Journal of World Economy
ISSN 2709-3999
www.pioneerpublisher.com/jwe
Volume 2 Number 4 December 2023

The Effects of Demographic Change on GDP Growth: Research Focus on Russia

Goran Miladinov[1]

[1] Independent Researcher, Macedonia
Correspondence: Goran Miladinov, Independent Researcher, Macedonia.

doi:10.56397/JWE.2023.12.01

Abstract

There has been a downward trend in economic growth in several economies over the past few decades, with the slowdown trend particularly evident in the case of Russia. These records estimate how much of this growth slowdown can be accounted for by demographic changes. Specifically, this study estimated how a changing age structure of the population (between four groups-ages 0-14, 15-64, and 65+) has affected GDP growth using annual time series data for Russia. The analysis is applied using the Bayesian VAR model. The data for the study are obtained from the World Bank. It was found that demographic changes account for a significant portion of the downward trend in the economic growth of Russia during the past decade. Moreover, the continuation of the demographic shift toward an older population is likely a valuable factor that has increased GDP growth in Russia over the last couple of decades. The research results point out that during the last decade; demographic effects have not had any significant influence on the change of GDP growth levels in Russia. Therefore, the research study contributes in a way indicating that future growth of GDP in Russia will depend much more on the growth of structural productivity, new technologies and worker profitability and much less on demographic changes.

Keywords: Bayesian VAR, Russia, demographic changes, age structure, GDP growth, economy

1. Introduction

Numerous global economic trends will depend on changes in family behavior and changes in public policy that affect economic age profiles (Mason et al, 2022b). Because a person is not only a producer but also a consumer of socioeconomic needs, the capacity of the national market and the economic potential of the country depend precisely on population size and age characteristics (Mabiala et al, 2023). Demographic change can affect the economy's underlying growth rate, the growth of structural productivity, living standards, savings rates, consumption and investment; also demographic change can affect the long-run unemployment rate and the equilibrium interest rate, housing market trends as well as the demand for financing (Mester, 2018). Furthermore, differences in demographic trends between countries can be expected to affect current account balances and exchange rates. Therefore, to understand the global economy, it is needed to understand demographic changes and the challenges they produce for monetary and fiscal policymakers.

Economic growth and economic development are two different concepts. Thus, growth is referred to as GDP, and therefore economic growth means an increase in production, production capacity and all other components of an economy (Guga et al, 2015; Mester, 2018). Economic growth is due to the increase in labor or capital, technology or worker profitability. Peterson (2017) notices that "economic growth always includes a purely demographic component and a purely economic component, and only the latter allows for an improvement in the standard of living" (p. 1). If expressed in percentage changes, economic growth is equal to population growth plus growth in GDP *per capita* (Peterson, 2017). On the other hand, economic development includes policies and processes by which a nation improves economic and social prosperity. This covers adaptations to various indicators such as educational level, life expectancy indicators, poverty rates, environmental circumstances, etc. Economic development attributes importance to GDP *per capita* taking into account other indicators that show the quality of life such as access to education, access to health care, income distribution, environmental quality etc., (Guga et al, 2015).

Demographic structure, the percentage of the population in each age group, is important to the economy (Aksoy et al, 2012). Accordingly, different age groups have different saving behavior and investment opportunities, different productivity, and different amounts and wages, so the very young and the very old tend not to work, with implications for labor input (Aksoy et al, 2012). Changes in the age structure mainly under the influence of reduced fertility play a significant role in economic growth when the reduction in the growth of the young dependent population leads to a higher share of the working population (Sijia, 2013). Demographic change will produce a slower-growing and older population (Mester, 2018). The magnitude of these effects and timing are uncertain as they depend on the complicated dynamics and behavior of consumers and business cycles. Population aging is due to a general decline in the birth rate, and if fertility rates remain very low, then improvements in life expectancy are seen (Bo & Sommestad, 2000). The challenges caused by the aging of the population determine the need for a complete reorganization of the whole socioeconomic system, as well as the proper adjustment of society and the economy to the features of the "old" population (Mabiala et al, 2023).

One way to approach the challenge of economic growth is to analyze the consequences of changes in the age structure in the past. This research work contributes to the continuing discussion about the role of demographic changes on economic growth. This paper strictly investigated the demographic impact of the dramatic changes in demographic structures on economic growth using a Bayesian VAR model on data for Russia over the last three decades. Our aim is to provide estimates of the impact of demographic structure on the main macroeconomic indicator (GDP growth) that may help to inform the development of the theory. Our discussion has an objective to explain why it is rational to expect that age structure matters to economic development, and to what degree this presumption is confirmed by the empirical data. The paper is organized as follows. Section 2 presents the theoretical background. In Section 2.1 related literature is discussed. Section 3 provides the methodology framework for our research study. Section 4 presents the empirical estimates and results of our model. Section 5 presents a discussion of the results. Finally, Section 6 concludes.

