery	Control		

Source: Authors' own specification based on the World Bank data and RBI data



“The decline in population growth has been visible since the mid-1970s when the adult working-age population in several countries outpaced child population” (Mason and Lee 2011). The process is now rapidly approaching the developing world, and where India is not an exception. Table 2 represents the age-wise distribution of the population of India. It is seen from Table 2 that the share of the 60 and above population in the total population has increased from 5.27 to 9.38% and the share of 15–59 age group increased from 56.63 to 65.99% during 1960 to 2017, while at the same time the share of the 0–14 age group decreases from 40.3 to 28.19%. Population ageing is directly reflected in population cohort, and it was more or less static in the pre-independence period. But in recent times the cohort suggests that the share of people of age 60 and above started increasing from the early years of the last century.

The table divulges that India economy is gradually approaching to the elderly economy. This then justifies undertaking this study.

### Summary Statistics: Causal and Control Variables

The study period for this paper covers from 1988 to 2016 inclusive (29 years). An overview of the variables incorporated for the study can be envisaged by considering the summary statistics. The result is furnished in Table 3.

An inspection of the table corroborates that during the study period approx., 6 per cent of the total population is the elderly population with maximum percentage is approx., 9 per cent. In fact, according to the United Nations, if 7% of the total population is elderly, then the corresponding economy is analogous to the elderly economy (Uddin et al. 2013). This figure ensures that India, although individually is recognized as the largest contributor to the global demographic transition, gradually is entangling in the ageing economy. This

**Table 2** Age-wise distribution of population in India (in percentage)

Year	Age group			Percentage
	0–14	15–59	60 and above	
1960	40.3	54.42	5.27	100
1965	41.41	53.25	5.34	100
1970	40.84	53.6	5.54	100
1975	40.06	54.24	5.69	100
1980	39.24	54.9	5.85	100
1985	38.72	55.3	5.97	100
1990	37.92	55.93	6.14	100
1995	36.62	56.91	6.46	100
2000	34.73	58.37	6.89	100
2005	32.78	59.94	7.26	100
2010	30.89	61.3	7.80	100
2015	28.65	62.42	8.91	100
2017	27.78	62.83	9.38	100

Source: Authors’ own calculation based on the World Bank data

**Table 3** Descriptive statistics

Variables	Mean	Median	Maximum	Minimum	SD	Observations
Real GDP (RGDP)	1.10E+12	8.73E+11	2.46E+12	4.17E+11	6.16E+11	29
Population ageing (AGE)	6.43	6.07	9.16	5.28	1.01	29
Openness index (OI)	0.34	0.29	0.58	0.15	0.14	29
Per capita deposit bank A/C (PDBAC)	0.52	0.41	1.25	0.35	0.23	29
Per capita social expenditure (PSE)	4.55	3.55	11.03	1.43	3.03	29
Urbanization (URBA)	28.63	28.24	33.14	25.06	2.45	29
Manufacturing export (MANFEX)	70.85	72.04	79.20	61.88	5.12	29
Medium and high tech export (MHTECH)	22.93	21.55	34.00	16.09	5.14	29

Source: Author's own calculation based on the World Bank data and RBI data

rationalizes as well as motivates us to attempt the study. The table also divulges that on average, Indians possess one bank account. On average 5% and maximum 11% of the total GDP is spent on the development of the social sector, involving spending on health and education. It is noteworthy that health and education are conceded as the fundamental ingredients of human capital development and accumulation. The table also confirms that almost 70% of the total population is living in the rural and suburban areas (29% in urban areas). The percentages of manufacturing and medium and high tech export are on average of approximately 71 and 23 of total merchandize export. In this study, we have considered “medium and high tech export” as the proxy for “knowledge spillover” and thus are one of the paramount variables in this study.

