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NAVIGATING DEMOGRAPHIC CHALLENGES FOR SUSTAINABLE ECONOMIC GROWTH IN THE BALTIC STATES

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Abstract. The Baltic States face severe demographic challenges, including low fertility rates, high emigration, an aging population, and urbanization pressures. These factors have significant implications for sustainable economic growth. This research study aims to assess the impact of these demographic trends on economic growth in the three Baltic States, Estonia, Latvia, and Lithuania and propose solutions to foster economic stability. Using a panel regression framework, this research analyzes longitudinal data from 1990 to 2023, sourced from the World Bank and United Nations Population Division. The study examines key demographic variables, fertility rates, age dependency ratios, urban population growth rates, and net migration. On the other hand, sustainable economic development is measured using GDD per capita data. Descriptive statistics, multicollinearity assessments, and robust fixed-effects regression models were employed to in the data analysis process. The statistical tool that was used is the R Software (R-code provided in Appendix 2:. The findings of the research study reveal that the age dependency ratio significantly influences GDP per capita. This highlights the burden of a growing elderly population on economic productivity. In contrast, urban population growth, net migration, and crude birth rates were not statistically significant predictors. The findings show that the increasing dependency ratio is the key demographic challenge affecting the Baltic States. To address these challenges, the study recommends resolutions to extend working lifespans, such as raising the retirement age and offering phased retirement options. Additionally, immigration policies targeting younger, skilled workers could mitigate labor shortages.

Key words: Age Dependency ratios, Baltic States, Demographic Challenges, Sustainable economic growth.

1 INTRODUCTION

1.1 The Research Problem

In the recent past, there have been contrasting demographic patterns across various regions of the world. In many developing countries, especially African, South Asian, and a section of the Middle Eastern nations, the population growth rate has been rising steeply. On the other hand, most of the developed countries in Europe, East Asia, and some parts of North America having a decline in their population (Gu et al., 2021). The Baltic States: Lithuania, Estonia, Latvia are high income economies in Europe that have also experienced a negative population growth in recent years (Khachatrian et al., 2023). It is important to note that this region is the most depopulating region in the world which has lost more than 20 per cent of population since 1992 (World Population Prospects, 2024).

Aitken (Aitken, 2024) highlights that the Baltic States have experienced depopulation due to low fertility rates. In recent decades, the fertility rates of the Baltic countries have reduced significantly, and this has negatively affected the economic output of the region. Low fertility rates have resulted in low birth rates which reduces the available workforce in the youth bracket who can be absorbed into the market to enhance economic growth in the region (Khachatrian et al., 2023). In addition, another demographic factor that has affected the economic output of the Baltic region is increased life expectancy rates. The rise in life expectancy rates has significantly caused another problem which is an aging population (Khachatrian et al., 2023). This has created a situation whereby there are many people in the elderly group than in the youth. As a result, they have been experiencing a shrinking working-age population and rising dependency ratio, which indicates that fewer numbers of working population are available for supporting the older population. Furthermore, the rise of the ageing population results in the need for increased pensions, health care and other social amenities, which are a heavy financial burden and therefore have a negative effect on the sustainable development of the region.

Furthermore, Galstyan et al.(Galstyan et al., 2021) indicates that the reduced population in the Baltic States has been caused by high emigration. A considerable proportion of the young persons has migrated to other countries in a bid to improve their quality of life. The movement of people from the Baltic states to other countries has been possibly due to integration of the Baltic states into the EU). This high emigration rates have played a crucial part in draining the local manpower needed for the production of goods and services hence leading to scarcities in the available workforce within the region.

Another demographic characteristic that has affected economic development of the countries of the Baltic states is urbanization (Varpina, 2018). It is important to note that a significant part of the population is migrating from rural to urban areas to get better job opportunities, education and standards of living. For this reason, the rural areas have had an economic loss due to the loss of a workforce in rural areas, which in turn has caused regional variations between different regions of the countries (Lang et al., 2022). On the other hand, increased urbanization has also created problems in urban areas such as increased pressure on infrastructure facilities, lack of housing, and increased demand for public services.

Therefore, there is need to analyse demographic challenges and their impact on sustainable economic growth. This research aims to explore these demographic challenges in the Baltic region and give recommendations to foster economic stability and growth in the region.

1.2 Topicality of the Research

This research study focuses on the demographic challenges that beset the Baltic states, Estonia Lithuania, and Latvia. The findings of this research study will provide insight to policy makers on what they can do to mitigate the democratic challenges in the region so as to enhance sustainable economic development. The findings of this research study will help policy makers in government to formulate strategies that can help in reversing the impacts of low birth rates and emigration, as well as develop measures to strengthen social security systems, health care, and employment policies for the older population. Furthermore, knowledge and insight derived from this research study will help businesses operating in the Baltic region to adopt existing demographic trends in the region, which include reduced working population and an aging population. This will help the business remain competitive despite emerging demographic changes in the region. Additionally, insight derived from this research study will inform help employers develop appropriate strategies for workforce development, talent retention and technological innovation. Moreover, this research study will be useful for scholars and researchers because its findings will extend the existing knowledge base on demographic changes and the effect they bring to economic and social structures. The outcomes of the study may be useful not only to the countries of the Baltic States but also to others that experience similar demographic shifts.

1.3 Goal of the Research

To examine the demographic challenges facing the Baltic states and identify effective policy responses that will promote sustainable economic growth in the region.

1.4 Research design and Methodology.

1.4.1 Data Collection

The data for this study was primarily sourced from the World Bank Group. The missing data from this source was complemented by data from the United Nations Population Division: World Population Prospects. The Link to the data is provided in Appendix 1. The researcher extracted data of the variables of interest and saved them in four csv data files which *include EstoniaData, LatviaData,* *LithuaniaData and Combinedbalticdata*. The link to the csv files is available in Appendix 1. The data collected was of the three Baltic States, which include Estonia, Latvia, and Lithuania. The data collected covered information from the year 1990 to the year 2023, which is the period that the data is available for all the three countries.

1.4.2 Variables of interest

The following variables will be used for the research study.

- **GDP per Capita (Constant LCU)**

GDP per capita represents the total economic output of a country divided by its population (Wang & Li, 2021). For this study, it is measured in constant local currency units (LCU), which adjusts GDP figures for inflation within each country. This adjustment ensures that comparisons over time reflect real changes in economic output, rather than distortions caused by price level changes.

- **Fertility Rate**

Fertility rate is defined as the average number of children a woman is expected to have during her lifetime (United Nations Glossary, 2024). A higher fertility rate is anticipated to have a negative association with economic growth, as it may indicate greater resource strain in countries with limited economic capacity (Li, 2016).

- **Crude Birth Rate**

Crude Birth rate refers to the number of live births per 1,000 people in a given year (United Nations Glossary, 2024). Higher crude birth rates are expected to negatively correlate with GDP per capita due to potential economic pressures associated with higher birth rates (Ilori & Akeju, 2022).