2. Theoretical Background

Demographic factors have sometimes taken center stage in the discussion of the sources of economic growth. Also, a central question for economists is whether economic growth causes a demographic transition or vice versa (Ranganathan et al, 2015). In the 18th century, Thomas Malthus made a pessimistic forecast that per capita GDP growth would fall due to the persistent rapid increase in world population (Jinill, 2016). What influence will the aging population have on economic development? Aging means that society achieves a higher rate of old-age dependency where the portion of elderly people, which depends on the working-age population, is increasing (Bo & Sommestad, 2000).

The *standard macroeconomic theory* does not help explore demographic effects on macroeconomic variables because, by definition, representative agent models cannot allow for such effects or allow it in quite a restricted way. As *conventional economic theory* asserts, an aging population can slow down the economy; hence population aging is a factor that can reduce economic expansion (Jayawardhana et al, 2023). A *lifecycle perspective* provides a better understanding of exactly how demographic change affects the economy. Indeed, the life cycle is a key concept to understanding the impact of population on economic issues (Mason et al, 2022b). The key tenet of the lifecycle perspective is that the profiles of average labor income and consumption are highly age-dependent (Mason et al, 2022a). Accordingly, individuals spend more than they earn when they are young or old, and earn more than they spend during productive middle age (Mason et al, 2022a; Mason et al, 2022b). These depicted facts apply to all economies, yet there are significant differences across economies. Moreover, life cycle theory predicts that as its population ages, a country's saving rate will rise (Jayawardhana et al, 2023). Although this theory predicts a decline in aggregate savings as the population ages and a greater proportion of the population reaches retirement age, this theory also indicates that the proportion of the population reaching retirement age will grow.

As argued by *Solow's growth theory*, an aging population makes it difficult for a nation to sustain steady economic growth. If the age distribution of the population is constant, it can be supposed that the economic growth is stable or the economy is stable. However, the age structure of an economy is not predictable as the population ages. As such, this scenario is only feasible when the economy is approaching its stable state. Thus, as stated in this postulate, a country's economy would suffer if its population continues to age (Jayawardhana et al, 2023).

The impact of the *demographic transition* on the age structure is strong. Thus, in the wake of the demographic transition, an age transition follows. This age transition consists of four peculiar phases, marked by the rise of a specific age group (Bo & Sommestad, 2000). First comes the child phase, then the young adult phase, then the population maturity phase and finally the aging phase. From a macroeconomic standpoint, the child phase is a period when consumption needs tend to be greater than productive capacity. The child dependency rate is high, and females in particular need to invest significant financial and time resources in the domain of reproduction. This picture changes dramatically when fertility rates start to decline. This decline generates a bulge in the age structure. The classic population pyramid in a gradual way changes its appearance: the base becomes narrower and the pyramid takes on an increasingly convex shape. The second stage in the age transition, the young adult stage, is reached when the bulge passes through the young adult ages. Later the bulge will pass through middle age, which marks the third stage, the maturity stage. Still more lately, typically about 60 years after the start of fertility decline, the bulge will enter the older age groups. All in all, a society experiencing an age transition goes through remarkably foreseen demographic phases, from an initial challenge to the high rates of child dependency to the final stage of maturation and finally aging (Bo & Sommestad, 2000).

Finally, Jinill (2016) emphasizes that demographic changes may affect GDP growth through several channels: 1) lower population growth directly implies reduced labor input; 2) lower population growth has an indirect potentially negative impact on individual labor supply; 3) Third, according to the life cycle hypothesis, the smoothing of consumption over the life course would imply that people move from being net borrowers in their youth to being net savers in their working years and, finally, to being dis-savers in their older years. Therefore, if the portion of the elderly in the population increases, aggregate savings would decline, leading to lower investment growth and, in turn, lower GDP growth.

2.1 Literature Review

A lot of studies of economic growth and demographic change found a significant relationship between the two, and overall, existing literature confirmed the importance of demographic changes in stimulating the economic growth of a country (Sijia, 2013). Cross-national evidence increasingly suggests that youth dependency (i.e., the ratio of children to productive adults) slows economic growth, but that adult population growth (i.e., the growth of the labor force) has the opposite effect (Crenshaw & Robison, 2010). In Aksoy et al, (2012) it was demonstrated that the inclusion of the initial proportion of the working-age population improves the forecast performance of per capita income growth for the period 1980–2000 for a panel of 67 economies. Also, it was found that the proportions of 15-64-year-olds people, as well as people aged 34-54 in the population, can explain more than half of global growth since 1960 and that the proportion aged 15-64 is also responsible for the continued divergence of rich and poor countries, as the age structure in the former is improved more dramatically than in the latter (Aksoy et al, 2012).

An interesting and ongoing debate is evident among the research community regarding the relationship between the elderly population and economic growth (Jayawardhana et al, 2023). Thus, the literature exists with contradictory findings across regions and countries of the world. However, the elderly population can have a favorable impact on economic growth and this can be attributed to the accumulation of capital and assets and the consumption patterns of the elderly in some nations. The negative effect of the elderly population on economic growth is mainly attributed to the increased costs of elderly care to the government and the burden of the elderly on the working population. Macroeconomic performance in Asia, and especially East Asia was closely scrutinized by the variations in age structure caused by demographic change. Additionally, Jayawardhana et al. (2023) mentioned that an increase in the percentage of the working-age population as a result of a decrease in the percentage of the youth population has helped in the growth of income in the past.