Before executing any estimation, it is necessary to check the “stationarity” of the variables; otherwise, the results could not be used for prediction as well as for policy prescriptions. The stationarity of the time series is tested by using “Phillips-Perron” (PP) unit root tests as “Phillips-Perron” (PP) test has greater power than the Augmented Dickey and Fuller (ADF) test (Banerjee et al. 1993). Another advantage of the PP tests over the ADF test is that the PP tests are robust to general forms of heteroskedasticity in the error term (Phillips and Perron 1988). Besides, unlike the ADF technique, the user does not have to specify a lag length for the test regression in the PP technique (Debnath and Roy 2012). The result of the unit root test on the natural logarithms of real GDP and ageing population is presented in Table 7 in the Appendix. An inspection of the table discloses that both the series are non-stationary at level (the null hypothesis of unit root is not rejected). But the first differences of both variables are found to be stationary. This means that all the variables are not integrated of order zero, that is, stationary. Thus, the test of co-integration is necessary. This is so because even if the variables are non-stationary, they may not be co-integrated and if so then the “Granger causality” test may give misleading results.

### Johansen Co-integration

In order to understand the co-integration relationship between real GDP and population ageing, we have orchestrated Johansen co-integration test. For this purpose, we have

considered two models: one without knowledge spillover effect and another by considering “medium and high tech export (MHTECH)” as a proxy of a knowledge spillover effect. The result of Johansen co-integration test is presented in Table 4.

A close perusal of Table 4 reveals that the null hypothesis of no co-integration is rejected at 1% level of significance for rank 0 in both the models. This implies that although real GDP and the ageing population processes are individually non-stationary but their combined effect is stationary, that is, they are co-integrated. Further, it is also implied that there is at least one direction of the relationship between real GDP and the ageing population in the long run.

However, the long-run relationship between the variables merely shows the degree of association, but we cannot say anything about the direction of the relationship through Johansen co-integration test. This implies that this test does not allow us to draw a concrete conclusion about the direction of the causal relation, that is, we cannot say whether real GDP causes ageing population or ageing population causes real GDP. So we have used Granger causality tests to examine the direction of linkage among the variables. It is noteworthy that within the framework of the vector auto regressive (VAR) system with co-integrated variables, the Granger causality test must be conducted in a vector error correction model (VECM) setting (Greene 2008). This approach, besides showing the direction of Granger causality among the variables, enables us to distinguish between “short-run” and “long-run” Granger causality.

### Vector Error Correction: Linkage Between Population Ageing and Economic Growth in India

We now contemplate the analysis of the empirical relationship between economic growth and population ageing in India. Since economic growth is influenced by several factors other than population ageing, we selected only those variables for which an association with economic growth was supported by the literature. The initial sets of explanatory variables included are the following: real per capita social expenditure; openness index; per capita deposit bank account; and share of agricultural GDP. We then examined the associations between each of these variables with the dependent variables, and the variables that are found to be insignificant and redundant are excluded from the models. For VECM estimation, we have considered two models:

**Table 4** Johansen co-integration test

	Rank	Eigen value	Trace statistic	Probability**	Max-Eigen statistic	Probability**
Model 1	None ( $r=0$ )	0.568352	21.24853	0.0061	21.24827	0.0034
	At most 1 ( $r \leq 1$ )*	1.03E-05	0.000267	0.9890	0.000267	0.9890
Model 2	None ( $r=0$ )	0.677004	29.38628	0.0002	29.38299	0.0001
	At most 1 ( $r \leq 1$ )*	0.000127	0.003293	0.9525	0.003293	0.9525

Source: Authors' own calculation based on the World Bank and RBI data

\*Rejection of the hypothesis at the 0.05 level

\*\*MacKinnon-Haug-Michelis (1999)  $p$  values

one without knowledge spillover effect and another by considering “medium and high tech export (MHTECH)” as a proxy for the knowledge spillover effect. Thus, final equations for the VECM are as follows:

Model 1:

$$\Delta \ln \text{GDP}_t = \alpha + \sum_{i=1}^n \beta_i \Delta \ln \text{GDP}_{t-i} + \sum_{j=1}^m \gamma_j \Delta \ln \text{PA}_{t-j} + \vartheta \text{ECM}_{t-1} + \phi \ln \text{OI}_t + \ln \text{PDBAC}_t + \varphi \ln \text{PSE}_t + \psi \ln \text{URBA}_t + \theta \ln \text{MANFEX}_t + u_t \quad (2)$$