- **Population Growth Rate**

Population growth rate is defined as the annual percentage change in a country's population, accounting for births, deaths, and net migration (United Nations Glossary, 2024). The relationship between population growth rate and economic development is expected to be mixed. Moderate population growth may support economic expansion, while excessively high or negative growth may strain resources or indicate declining economic vitality (Peterson, 2017).

- **Urban Population Growth Rate**

Urban Population Growth rate is the annual percentage growth of the population living in urban areas (United Nations Glossary, 2024). Higher urban population growth is anticipated to positively correlate with economic growth as urbanization is often associated with industrialization, innovation, and infrastructure development (Sarker et al., 2016).

- **Net Migration Rate**

Net migration rate refers to the net number of people entering or leaving a country per 1,000 people in the population (United Nations Glossary, 2024). Positive net migration (more people entering than leaving) is expected to positively influence economic growth by enhancing labor markets, innovation, and overall economic productivity (Oliinyk et al., 2021).

- **Age Dependency Ratio**

This refers to the percentage of the working-age population relative to the total population (Kirch, 2008). A higher age dependency ratio is expected to have a negative impact on economic growth since this means that there is a low working age population hence reducing the labor force available for production, increasing the economic burden on workers, and straining public resources such as pensions, healthcare, and social services (Arif et al., 2021).

1.4.3 Analytical framework

This study employs the Panel Regression Frameworks to analyze the relationship between demographic factors and economic development in the Baltic States. The general form of the regression model is presented as follows.

$$PcGDP_{it} = \theta_0 + \theta_1 ADR_{it} + \theta_2 FR_{it} + \theta_3 CBR_{it} + \theta_4 NMR_{it} + \theta_5 PGR_{it} + \theta_6 UPGR_{it} + \varepsilon \qquad \text{Eg 1.1}$$

Whereby

$PcGDP_{it}$ *: GDP per Capita of Country i, year t.*

θ_0 *is the intercept term.*

$\theta_1 \ldots \theta_6$ *are the coefficients of the independent variables, representing the magnitude and direction of their impact on GDP per capita.*

ε *is the error term.*

1.4.4 Data Analysis

1.4.4.1 Descriptive analysis

The researcher also presents the trends of demographic factors per country over the years so as to identify patterns, may influence the relationship between these factors and economic growth. The researcher also analyses trends through graphical illustrations to see how the demographic variables have evolved over time in each country. This helps to contextualize the statistical analysis and ensure the researcher understands the data's behavior across the study period.

1.4.4.2 Multicollinearity assessment

The Variance Inflation Factor (VIF) is calculated to detect multicollinearity among the independent variables. Variables exhibiting high collinearity were considered for exclusion to ensure reliable coefficient estimates.

1.4.4.3 Panel Regression analysis

This research study adopted Panel Regression analysis. Panel regression analysis refers to a statistical method used to analyze panel data (Hsiao, 2007). Panel data is a dataset that combines time series and cross-sectional data, containing observations over multiple time periods for the same units (e.g., individuals, firms, or countries) (Hsiao, 2007). It helps control for unobserved heterogeneity and explores both dynamic and static relationships by leveraging the two-dimensional structure of panel data.

Panel Regression analysis entails fitting the following models.

- **Pooled Ordinary Least Squares (OLS) model**

The pooled OLS model is a assumes uniformity across all units and time periods by treating panel data as a single dataset (Hsiao, 2007). It does not account for unit-specific or time-specific effects, making it appropriate when unobserved heterogeneity is minimal or uncorrelated with the explanatory variables. For this research study, this is a baseline model assuming no country-specific effects, used to test for unobserved heterogeneity.

- **Fixed Effects Model (FE) model**

The fixed effects model captures unit-specific effects that may be correlated with explanatory variables by focusing on variations within each unit over time (Hsiao, 2007). It removes time-invariant unobserved heterogeneity through data transformations. For this research study, this model accounts for country-specific differences by allowing each country to have its own intercept, controlling for time-invariant factors.

- **Random Effects Model (RE) model**

The random effects model assumes that unit-specific effects are random and uncorrelated with the explanatory variables (Hsiao, 2007). It leverages both within-unit and between-unit variations, offering greater efficiency than the fixed effects model when its assumptions are valid. For this research study, this model assumes country-specific effects are random and uncorrelated with the independent variables.

The Pooled OLS model was estimated first as a baseline. The Breusch-Pagan Lagrange Multiplier test was conducted to determine whether significant country-specific effects were present. This was done to determine the most appropriate model for inference.

1.4.4.4 Model Validation

Diagnostic tests are performed on the selected model to ensure the validity of results. the researcher conducts the test of heteroscedasticity. The researcher used The Breusch-Pagan test to detect non-constant variance. If heteroskedasticity is found, robust standard errors are applied.

2 LITERATURE REVIEW

2.1 Demographic factors affecting sustainable economic growth.

2.1.1 Population Growth Rate

Multiple Research studies have investigated the relationship between population growth and sustainable economic growth. The research study by Khursanaliev (Khursanaliev, 2023) highlighted the existence of a positive relationship between population growth and economic growth. The findings of this research study established that a greater population density implies a higher demand for products and services, which positively affects consumption patterns. However, the researcher highlights that higher demand and consumption of products and services depends on factors such as the availability of job opportunities and access to education.

Moreover, Adeosun & Popogbe (Adeosun & Popogbe, 2021) have also made a contribution toward the discussion on the effect of population growth on the use of human resources. The analysis of empirical data in their research study shows that the rate of population growth weakens the employment rate, which characterizes human resources utilization. A growing population makes the labour market fail to provide sufficient employment opportunities for the increasing labour force, hence leading to increased unemployment rates.

Peterson (Peterson, 2017) also analysed the role of population growth on economic growth. When emphasizing the implications of the research study, it was mentioned that low population growth in high-income countries is detrimental to labour and can hinder economic growth. When the population growth rate is low, it means a small number of working-age persons joining the workforce, coupled with rising numbers of early retirement and aged persons. This can result in a scarcity of human capital, thus affecting economic growth and development in the region.

Research conducted by Ubarevičienė, van Ham (Ubarevičienė & van Ham, 2017) highlighted the challenge of depopulation in the Baltic country of Lithuania. The research study highlights that a rapid rate of population decrement is likely to slow down the economic development of the region in the future. Additionally, the research study highlights that population reduction has a negative impact on demand for consumption in Lithuania. Low consumption patterns cause businesses to experience a sales decline, which slows down economic activity in the region.

It is important to note that rural-to-urban migration may lead to socioeconomic disparities in a region (Lang et al., 2022). When young people who are in the economically productive age decide to migrate from the rural areas to the urban centers in search of improved employment, education, and other necessities, the rural areas are left with a less productive populace, mostly the aged and the uneducated. That population trend is likely to slow the pace of economic growth and local investments as well as produce poorer quality public services in the rural regions (Lang et al., 2022). Therefore, rural regions can experience growing rates of poverty and the general worsening of the living conditions of the remaining populace.