Jinill (2016) assessed the effects of demographic changes on the economic growth performance of OECD countries and found that demographic changes caused significant growth slowdowns in several of these economies in recent decades. Jinil's (2016) predictions using population projections by age group also suggest that demographic factors will continue to hold back GDP growth for several years, at least in most cases. The study by Abdulaziz A. Bawazir et al. (2020) sought to empirically examine the effects of demographic change on economic growth in Middle Eastern countries. Their findings showed that young workers, middle-aged workers, older workers, population growth rate, and old-age dependency ratio positively impact economic growth, while the youth dependency ratio negatively impacts economic growth. The analysis by sex revealed that the male working population contributed more to economic growth than the female working population.

3. Data and Methods

The data for this research study were retrieved from the database of World Bank Development Indicators (https://data.worldbank.org/indicator), covering annually the period from 1990-2022 (World Bank, 2023). Our data set provides data on macroeconomic and demographic variables for Russia.

To link the general Bayesian framework to Vector Autoregressions, the VAR will be written as in eq. (1):

$$y_t = \delta_0 + \sum_{j=1}^{p} \Pi_j y_{t-j} + \gamma F_t + \epsilon_t \quad (1)$$

where, $y_t = (y_{1t}, y_{2t}, \dots, y_{Mt})'$ represents an M vector of endogenous variables (the VAR has M variables and p lags, δ_0 is M vector of intercept coefficients, Π_j represent M x M matrices of the lagged coefficients, F_t represents $(d-1)$ vector of the exogenous coefficients, γ presents M x $(d-1)$ matrix of the exogenous coefficients, and ϵ_t is M vector of the errors where it is assumed that $\epsilon_t \sim N(0, \Sigma)$, (Koop & Korobilis, 2010). If the variables on the right-hand side of eq. (1) are collected into the $(Mp+d)$ vector x_t, and the appropriate coefficients into B, then the eq. (2) is presented below:

$$x_t = (y_{t-1}', \dots, y_{t-p}', 1, F_t') \quad (2)$$
$$B = (\Pi_1, \dots, \Pi_p, \delta_0, \gamma)'$$

Thus, eq. (1) can be rewritten as in eq. (3):

$$y_t' = x_t' B + \epsilon_t' \quad (3)$$

In the BVAR literature, there are more classes of priors (e.g., Litterman/Minnesota prior, normal-Wishart prior, independent normal-Wishart prior, Giannone, Lenza and Primiceri prior), (Koop & Korobilis, 2010; Giannone et al, 2012). Bayesian VAR (BVAR) methods (Koop & Korobilis, 2010; Giannone, et al, 2012) are also an in-demand approach for achieving shrinkage, as Bayesian priors provide a consistent and logical method for imposing restrictions on parameters. In our BVAR model, the independent normal-Wishart was implemented. Independent normal-Wishart prior resembles the normal-Wishart prior, but allows each endogenous equation's coefficients' distributions to be independent of each other and removes the dependence of β on Σ. The independent normal-Wishart prior also allows for differing variables in each endogenous equation of variables, which is also a feature of the restricted VAR model (Koop & Korobilis, 2010). The unconditional posterior distributions from the independent normal-Wishart priors are mathematically not tractable. These conditional posteriors require the use of a Gibbs' sampler to obtain attributes of the unconditional posteriors. Thus, in estimation, this implies sequentially drawing from the conditional distributions, beginning with a primary estimate of Σ to draw β. After discarding a certain number of burn-in draws, the mean value of the draws is taken. In addition, the marginal log-likelihood also has no analytical solution; an estimate of its value can be calculated from the outputs of the Gibbs sampler using Chibb's method (Siddhartha, 1995; Ma et al., 2021).

4. Results

Figure 2 clearly shows that the slowdown in population growth in Russia among the population aged 0-14 and 15-64 is accompanied by a dramatic increase in the proportion of the population aged 65 and above. This change in population composition has important implications for economic growth as well as fiscal sustainability (Jinill, 2016). To provide demographic development in the last three decades in Russia, the Figure 2 plot shows how the age structure of the population has changed in Russia between 1990 and 2022. As can be seen, the portion of the Russian population in age groups 0-14, 15-64, and 65+ in 1990 were about 23 percent, 67 percent, and 10 percent, respectively. Figure 2 shows the noticeable population aging that has occurred in Russia during the last thirty-three years. By 2022, the youth (0-14) had dropped by 5 percentage points; the productive population share (15-64) is around the same as in 1990, while the elderly population share (65+) had risen by around 6 percentage points.

As Russia is in a later stage of the demographic transition, fertility rates since 2000 reveal that fertility in Russia has either fluctuated or remained relatively stable (Lal, 2022). Additionally, Russia even saw its population decline for most of the 2000s and again in the late 2010s. To a significant extent, the transition to low fertility in Russia was accelerated by a series of continuous social crises that went together with the modernization of Russian society. Thus, not only did living standards fall during the crises, but individual control over reproductive behavior became a widespread practice among the population (Zakharov, 2008). Accordingly, partners had to constantly adapt their reproductive practices to the changing socioeconomic reality.