Model 2:

$$\Delta \ln \text{GDP}_t = \alpha + \sum_{i=1}^n \beta_i \Delta \ln \text{GDP}_{t-i} + \sum_{j=1}^m \gamma_j \Delta \ln \text{PA}_{t-j} + \vartheta \text{ECM}_{t-1} + \phi \ln \text{OI}_t + \ln \text{PDBAC}_t + \varphi \ln \text{PSE}_t + \psi \ln \text{URBA}_t + \theta \ln \text{MANFEX}_t + \delta \ln \text{MHTECH}_t + u_t \quad (3)$$

where GDP represents real per capita GDP and PA represent a share of 60 and above population in the total population. The control variables OI, PDBAC, PSE, URBA, MANFEX and MHTECH represent openness index, per capita deposit bank A/C, per capita social expenditure, urbanization, manufacturing export and medium and high tech export respectively (see Table 2 for details descriptions of the selected variables). It is noteworthy, that according to AIC and SIC the selected lag-length is 1 (see Table 8). Finally, the result of Granger causality based on VECM is presented in Table 5.

In Table 5, we begin with the short-run relationship between population ageing and economic growth. The estimated results contemplate that the coefficients of population ageing are not statistically significant in both model 1 and model 2. This implies that there is no short-run relationship between population ageing and economic growth in India.

Among the control variables, the coefficient of openness index is negative and significant in both model 1 and model 2. This implies that the openness index hurts the economic growth in India. This may be because India was specialized in the production of the low-quality product instead of a high-quality product (Hausmann et al. 2007). On the contrary, the positive and significant coefficient of urbanization indicated that it affects economic growth positively. This is because with the increase in urbanization, more businesses will open up which increases the employment opportunity and it ultimately increases income (Nguyen and Nguyen 2018).

Similarly, manufacturing export positively impacts the economic growth in India. This is true from the fact that the coefficient of manufacturing export is positive and significant in both model 1 and model 2. This may be because the manufactured exports can promote high rates of investment into profitable economic activities by fostering closer connections with international firms using leading-edge technologies. Besides, its markets allow labour and capital to move rapidly from low to high productivity sectors without encountering diminishing returns (Torayeh 2011). As expected, the public sector expenditures have a positive impact on economic growth, and it is reflected by the positive and significant estimated coefficient of the variable. The result is quite obvious because the public sector expenditures can be viewed as the investment in human capital through the development of the education and the health sectors of the economy. Increase in public sector expenditures means improvization in human capital accumulation. Higher human capital accumulation greater will be the economic growth rate (Furceri and Zdzienicka 2011). The most interesting result is obtained for the coefficient of the “medium and high tech export”.

**Table 5** Vector error correction model—linkage between population ageing and economic growth in India

Variable	Effect		Cause		ECT	t-stat	Control variables	Coefficient	t-stat
	Real GDP (LRGDP)	Population ageing (LAGE)	Population ageing (LAGE)	Long run relation					
Model 1: Causal relation between economic growth and population ageing			2.19	-5.33**	-0.49***	-4.19	LOI	-0.09*	-1.52
							LPDBAC	0.003	0.20
							LPSE	0.15***	4.01
							LURBA	8.24***	4.46
		Constant	-35.73				LMANFEX	0.15*	1.16
		Short-run relation					Constant	-28.59***	-4.43
		D(LAGE(-1))	0.10	0.08			R <sup>2</sup>	0.70	
		D(LAGE(-2))	1.12	0.80	---	---	R <sup>2</sup>	0.50	
							Akaike AIC	-5.28	
							Schwarz SC	-4.75	
Model 2: Causal relation between economic growth and population ageing with knowledge spill over effect			2.35	-4.23**	-0.57***	-5.07	LOI	-0.13**	-2.24
							LPDBAC	0.01	0.79
							LPSE	0.14***	4.29
		Constant	34.05				LURBA	8.81***	5.50
		Short-run relation					LMANFEX	0.13*	1.16
		D(LAGE(-1))	-0.66	-0.57			LMHTECH	0.12**	2.31
		D(LAGE(-2))	1.15	0.93			Constant	30.06***	-5.43
							R <sup>2</sup>	0.78	
							R <sup>2</sup>	0.61	
							Akaike AIC	-5.52	
						Schwarz SC	-4.94		

Source: Authors' own calculation based on the World Bank data

The estimated coefficient of it is positive and significant in model 2. This suggests that the medium and high tech export affects economic growth positively. The reason for such a relationship is discussed in details in the “Discussion” section.