On the other hand, emigration may lead to a loss of skilled labor and brain drain Bhardwaj & Sharma (Bhardwaj & Sharma, 2023). This is especially the case where people, especially those who have academic qualifications and or specialized skills, move to other countries in search of better employment opportunities for themselves and their families, thus leaving behind their home countries. This drain of human capital is more anticipated to have negative impacts on the economy since it decreases the pool of human capital required by different business lines and sectors. The loss of talent is detrimental to innovation, productivity, and capacities necessary for economic growth and development.

2.1.2 Age Structure

Age structure is an important demographic factor because it affects various socioeconomic factors such as productive population capacity, dependency ratios, and consequentially economic growth. The research study by Zhang (Zhang et al., 2015) focused on the fact that there is a positive correlation between population growth and the age structure of the population, which in turn affects economic development. According to the research study, labour force increases if the country's populace comprises a young working population. A young demographic composition promotes economic development since young, skilled professionals are more innovative, leading to increased productivity.

The research study by Varpina (Varpina, 2018) analysed the impact of an aging population on economic development in Estonia, Lithuania, and Latvia. The findings of the research study suggested that an aging population negatively affects economic development in the Baltic states. As the proportion of elderly individuals increases, the working-age population shrinks, leading to a smaller labor force and reduced productivity. This demographic shift results in higher dependency ratios, where fewer workers support old people, which in turn increases the burden on social security and healthcare systems.

Varpina (Varpina, 2018) adds that an aging population leads to lower consumption rates. As the population ages, older individuals tend to spend less compared to younger, economically active individuals. This reduction in consumption is due to several factors, including lower income levels after retirement, decreased mobility, and a shift in spending priorities towards healthcare and basic needs rather than discretionary goods and services. The decline in consumer demand results in reduced business activities and, consequently, slower economic growth.

3 RESULTS AND FINDINGS

3.1 Descriptive statistics

In the preliminary stages of the data analysis, the researcher conducted a descriptive analysis to summarize the characteristics of the dataset and gain insights into the distribution and variability of the variables. The results of the descriptive analysis for each of the three countries are presented in the table below.

Table 1

Showing descriptive statistics.

Variable name	Country	Mean	Sd	Min	Max	Skewness
FR	Estonia	1.52	0.21	1.23	2.03	0.82
	Latvia	1.46	0.22	1.09	7.60	0.35
	Lithuania	1.53	0.18	1.20	2.05	0.44
CBR	Estonia	10.32	1.83	7.80	15.40	1.39
	Latvia	9.79	1.51	7.60	14.20	0.83
	Lithuania	10.36	1.30	7.50	14.20	0.51
PGR	Estonia	-0.73	0.77	-2.26	1.41	0.72
	Latvia	-1.03	0.47	-2.08	0.13	-0.07
	Lithuania	-0.41	0.85	-2.57	1.34	-0.47
UPGR	Estonia	-0.69	0.84	-2.28	1.75	0.92
	Latvia	-1.05	0.54	-2.05	0.32	0.23
	Lithuania	-0.47	1.01	-2.84	1.62	-0.25
NMR	Estonia	-1.75	8.22	-24.93	29.44	0.75
	Latvia	-5.52	5.72	-19.95	11.71	0.00
	Lithuania	-4.67	8.70	-25.47	25.59	1.28
ADR	Estonia	51.30	2.30	48.67	57.84	1.17
	Latvia	51.64	4.01	47.40	60.45	0.88
	Lithuania	51.57	3.73	48.88	59.16	0.58
PcGDP	Estonia	9748.09	4021.64	4274.08	16705.60	0.27
	Latvia	9499.09	3648.10	4290.04	15335.22	0.01
	Lithuania	12565.20	4339.52	6016.43	19400.12	-0.08

3.1.1 Fertility rates

The results in Table 1 show that Estonia demonstrates stable fertility rates with a mean of 1.52 and low variability (SD = 0.21). Latvia and Lithuania have slightly lower means of 1.46 and 1.53, respectively, and similar levels of variability (SD = 0.22 and 0.18, respectively). Skewness values for all three countries are low (Estonia = 0.82, Latvia = 0.35, Lithuania = 0.44), indicating near-symmetric distributions. This stability across the Baltic States reflects common demographic trends and policy influences impacting fertility.

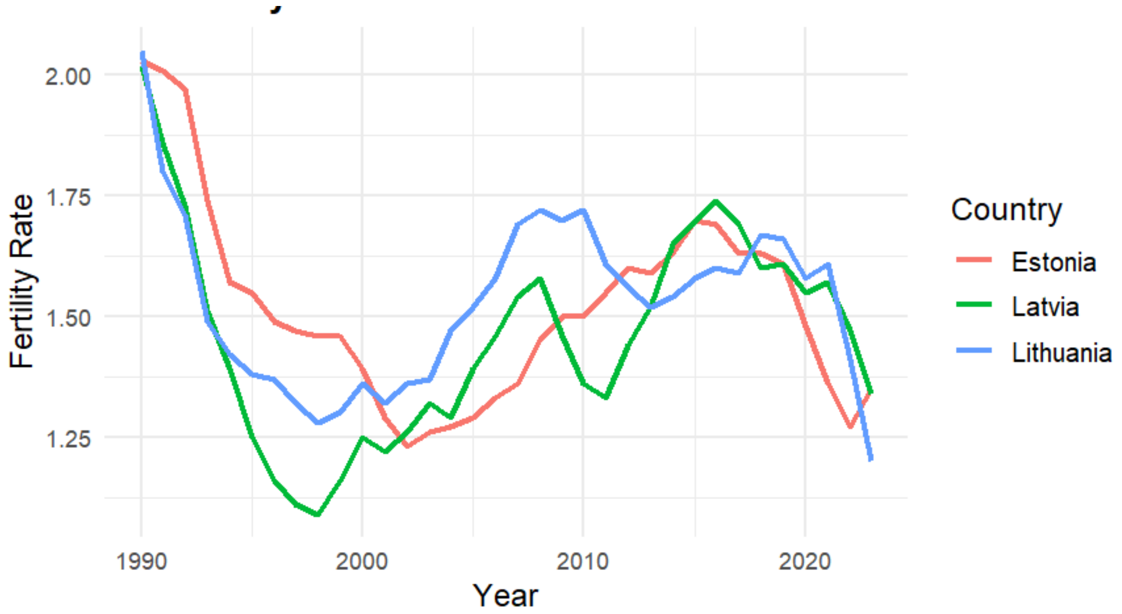


Fig. 1. Showing Trends of Fertility rates in the Baltic States Appendix 2:

The plot shows a decline in fertility rates across Estonia, Latvia, and Lithuania during the 1990s. Fertility rates began recovering in the early 2000s, with Estonia and Lithuania showing steadier trends, while Latvia experienced more fluctuations. By 2015, the rates converged, but a decline is observed again towards 2020, particularly in Lithuania.