The Soviet Union, which preceded Russia in the 20th century, had the second-largest economy in the world. However, the collapse of the Soviet Union caused an economic downturn that lasted in the 1990s until a recovery in the 2000s, when the economy was noted as a developing economy (Lal, 2022). Figure 1 presents the GDP growth for Russia during 1990-2022. Russia experienced a decline in GDP growth during the 2008 global financial crisis and again during the 2020 coronavirus pandemic. Russia had a recession in 2014 as oil prices fell and economic sanctions were implemented after it took over Crimea. The question is relevant since Russia, like other countries that have largely completed their demographic transition (from high to low fertility and mortality), is moving into a new period in which its demography becomes less favorable from an economic point of view (Vishnevski & Shcherbakova, 2018).

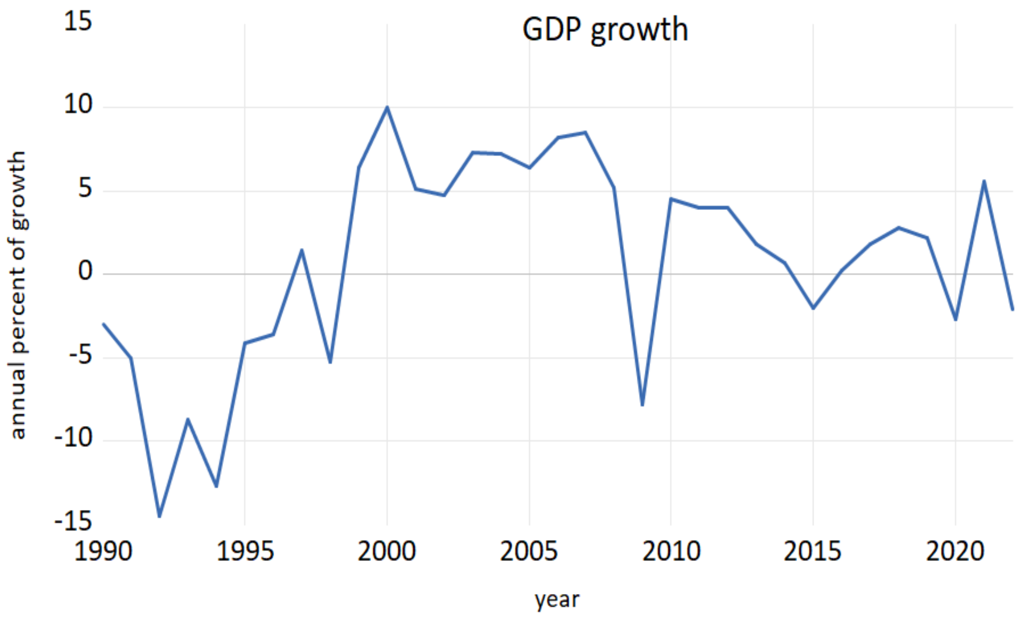

Figure 1. GDP growth, Russia 1990-2022

Source: Author's design based on World Bank data.

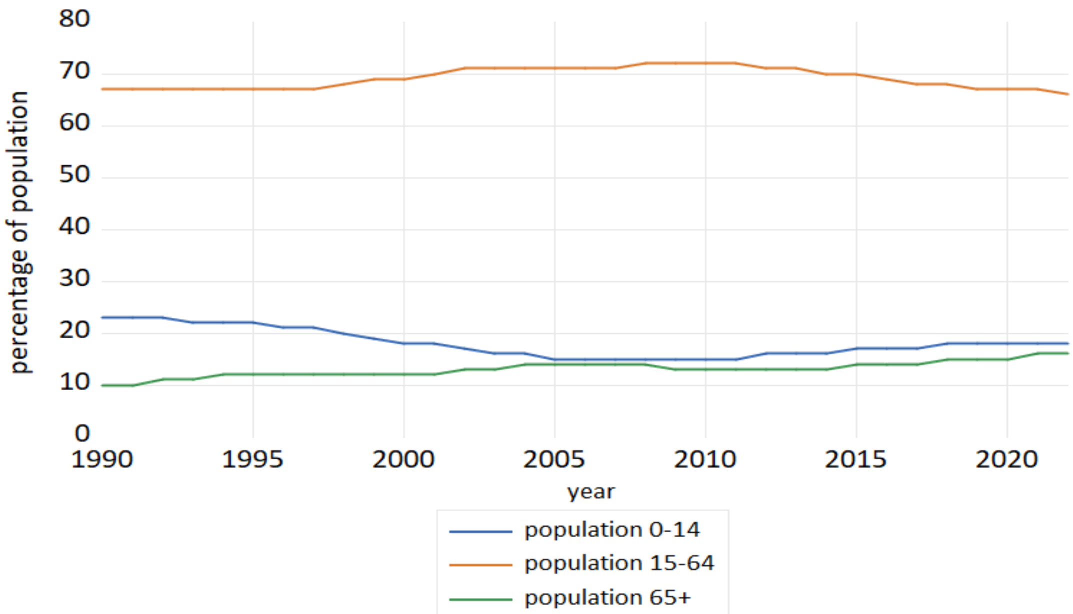

Figure 2. Population structures, Russia 1990-2022

Source: Author's design based on World Bank data.