Moreover, if we look at the coefficient of the error component term in model 1 (–0.57) and model 2 (–0.49), it is observed that both are negative and highly significant. This suggests that there is causality running from population ageing to economic growth in the long-run and the nature of the relationship is negative. The long-run association between economic growth and the ageing population is as follows:

Model 1: A long-run relationship without knowledge spillover effect

$$\ln RGDP = 35.73 - 5.33 \ln AGE \quad (4)$$

Model-2: A long-run relationship with knowledge spillover effect

$$\ln RGDP = 34.05 - 4.23 \ln AGE \quad (5)$$

Here, we have considered two models: one is with knowledge spillover effect and another is without the effect.

Equations (4) and (5) conclude that even in India, which is recognized as a relatively young economy, economic growth and population ageing are negatively associated. However, interestingly, the negative footprint of population ageing on economic growth is reduced, –4.23, when we consider “medium and high tech export” as an added control variable. It is noteworthy that the “medium and high tech export” is considered in this paper as a proxy of the “knowledge spillover effect”. Thus, the footprint of population ageing on economic growth can only be counterpoised through “knowledge spillover effect”.

### VEC Granger Causality/Block Exogeneity Wald Tests

The investigation of the short-run causality between GDP (economic growth) and population ageing is performed by estimating the Granger Causality/Block Exogeneity Wald Tests. The test results are presented in Table 6.

Table 6 divulges that the hypothesis of the non-causality between GDP (economic growth) and population ageing is rejected in both the models in the short-run. This is reflected

**Table 6** VEC Granger Causality/Block Exogeneity Wald Tests

Model	Null hypothesis: non-causality	$\chi^2$	df	Prob	Coefficient of ECM	<i>t</i> -statistic
Model 1	$\Delta \ln GDP \Rightarrow \Delta \ln AGE$	0.65	2	0.71	–0.49***	–4.19
	$\Delta \ln AGE \Rightarrow \Delta \ln GDP$	2.90	2	0.23		
Model 2	$\Delta \ln GDP \Rightarrow \Delta \ln AGE$	1.18	2	0.55	–0.57***	–5.07
	$\Delta \ln AGE \Rightarrow \Delta \ln GDP$	1.60	2	0.44		

Source: Authors’ own calculation based on the World Bank and RBI data

\*Significant at 10% level

\*\*Significant at 5% level

\*\*\*Significant at 1% level

by the fact that the chi-square variate (0.65 for model 1 and 1.18 for model 2) with degrees of freedom two turns out statistically insignificant. Similarly, the testing of causality between population ageing and economic growth (follows the chi-square distribution with one degree of freedom) with Chi-square values 2.90 (for model-1), and 1.60 (for model-2), are not found to be statistically insignificant. Thus, this indicates that there is no causal relationship between economic growth (measured by GDP) and population ageing in the short-run in India. This result is not at all surprising as “population ageing” is a long-run phenomenon.

## Discussion

Conventionally, the effect of ageing on GDP is negative. Thus the first equation divulges that the long-run association between economic growth and ageing population is negative with the absolute value of the coefficient is 5.33, without incorporating “Medium and high tech export” as a proxy of the “knowledge spillover effect” in the model of “Granger Causality with VECM” as one of the control variables. However, this is not the central concern of the present paper. In the present paper, an attempt has been made to furnish an economic reason for this well-established fact of a negative relationship between ageing and economic growth. In conjunction with this, the present research attempted to figure out a way to surmount with this negative relation. Initially, we aim to provide clarification for this negative relation. It is a well-accepted fact that ageing will affect economic growth or GDP negatively. But the question is that why? In this paper, we have considered the input labour in the line as defined by Romer (1990), and thus, we have two types of labour employed in the production process, viz., ordinary labour and human capital. In the line of Romer (1990), we have assumed that the supply of “human capital” is fixed. A part of it is used for the production of the final good, and a part is used for the improvement of technology. “Human capital” simply means here the “general skill level of the labour” (Lucas Jr 1988). The “accumulation of the human capital” is important for both the preservation, and the development of human capital. Furthermore, a minimum effort, is required for the accumulation of human capital. However, “human capital cannot serve as an alternative engine of growth to the technology” (Lucas Jr 1988). Concomitantly, it is also true that “the growth rate of human capital must eventually tend to zero with growing skill no matter how much effort is devoted to accumulate it” (Lucas Jr 1988). This is the principal cause of the negative relationship between GDP and population ageing. In fact, there are “diminishing returns in individual patterns of human capital accumulations” (Uzawa 1965). This is so because “people accumulate it rapidly in early life, then less rapidly and then not at all” (Lucas Jr 1988). We can also mention that “an individual’s lifetime is finite so that the return to increments falls with time” (Rosen 1976). Thus, the accumulation of human capital only is unable to offer an uninterrupted growth rate in the economy. This is the fundamental cause of a negative relationship between ageing and economic growth. The application of improved technology is the only way out in this case. The technological improvement can be attained either by domestic “research and development” or by “export”. We recognize these as “knowledge spillover” (Romer 1990).