3.1.2 Crude Birth Rates

The results presented in table 1 show that Crude birth rates are slightly higher in Estonia (mean = 10.32) and Lithuania (mean = 10.36) compared to Latvia (mean = 9.79). Variability is moderate across the three countries, with standard deviations ranging from 1.30 (Lithuania) to 1.83 (Estonia). Skewness values are positive (Estonia = 1.39, Latvia = 0.83, Lithuania = 0.51), suggesting occasional periods of higher birth rates.

The plot illustrates the crude birth rate trends in Estonia, Latvia, and Lithuania from 1990 to 2020. All three countries show a sharp decline during the 1990s. From the early 2000s, crude birth rates exhibit a gradual recovery, with Estonia and Lithuania displaying steadier increases compared to Latvia, which shows more variability. Around 2015, the rates converge across the countries but decline again towards 2020, reflecting continued demographic challenges in the Baltic States

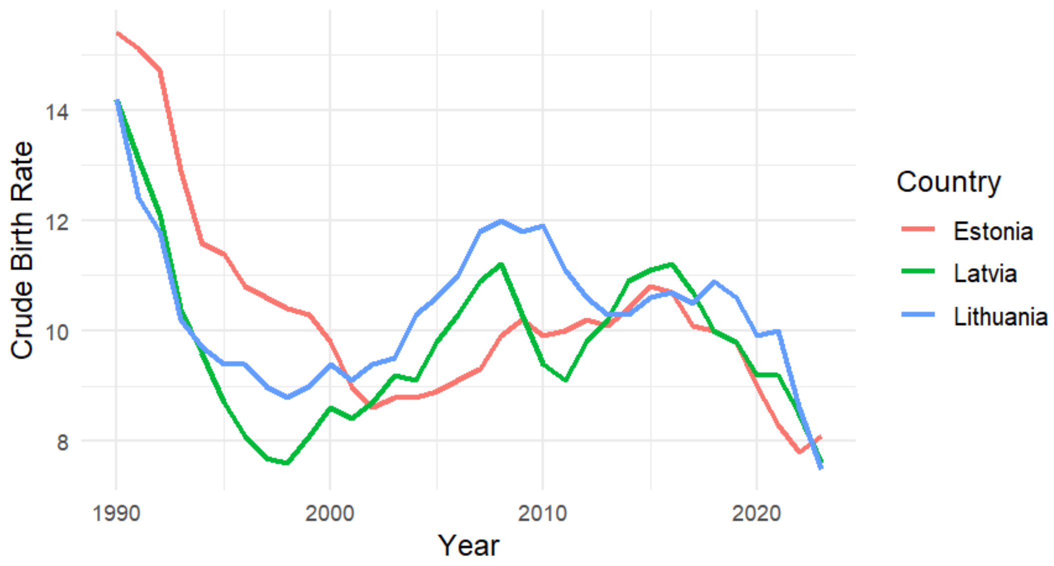


Fig. 2. Showing Trends of Crude Birth rates in the Baltic States Appendix 2:

3.1.3 Population Growth Rate

Additionally, the descriptive statistics presented in table 1 show that Population growth rates are negative for all three countries, reflecting ongoing demographic declines. Latvia shows the steepest decline (mean = -1.03) but with the least variability (SD = 0.47). Estonia and Lithuania have less negative growth rates (means = -0.73 and -0.41, respectively) but display higher variability (SD = 0.77 and 0.85, respectively). Skewness values indicate near-symmetry for Latvia (-0.07) and slight asymmetry for Estonia (0.72) and Lithuania (-0.47), highlighting differing dynamics in population trends.

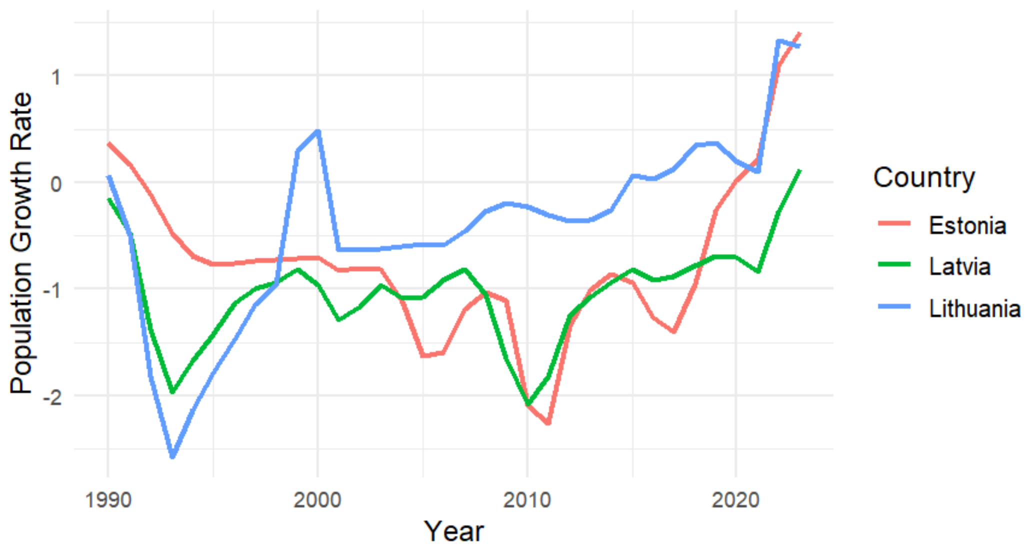


Fig. 3. Showing trends of Population Growth Rates in the Baltic States Appendix 2:

3.1.4 Urban Population Growth Rate

Moreover, table 1 shows that Urban population growth rates are negative across all countries, with Latvia recording the lowest mean (-1.05) and the least variability (SD = 0.54). Lithuania has the highest mean (-0.47) but also the greatest variability (SD = 1.01). Estonia falls in between with a mean of -0.69 and variability (SD = 0.84). Skewness values are low across the board, with Estonia (0.92), Latvia (0.23), and Lithuania (-0.25), indicating mostly symmetric trends. These figures suggest differing levels of urbanization pressures across the countries.