In our Bayesian approach, the coefficients of a VAR model were estimated without using the first differences. The model contains four series: GDPG (GDP growth), POP0_14 (population ages 0_14), POP15_64 (population ages 15_64), and POP65 (population above 65). All four variables are outlined at an annual frequency. Independent normal-Wishart was selected for the Prior type for the VAR and the Univariate AR estimate for the Initial residual covariance. Univariate AR estimated a univariate AR model with two lags for each endogenous variable corresponding to those specified for the VAR. The hyper-parameter, Mu1, was set to be equal to 1 since all of the data were not differenced. The Independent normal-Wishart prior requires a connection to the optimization algorithms; Convergence tolerance and Maximum iterations. The Maximum iterations algorithm requires estimation via the Gibbs Sampler and thus offers options for the number of draws from the sampler, the percentage of draws to discard as burn-in draws, and the seed value of the random number generator (see Table 1). All inverse roots are less than 1, indicating that our BVAR model is stationary (See Appendix). The autocorrelation with a 5 % confidence interval was tested. The goal was to eliminate all autocorrelation. There were found only a few autocorrelation values outside of our confidence intervals, thus the autocorrelation problem was sufficiently resolved (see Appendix). The first upper part of Table 1 provides the basic specifications of the settings used in estimation, as well as the prior information and hyper-parameter values. In the middle part of Table 1, the mean and standard errors from the posterior distribution are shown. At the end of Table 1, the summary statistics for a VAR are displayed. Even though these values do not have a Bayesian interpretation, they are shown for comparison purposes. In our BVAR model, the data-generating process for GDPG is estimated in eq. (4):

$$GDPG = 0.06 + 0.191 \cdot GDPG_{t-1} + 0.106 \cdot GDPG_{t-2} - 2.855 \cdot POP0_{14_{t-1}} + 2.092 \cdot POP0_{14_{t-2}} + 1.123 \cdot POP15_{64_{t-1}} - 1.046 \cdot POP15_{64_{t-2}} + 0.579 \cdot POP65_{t-1} + 0.076 \cdot GDPG_{t-2} \quad (4)$$

Table 1. Bayesian VAR estimate results:*

Bayesian VAR estimates			
Sample (adjusted): 1992-2022			
Included observations: 31 after adjustments			
Prior type: Independent normal-Wishart			
Initial residual covariance: Univariate AR			
Constant included in covariance calculation			
100000 draws, 10% burn- in, seed=1			
Hyper-parameters: Mu1: 1, C1: 0.1, C2: 0.1, C3: 5			
Standard errors in ( )			
	GDPG	Standard errors	
GDPG(-1)	0.1910	(0.2006)	
GDPG(-2)	0.1061	(0.2066)	
POP0_14(-1)	-2.8552	(1.4624)	
POP0_14(-2)	2.0917	(1.3469)	
POP15_64(-1)	1.1232	(1.3578)	
POP15_64(-2)	-1.0461	(1.3734)	
POP65(-1)	0.5792	(1.4759)	
POP65(-2)	0.0906	(1.5746)	
C	0.0758	(3.1617)	
Summary statistics			
R-squared	0.5237		
Adj. R-squared	0.3505		
Sum sq. resids	547.81		
S.E. equation	4.9900		
F-statistic	3.0239		
Mean dependent	1.1129		

S.D. dependent	6.1919	
Data marginal log-likelihood	-186.3952	

**Dependent variable*: GDP growth (GDPG). *Sample*: 1990-2020.

Source: Author's calculations.

The coefficient estimates are presented without brackets. The coefficients on the 0-14 age group are obtained as negative (-2.855) for POP0_14 (-1) and positive (2.092) for POP 0_14 (-2). The coefficients for the age group 15-64 are estimated as positive (1.123) for POP15_64 (-1) and negative for POP15_64 (-2). The two coefficients for the 65+ age group are estimated to be positive, 0.579, and 0.091. These results show that an increase in the population share of the young population tends to lower the growth rate of GDP while an increase in the population in the age groups between 15-64 years old would lead to a mild increase in the GDP growth rate. Furthermore, results show that an increase in the population in the age group 65 years old and above in Russia would tend to boost the GDP growth rate.

Since the VAR was estimated, our research interest was to look at the impulse responses of demographic variables to a shock in GDP growth (GDPG). A shock to the *i*-th variable not only affects the *i*-th variable directly but is transmitted to all other endogenous variables through the dynamic lag structure of the VAR. Additionally, the impulse response function detects the effect of a one-time shock on one of the innovations on the present and future values of the endogenous variables. Figure 3 presents the Impulse Response function where the graph of the responses was produced in which all other settings are kept at GDPG default.