Now the question is how to address the challenge of population ageing. What we perceive from this study is that only through “technological innovation” we can deal with the problem of population ageing smoothly. This is owing to the fact that the second equation of the long-run association between economic growth and ageing population as depicted by the “Granger causality test with VECM” is still negative but the absolute value

of the coefficient of “age” has reduced to 4.23. It is noteworthy that in the second model, we consider “medium and high tech” as an added control variable of the “Granger causality test with VECM” model. The definition of “medium and high tech” ensures that it is a result of technological innovation achieved through “research and development” process of any country. In the case of India, “medium and high tech export” comprises a product with high R&D intensity, such as in aerospace, computers, pharmaceuticals, scientific instruments and electrical machinery. Although India exports these medium and high technology goods, the reality is that the main ingredients (inputs) are not originated in India. In fact, India imports these inputs from developed countries, and by compiling these inputs with indigenous technology, India developed the finished goods. Finally, India exports these “high technology” goods (Nayak et al. 2013). The whole process may be identified as “knowledge spillover” (Romer 1990). The present scenario implicitly connotes that in today’s world with “globalization”, any country can achieve the desired success in technological research without complete involvement through “knowledge spillover” (Romer 1990). However, the countries compulsorily require developing its “human capital”. The two main ingredients for the development of “human capital” are education and health (Human Capital Theory: Welch 1975; Becker 1964; Schultz 1994; Todaro and Smith 2003). The further advancement of the existing “human capital” or “skilled labour” necessitates devoting non-leisure time in “human capital accumulation” (Lucas Jr 1988). “Human capital” is regarded as a “rival good”, and it is necessary for any country to ameliorate its “human capital”. In fact, the “knowledge spillover” can only be achieved if the country has a highly enhanced “human capital” or “skilled labour” who can involve themselves in the final good production as well as in the improvement of technology. Thus, to take care of the ageing problem, the country needs to involve itself in “human capital accumulation”.

## Conclusion and Policy Prescription

Population ageing is one of the serious issues in the recent period. Many developed countries are approaching an era of the ageing population due to an increase in longevity, a decrease in mortality rates and a decrease in fertility rates (Harper and Leeson 2009). “The decline in population growth has been visible since the mid-1970s when the adult working-age population in several countries outpaced child population” (Mason and Lee 2011). The process is now rapidly approaching to the developing world, and where India is not an exception.

Patently, ageing will indeed affect economic growth inversely. Again, ageing is the natural process of human life. Manifestly, the process of demographic dividend will not persist in the economy forever. Demographic transition is the movement or shifting from high birth rate and high death rate to low birth rate and low death rate. In fact, uncontrolled growth of the population will result in baby boom and/or population explosions. Both of the situations are not desirable in the economy. Thus, any economy in the present world economic scenario will pursue “family planning policy”. It is noteworthy that the fertility, mortality, migration and life expectancy are the factors which influence the process of ageing in any country. The most significant reason behind the population ageing in India is the process of demographic transition.

The ageing in the economy is contributed by three main demographic variables, viz., “life expectancy, death rate and birth rate”. In the process of transformation of developing