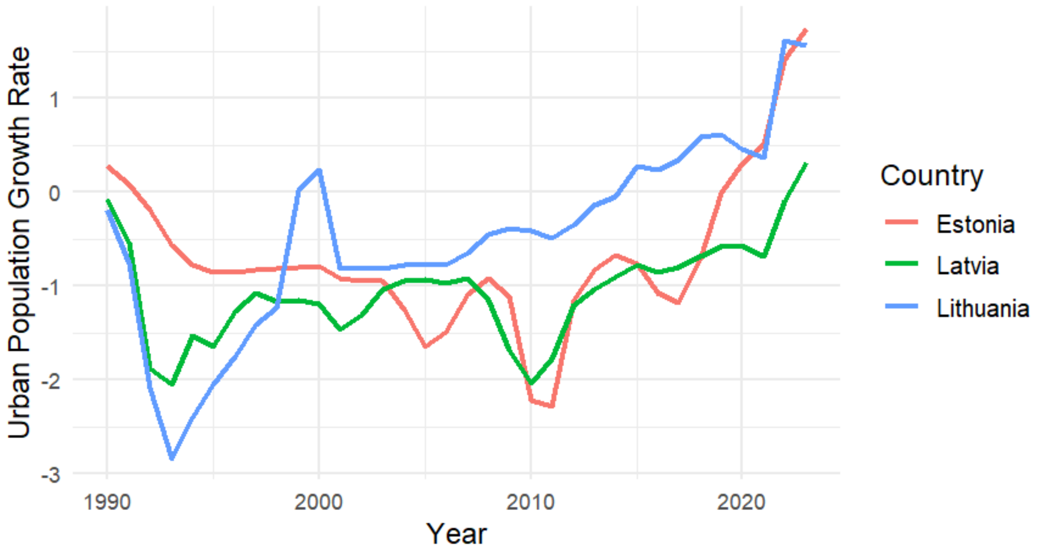


Fig. 4. Showing Trends in Urban Population Growth Rates in the Baltic States Appendix 2:

All three countries exhibit negative growth rates during the 1990s, reflecting post-Soviet population declines. Latvia and Estonia display consistent negative trends throughout most of the period, while Lithuania shows higher variability, including periods of recovery in the 2000s. Notably, all three countries experience a marked improvement after 2015, with Lithuania showing the most significant increase.

3.1.5 Net Migration rate

Furthermore, table 1 shows that Net migration rates vary significantly, with Estonia showing the greatest variability (SD = 8.22) and a wide range (-24.93 to 29.44). Lithuania exhibits similar variability (SD = 8.70) and a range of -25.47 to 25.59, with a higher skewness (1.28) indicating occasional positive spikes. Latvia has more stable migration rates, with a mean of -5.52, SD of 5.72, and skewness of 0.00.

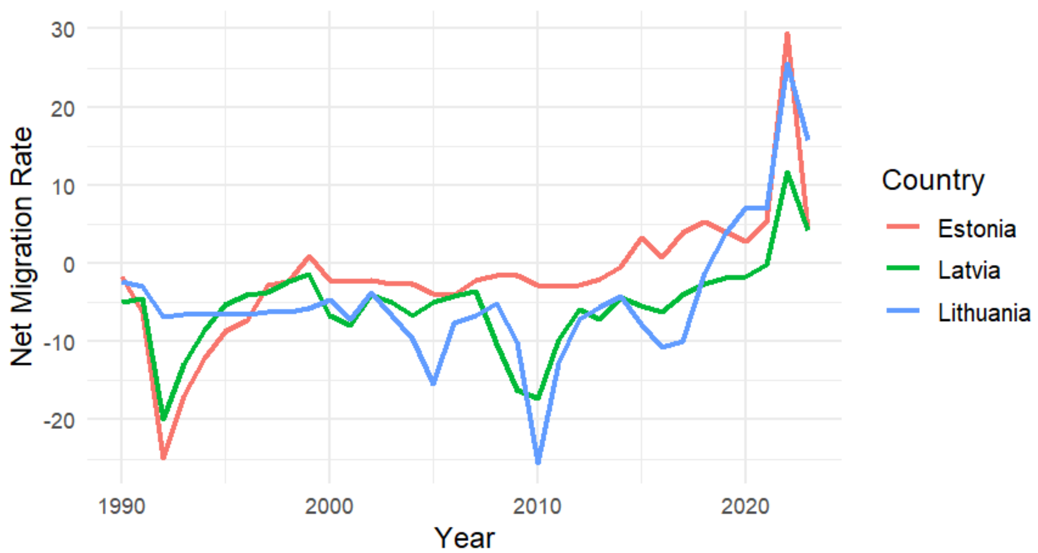


Fig. 5. Showing the trends in Net Migration Rates in the Baltic States Appendix 2:

All three countries experienced negative net migration during the 1990s, reflecting significant outflows following the collapse of the Soviet Union. In the 2000s, migration rates began to stabilize, with occasional fluctuations, particularly in Lithuania. A noticeable upward trend emerges after 2015, with all three countries transitioning to positive net migration by 2020. Estonia shows the sharpest increase around 2020, suggesting a recent reversal in migration patterns, potentially due to improved economic opportunities and policy changes in the region.

3.1.6 Age Dependency ratios

The results in table 1 show that Age dependency ratios are similar across the three countries, with means around 51.5 (Estonia = 51.30, Latvia = 51.64, Lithuania = 51.57). Variability is highest in Latvia (SD = 4.01) and lowest in Estonia (SD = 2.30). Skewness values are moderate, with Estonia (1.17), Latvia (0.88), and Lithuania (0.58), suggesting slight asymmetry in dependency structures.

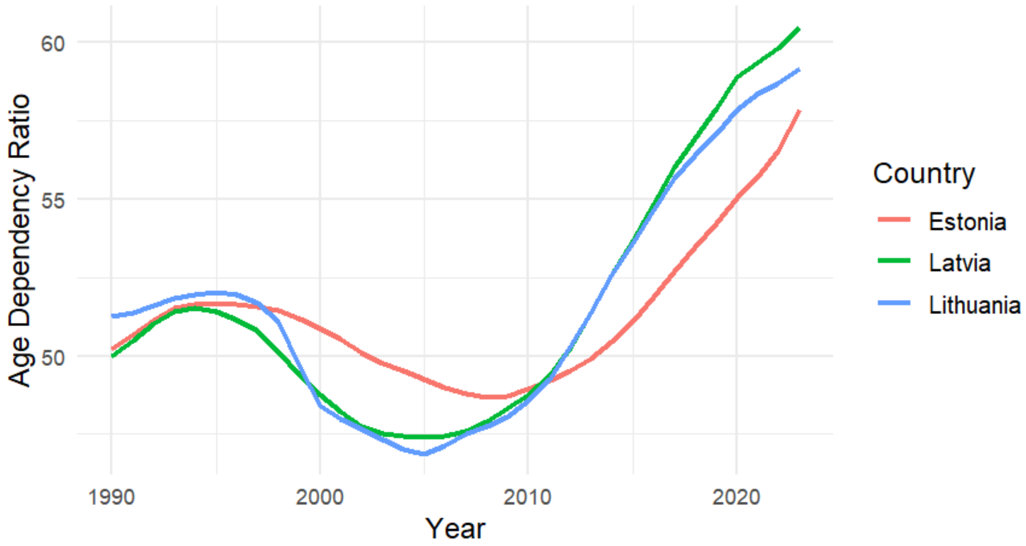


Fig. 6. Showing trends in Age Dependency Ratios in the Baltic States Appendix 2:

All three countries exhibit a decline in dependency ratios during the 1990s and early 2000s, reflecting a shrinking proportion of dependents relative to the working-age population. Around 2010, the trend reverses, and dependency ratios begin to rise steadily across all countries, with Latvia showing the steepest increase. By 2020, Latvia has the highest dependency ratio, followed by Lithuania and Estonia. This upward trend highlights the aging populations in the Baltic States, posing challenges for economic sustainability and social support systems.