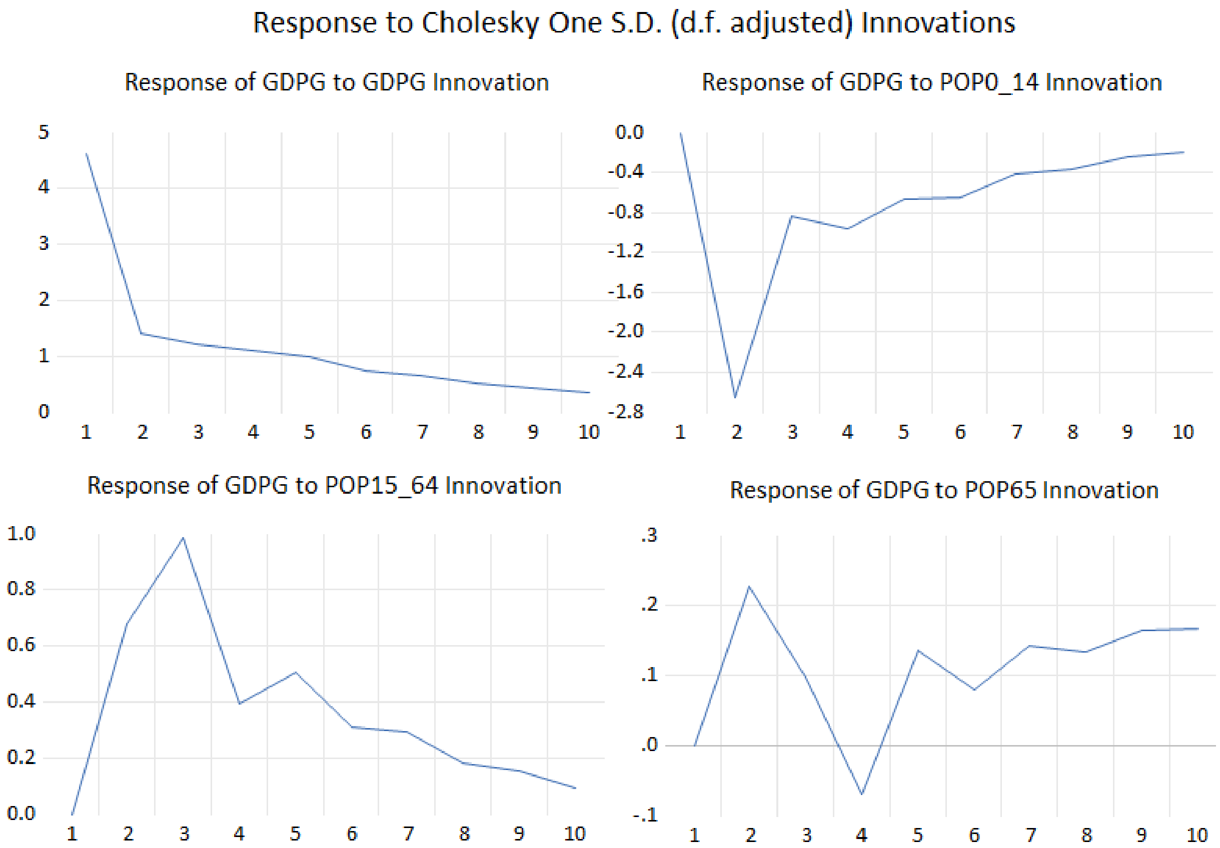

Figure 3. Responses of GDP growth to demographic variables, Russia 1990-2022

Source: Author's design based on World Bank data.

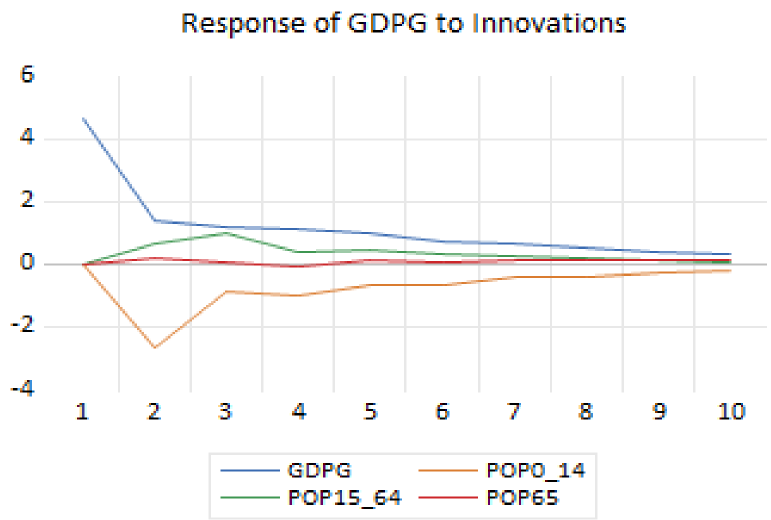

Figure 4. Responses of GDP growth to demographic variables, combined effects, Russia 1990-2022
Source: Author's design based on World Bank data.