to the developed country, the economy experiences an increase in GDP and life expectancy of the citizens, and India is not an exception of this. The significant reasons for the increase in the life expectancy of Indian people are falling birth rate and death rate in both rural and urban areas of all the states. Along with this access to primary health centres, health personnel, medicines, roads, schools, etc. also contributed in increasing the life expectancy of Indian people (Vasant 1994; Chakrabarti and Sarkar 2011; Indira 1999). Thus, as a result of a fall in the fertility and the mortality, the proportion of the older adults in the total population has started to rise (Reddy 1996). Consequently, ageing is a common phenomenon of economic development and demographic transition. The challenge for any economy is how to maintain a faster growth rate with ageing. Migration of labour force can furnish some temporary solution, but the permanent solution of this circumstance is the “accumulation of the knowledge”. In the present paper, we define “knowledge” in Romer’s (1986, 1990) way, and thus it has two components, viz., “human capital” and “technology”. By definition, the first component is “rival good”, and the second one is “non-rival good”. The non-rivality of the “technology” designates “the discoverer will not be the sole beneficiaries of a new technology” (Sarkhel 2005). Consequently, others can also use innovated technology. This is denominated as a “knowledge spillover”, which is the most ideal way to cope with the ageing. The present study empirically establishes this well-acclaimed fact. In the study, we perceived that with the inclusion of the proxy control variable of “knowledge spillover” (medium and high tech export), the adverse effect of ageing on economic growth was reduced in absolute term from 5.33 to 4.23. Accordingly, the present study bestows a solution to an ageing economy to cope with the ageing problem. The empirical results authorize us to conclude that a greying economy can perpetuate its rate of economic affluence even under the scenario of demographic transition only through the adoption of ameliorated technology, termed as “knowledge spillover”. Consequently, knowledge transformation in Romer’s (1986, 1990) sense, among countries, is crucial for the sustainability of the growth process of any country in the globe irrespective of its current economic and demographic scenario. This is the idiosyncratic contribution of the present paper to global economic science. It is apparent that if we can include “human capital” as an added control variable, the adverse effect of ageing on economic growth can superintend more appropriately. From this perspective, we suggest that emphasis should be inclined to “the development of knowledge”. This could be achieved in two ways: through “development of human capital” of the country and through the “knowledge spillover”. Both the developed and the developing countries should take appropriate initiatives to develop their existing “human capital”. Any effort for “human capital accumulation” should be rewarded. The development of the existing “human capital” in the case of India can only be attained through the development of the two main ingredients of the “human capital”, viz., “education” and “health”. To attain this overall institutional development, related to education and health services must be improved so that the population of the country gets enough opportunity for their “human capital development” as well as for “human capital accumulation”. Again, “knowledge spillover” can be acquired through the appropriate implementation of the “globalization” policy.

As a limitation of the study, we can pinpoint that, although we include one component of “knowledge” in Romer’s (1986, 1990) sense, but because of the non-availability of data, we fail to include any control variable as a proxy of “human capital”, the other component. The inclusion of two of Romer’s (1986, 1990) “knowledge” components in the analysis will accredit us to offer a more germane solution for the sustainability of the

process of economic affluence within the ageing domain. In fact, this is *the* future research agenda of the authors. An appropriate measure of “human capital” can be developed through the construction of the “human capital index”. The successful attempt of indexing “human capital” for India or any other country will facilitate us to verify the sustainability of our present. This is our future research plan.

## Compliance with Ethical Standards

**Conflict of Interest** The authors declare that they have no conflict of interest.

## Appendix

**Table 7** Phillips-Perron unit root test

Variables	Level	First difference
lnRGDP	-1.87	-4.56***
lnAGE	-1.85	-2.45*

Source: Authors' own calculation based on the World Bank and RBI Data

\*Significant at 10% level

\*\*Significant at 5% level

\*\*\*Significant at 1% level

**Table 8** VAR lag order selection criteria

Variables	Lag	Sequential modified LR test statistic	Final prediction error	AIC	SIC	HQIC
Endogenous variables: ln(GDP), ln(AGE)	0	NA	1.99e-07	-9.77	-9.28	-9.63
Model 1 Exogenous variables: Constant	1	98.76*	2.32e-09*	-14.09	-13.22	-14.04*
LOI	2	2.74	2.77e-09	-14.23*	-13.56*	-13.84
LPDBAC						
LPSE						
LURBA						
LMANFEX						
Model 2 Exogenous variables: Constant	0	NA	2.08e-07	-9.73	-9.15	-9.56
LOI	1	87.24*	2.28e-09*	-14.24	-13.28	-14.04*
LPDBAC	2	4.57	2.43e-09	-14.27*	-13.49*	-13.96
LPSE						
LURBA						
LMANFEX						
LMHTECH						

Source: Authors' own calculation based on the World Bank and RBI data

\*Lag order selected by the criterion

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