3.1.7 GDP Per Capita

Lithuania leads economically with the highest GDP per capita (mean = 12,565.20, range = 6,016.43 to 19,400.12) and variability (SD = 4,339.52). Estonia (mean = 9,748.09, SD = 4,021.64) and Latvia (mean = 9,499.09, SD = 3,648.10) have lower but comparable GDP levels. Skewness values are close to zero for all three countries (Estonia = 0.27, Latvia = 0.01, Lithuania = -0.08), indicating symmetrical distributions.

All three countries show relatively low GDP per capita in the early 1990s, followed by significant growth starting in the late 1990s. Lithuania consistently leads with the highest GDP per capita, showing rapid growth, particularly after 2010. Estonia and Latvia have similar trajectories, with Latvia lagging slightly behind. The upward trend reflects economic development in the region, with Lithuania achieving the strongest performance overall. This economic growth highlights improvements in productivity and living standards across the Baltic States.

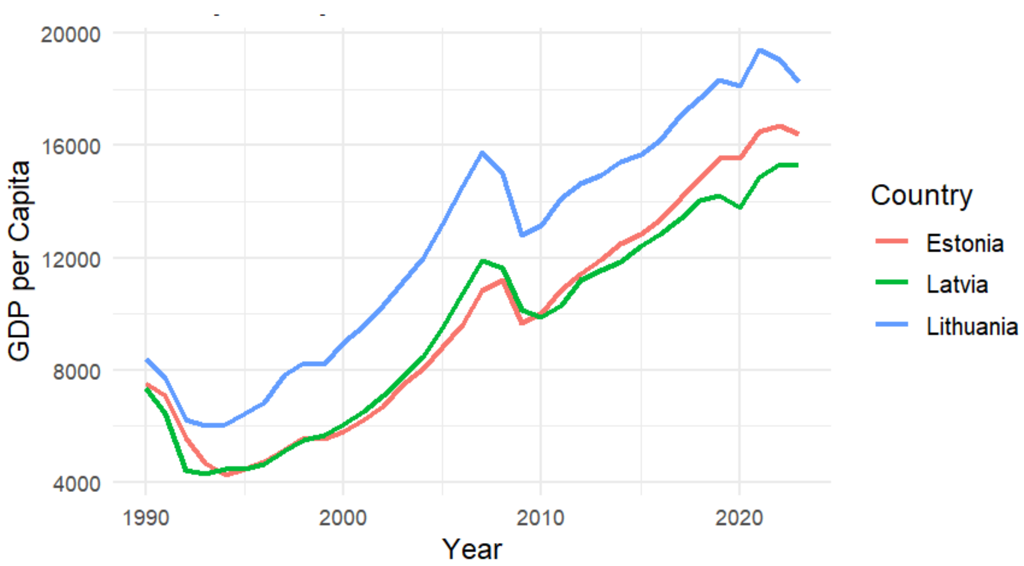


Fig. 7. Showing trends in GDP per Capita in the Baltic States Appendix 2:

3.2 Multicollinearity analysis

After analysng the trends, the researcher conducted a multicollinearity analysis to analyse the level of correlations between the independent variables. This was achieved through a VIF analysis. The results of the VIF factors are presented in Table 2 below.

Table 2

Showing results of VIF analysis. Appendix 2:

Variable	ADR	CBR	FR	NMR	PGR	UPGR
VIF	2.595132	19.223396	17.075025	2.142514	37.955552	42.075840

The results above show that CBR and FR both had VIF values of 19.22 and 17.08, respectively, indicating high multicollinearity because they exceeded the conventional value of 10. Likewise, PGR and UPGR exhibited high multicollinearity with VIF values of 37.96 and 42.08, respectively, which exceeded the conventional threshold of 10, confirming that the inclusion of both variables in each pair would lead to unreliable coefficient estimates due to inflated standard errors. Therefore, the decision was made to eliminate Fertility rates, and retain Crude Birth rate. In addition, PGR was excluded and UPGR included due to its stronger association with economic growth. The refined regression model is as follows.

$$PcGDP_{it} = \theta_0 + \theta_1 ADR_{it} + \theta_2 CBR_{it} + \theta_3 NMR_{it} + \theta_4 UPGR_{it} + \varepsilon \qquad \text{Eq 3.1}$$

Whereby

$PcGDP_{it}$ *: GDP per Capita of Country i, year t.*

θ_0 *is the intercept term.*

$\theta_1 \ldots \varepsilon$ *are the coefficients of the independent variables, representing the magnitude and direction of their impact on GDP per capita.*

ε *is the error term.*

3.3 Panel Regression modelling

3.3.1 Pooled Ordinary Least squares

In the first step of the panel regression modeling, the researcher began by fitting the Pooled Ordinary Least Squares (OLS) model and conducting the Breusch-Pagan Lagrange Multiplier (LM) test to determine whether there were significant entity-specific effects that needed to be accounted for. The following hypothesis was set.

H_0: No Significant entity specific effects

H_1: Significant entity specific effects

The results of the Breusch-Pagan Lagrange Multiplier (LM) test are presented in Table below.

Table 3

Showing the Breusch-Pagan Lagrange Multiplier (LM) test results Appendix 2:

Lagrange Multiplier Test – (Breusch-Pagan)		
Chi-Square	df	p-value
12.838	1	0.002391

The results presented in the table above imply that the null hypothesis of no significant entity-specific effects is rejected at a 0.05 significance level. This finding confirms the presence of unobserved heterogeneity across entities (countries) in the dataset, indicating that the Pooled OLS model is inappropriate for the analysis. Therefore, the next step in the analysis involves fitting both the Fixed Effects and Random Effects models to account for these significant entity-specific effects.

3.3.2 Choosing between the Fixed effects model and the Random effects model

The researcher proceeded to fit the fixed effects model and random effects model to account for potential entity-specific effects identified. However, during the estimation of the Random Effects model, an error occurred due to the limited number of entities in the dataset. With only three countries (Estonia, Latvia, and Lithuania), the Swamy-Arora method could not estimate the "between" variability, making the Random Effects model infeasible. Given this limitation, the researcher selected the Fixed Effects model, which addresses unobserved heterogeneity by allowing each country to have its own unique intercept, accounting for time-invariant differences across countries.

Therefore, the fixed effects model is as follows.

Table 4

Showing the Fixed effects model. Appendix 2:

Fixed effects model				
Variable	**Estimate**	**Standard error**	**t-value**	**P-value**
Intercept	2277.112	6942.719	0.3280	0.74363
ADR	240.931	119.143	2.0222	0.0451*
CBR	-205.592	235.807	-0.8803	0.38085
NMR	34.436	57.732	0.5965	0.55224
UPGR	2495.344	492.849	5.0631	$1.962\,e^{-06}$ ***
Significance:'***' 0.001 '**' 0.01 '*'0.05 '. '0.1'				

To validate this model, a test for heteroskedasticity was conducted using the studentized Breusch-Pagan test. A hypothesis was set.