The first graph shows how the variable GDPG reacts to its shocks. The second graph presents that the response of GDPG to POP0_14 is a big negative change first and then the negative response decreases significantly, meaning that a shock from POP0_14 causes a negative response to GDPG for the whole period of observation. The third graph shows that the response of a shock of POP15_64 to GDPG is a big positive change in GDPG in the first period. In the further period, the effect from POP15_64 gradually contributes to the reduction of the positive response of GDPG, and the effect dies out over time oscillating around zero in the later part of the observed period. The fourth graph presents that for a shock to POP65, the response of GDPG is positive, meaning that a shock to POP65 causes a positive shock to the GDPG. The effect lasts all the time with a small oscillation leading to a small negative response to GDP in the pre-intermediate period. Moreover, the graph from Figure 4 clearly shows that the coefficients of all three demographic variables have been shrunk effectively, from being significant at the beginning of the period and later on (i.e., during the 1990s and first years of the 2000s) to being non-significant coefficients and shrunk toward zero particularly from around of 2010 to the end of the observed period.

5. Discussion

BVAR estimates show how a changing age composition in Russia during 1990-2022 has affected GDP growth. The contribution of demography to Russian economic growth was broadly negative before the 2000s but positive since then besides the rapid ageing of Russia's population. It can be noted that the effects of demographics on Russian GDP growth are most prominent during the 1990s and the first period of the 2000s. It can be indicated that during the last decade, demographic effects have no significant influence on the change of GDP growth levels. The mild positive effect of the coefficients of the age group of 15-64 on GDP growth with only 0.07 (i.e., 1.23-1.05) over the period 1990-2022 interval is definitely due to the rapid exit of the baby boom generation from the workforce and the rapid rising of the proportion of the elderly population during this observation period in Russia. In other words, most probably this is also due to the advanced character of the demographic transition in Russia during this period (Lal, 2022). However, it is evident that the increase in the proportion of the working-age population as a result of a decrease in the proportion of the youth population has helped in the growth of economic growth in Russia during the past decades. This finding is in line with the general global trends as well as with the impact of the demographic transition on the age structure presented here in this paper by Bo and Sommestad (2000) and by other similar viewpoints regarding demographic changes and the challenges they produce for monetary and fiscal policies.

It was unexpected to find a positive relationship between the elderly population and GDP growth. One important factor for this finding may be the savings behavior of the elderly, those aged 65 and above and their tendencies of investment to financial assets which probably started already during the working ages (Bo & Sommestad, 2000). To some extent, these findings are consistent only with the life cycle theory (Jayawardhana et al, 2023), which predicts that as its population ages, the saving rate in a country will rise. It was probably what happened in Russia during the last decades. Therefore, it is undoubtedly that over some time, the elderly population may have a favorable impact on economic growth through the accumulation of capital and assets, as well as from the consumption patterns and saving rates of the elderly people. Concerning our empirical findings for Russia about the impact of demographic changes on economic growth it is hard to say they can relate firmly in terms of aging and economic growth with the other theoretical approaches, such as the conventional economic theory or Solow's growth theory (Jayawardhana et al, 2023) that were presented in Section 2.

However, if the process of population aging continues and especially if the proportion of the population reaching retirement age in Russia will grow, maybe there will be come to decline in aggregate savings of the elderly as claimed by life cycle theory (Jinill, 2016; Jayawardhana et al, 2023), leading to lower investment growth and, in turn, lower GDP growth. However, it is, there is no doubt that the future growth of GDP in Russia will primarily depend on the growth of structural productivity, new technologies and worker profitability and much less on demographic changes.

6. Conclusions

With the use of the Bayesian VAR model, a continuously widely used approach in a lot of applied work, a robust model is ensured in this research work. It included a discussion of the Independent normal-Wishart prior applied to the VAR model. This prior can provide a consistent and logical estimate resulting in a certain degree of parameter shrinkage. Taken together, our analysis of age effects on economic growth in Russia suggests that changes in the age structure have played a powerful role in macroeconomic change processes. Our argument here is not that the economic growth or macroeconomic processes in Russia are fully explained by demographic factors alone. Nevertheless, our argument is that given the very limited interest in this field of research, more studies are indeed needed, not only in order to understand the past, but also to predict future trends. In particular, future research studies should take into account the differences in labor force participation rates or movements over time of the participation rate within the country. The responses including greater female labor force participation and policy reforms, such as an increase in the legal age of retirement, extended education and training or the development new technology can help understand the mitigating negative effects on GDP growth.

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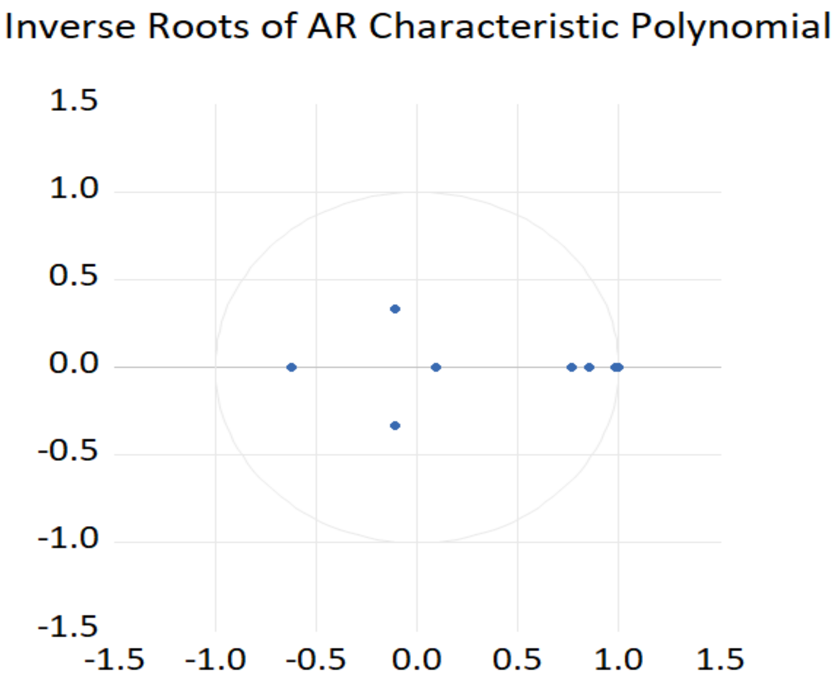
Appendix

A: Figure—Inverse roots of AR Characteristics Polynomial: Stationarity test



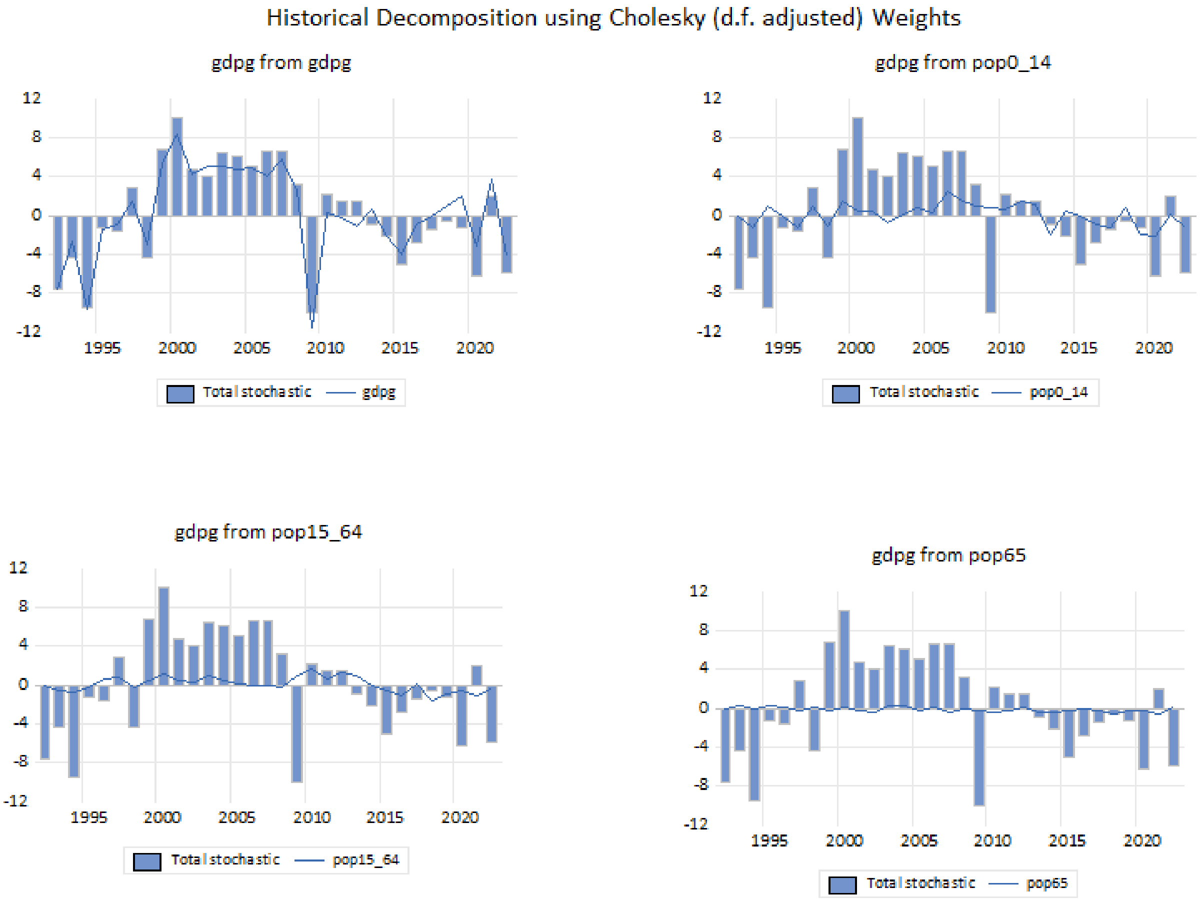
B: Table—Inverse roots of AR Characteristics Polynomial: Stationary Test

Roots of Characteristic Polynomial
Endogenous variables: GDPG POP0_14 POP15_64 POP65
Exogenous variables: C
Lag specification: 1 2
Date: 07/22/23 Time: 22:23

Root	Modulus
0.997018	0.997018
0.981320	0.981320
0.850218	0.850218
0.767744	0.767744
-0.623650	0.623650
-0.108582 - 0.329496i	0.346926
-0.108582 + 0.329496i	0.346926
0.096962	0.096962

No root lies outside the unit circle.
VAR satisfies the stability condition.

C: Figure—Historical decomposition graphs using Cholesky weights



D: Figure—Autocorrelations graph