H_0: Assumes homoscedasticity (Constant variance of residuals)

H_1: Presence of heteroscedasticity (non-constant variance)

The results are presented in the table below.

Table 5

Showing the results of the studentized Breusch-Pagan test Appendix 2:

Studentized Breusch-Pagan test Data: Fixed effects model		
BP	df	p-value
15.878	4	0.003187

According to the results presented in the above table, the null hypothesis of homoscedasticity is rejected at the 0.05 significance level, as the p-value is below the threshold. This indicates the presence of heteroskedasticity in the model. To address this issue, robust standard errors will be applied to ensure the reliability and validity of statistical inferences. The robust standard errors correct for the non-constant variance. The results of the final regression model are presented in the table below.

Table 6

Showing the results of the final regression model Appendix 2:

Final Fixed effects Regression Model				
Variable	**Estimate**	**Standard error**	**t-value**	**P-value**
ADR	240.641	118.352	2.00333	0.04481*
CBR	-143.748	166.296	-0.8644	0.38954
NMR	79.152	118.601	0.6674	0.50615
UPGR	2059.202	1089.609	1.8899	0.06183
Significance:'***' 0.001 '** '0.01 '*'0.05 '. '0.1'				

The results from the Fixed Effects model with robust standard errors reveal that Age Dependency Ratio (ADR) is a statistically significant predictor of GDP per capita at the 5% level with a positive estimated coefficient of 240.641. These findings suggest that variations in the Age Dependency Ratio variable have a meaningful relationship with economic growth in the Baltic States. On the other hand, Net Migration Rate (NMR), Crude Birth Rates, (CBR) and Urban Population Growth Rate (UPGR) are not statistically significant, this indicates that changes in migration, birth rates and urbanization do not have a significant impact on GDP per capita in this model.

4 CONCLUSION

4.1 Key findings

The focus of this research study was to assess the demographic factors that affect the economic growth within the Baltic States. Based on the findings of the data analysis, the researcher pointed out that Age Dependency Ratio played a major role in the economic development of the Baltic States. An increase in the overall ADR means that a larger proportion of the population is in the dependent age groups. This raises the pressure on the working-age population, lowering their output and also pushes the costs of social security and health care to higher levels. This finding supports Varpina (Varpina, 2018) who observed that ageing population in the Baltic States reduces the labour force and economic productivity as a result of the growing dependency ratios. Figure 3.6 presented above show a trend of increasing dependency ratios. The shrinking workforce and growing elderly population pose challenges to economic sustainability for the Baltic States.

4.2 Policy responses to Emerging Demographic Challenges

A key strategy to mitigate the impact of an aging population is to extend working lifespan. Raising the retirement age will allow older individuals to remain economically active for longer, which will play a crucial role in reducing the dependency burden. Additionally, the researcher recommends Flexible retirement options, such as phased or partial retirement. This can help ease the transition for older workers while retaining their valuable experience and expertise. In addition, the researcher also recommends creating immigration policies that attract younger and skilled immigrants. This will play a crucial role in addressing the labor shortages in the Baltic States and in the long run sustain economic productivity.

References:

1. D. Gu, K. Andreev, and M. E. Dupre, “Major Trends in Population Growth Around the World,” vol. 3, no. 28, 2021.
2. V. Khachatrian, A. Nepytaliuk, M. Pasichnyi, O. Nasibova, and J. Tabenska, “Demographics’ Impact on Economic Growth in Central Europe and the Baltic States,” *ECONOMICS*, vol. 11, no. s1, pp. 37–54, Dec. 2023, doi: 10.2478/eoik-2023-0062.
3. World Population Prospects, “Latvia Population 2024 (Live).” Accessed: Jul. 11, 2024. [Online]. Available: https://worldpopulationreview.com/countries/latvia-population
4. R. J. Aitken, “Population decline: where demography, social science, and biology intersect,” *Reproduction*, vol. 168, no. 1, 2024, Accessed: Jul. 13, 2024. [Online]. Available: https://rep.bioscientifica.com/view/journals/rep/168/1/REP-24-0070.xml
5. A. Galstyan, M. Grabowska, and V. Bačiulienė, “Economic development and migration after EU accession: The case of Baltic states,” *Pressburg Economic Review*, vol. 1, no. 1, pp. 47–55, 2021.
6. Z. Varpina, “Countries of old men? Demographic challenges in Estonia, Latvia and Lithuania,” May 2018.
7. T. Lang, D. Burneika, R. Noorkõiv, B. Plüschke-Altof, G. Pociūtė-Sereikienė, and G. Sechi, “Socio-spatial polarisation and policy response: Perspectives for regional development in the Baltic States,” *European Urban and Regional Studies*, vol. 29, no. 1, pp. 21–44, Jan. 2022, doi: 10.1177/09697764211023553.
8. Q. Wang and L. Li, “The effects of population aging, life expectancy, unemployment rate, population density, per capita GDP, urbanization on per capita carbon emissions,” *Sustainable Production and Consumption*, vol. 28, pp. 760–774, 2021.
9. United Nations Glossary, “World Population Prospects - Population Division - United Nations.” Accessed: Dec. 02, 2024. [Online]. Available: https://population.un.org/wpp/GlossaryOfDemographicTerms/
10. Y. Li, “The relationship between fertility rate and economic growth in developing countries,” 2016, Accessed: Dec. 02, 2024. [Online]. Available: https://lup.lub.lu.se/student-papers/record/8727479/file/8768892.pdf
11. I. Ilori and K. Akeju, “Crude death and crude birth rates, and economic development in sub-Saharan Africa Countries,” *International journal of health sciences*, pp. 10243–10264, Jul. 2022, doi: 10.53730/ijhs.v6nS4.11050.
12. E. W. F. Peterson, “The Role of Population in Economic Growth,” *SAGE Open*, vol. 7, no. 4, p. 215824401773609, Oct. 2017, doi: 10.1177/2158244017736094.
13. S. Sarker, A. Khan, and M. Mannan, “Urban population and economic growth: South Asia perspective,” *European Journal of Government and Economics*, vol. 4, pp. 64–75, Jul. 2016, doi: 10.17979/ejge.2016.5.1.4316.
14. O. Oliinyk, Y. Bilan, H. Mishchuk, O. Akimov, and L. Vasa, “The impact of migration of highly skilled workers on the country’s competitiveness and economic growth,” *Montenegrin Journal of Economics*, 2021, Accessed: Dec. 02, 2024. [Online]. Available: https://publikace.k.utb.cz/handle/10563/1010443
15. W. Kirch, Ed., “Age-Dependency RatioAge-dependency ratio,” in *Encyclopedia of Public Health*, Dordrecht: Springer Netherlands, 2008, pp. 23–23. doi: 10.1007/978-1-4020-5614-7_77.
16. M. Arif, R. Rosni, Z. Islami, and T. Rahmadi, “THE ANALYSIS OF THE IMPACT OF WORKING-AGE POPULATION ON INDONESIAN LABOUR,” *JURNAL GEOGRAFI*, vol. 13, p. 97, Feb. 2021, doi: 10.24114/jg.v13i1.21145.
17. C. Hsiao, “Panel data analysis–advantages and challenges,” *TEST*, vol. 16, no. 1, pp. 1–22, May 2007, doi: 10.1007/s11749-007-0046-x.
18. B. Khursanaliev, “The impact of population growth on the country’s economic development,” *Qo ‘qon universiteti xabarnomasi*, vol. 1, pp. 8–11, 2023.
19. O. T. Adeosun and O. O. Popogbe, “Population growth and human resource utilization nexus in Nigeria,” *Journal of Humanities and Applied Social Sciences*, vol. 3, no. 4, pp. 281–298, 2021.
20. R. Ubarevičienė and M. van Ham, “Population decline in Lithuania: who lives in declining regions and who leaves?,” *Regional Studies, Regional Science*, vol. 4, no. 1, pp. 57–79, Jan. 2017, doi: 10.1080/21681376.2017.1313127.
21. B. Bhardwaj and D. Sharma, “Migration of skilled professionals across the border: Brain drain or brain gain?,” *European Management Journal*, vol. 41, no. 6, pp. 1021–1033, 2023.
22. H. Zhang, H. Zhang, and J. Zhang, “Demographic age structure and economic development: Evidence from Chinese provinces,” *Journal of Comparative Economics*, vol. 43, no. 1, pp. 170–185, 2015.

5 APPENDIX

5.1 Appendix 1

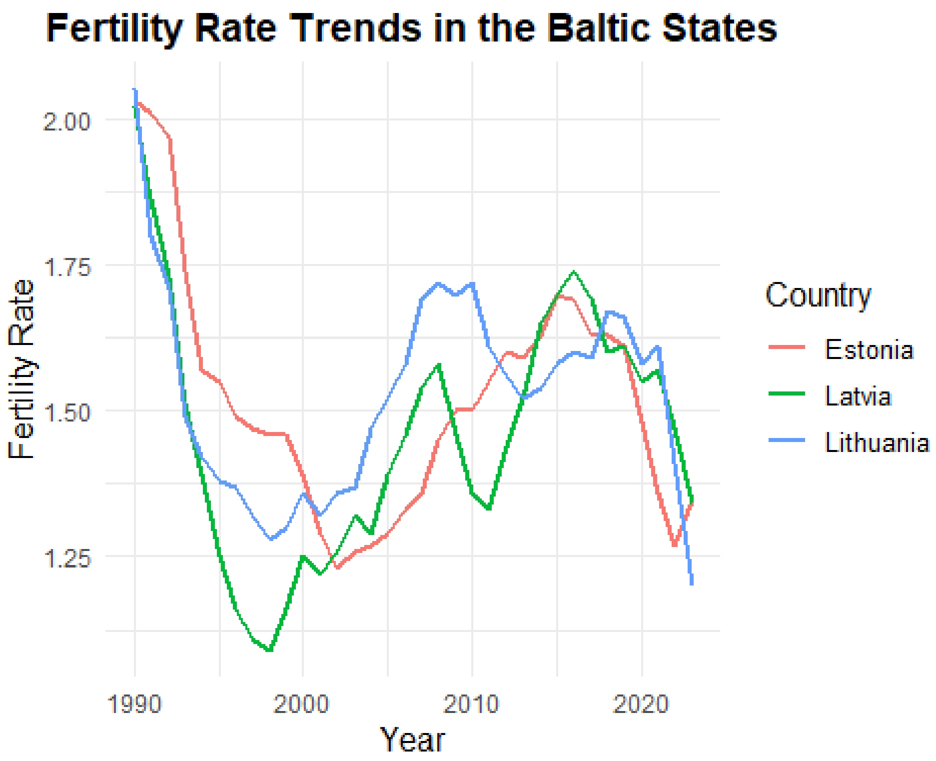
Link to the data.
World Bank Open Data | Data
World Population Prospects - Population Division - United Nations
https://drive.google.com/drive/folders/1kh9ETgn2CqrF4WY4VOr5NRGOXsjacgYq?usp=sharing

5.2 Appendix 2:

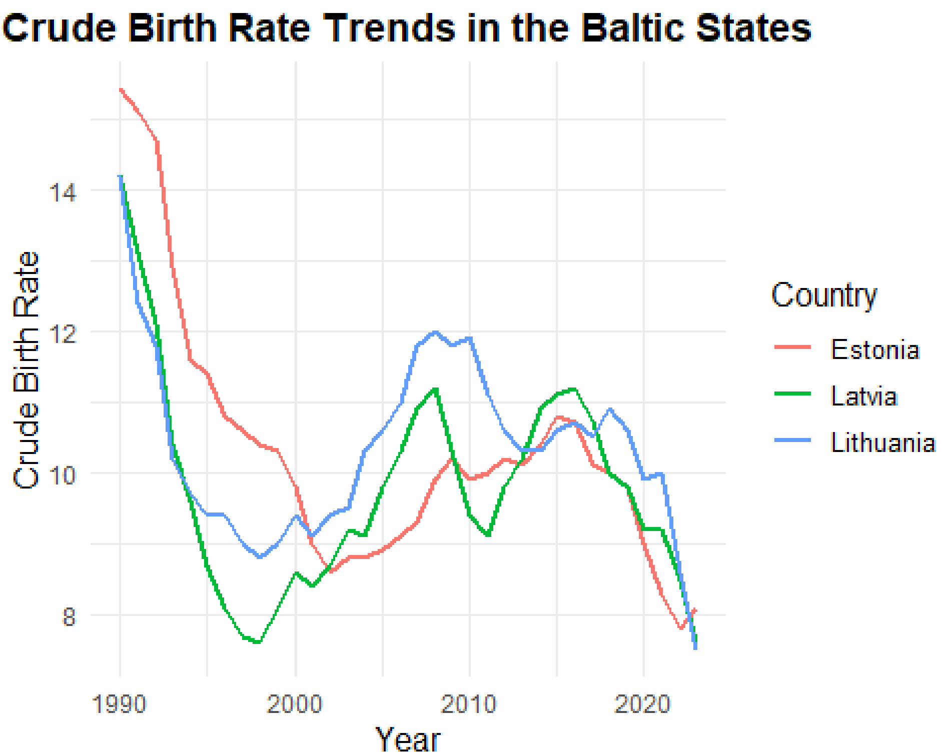
Rcode

```
#Load package
library(psych)
library(tidyverse)
library(plm)
library(ggplot2)
library(tidyr)
library(dplyr)
library(car)
library(lmtest)
library(sandwich)
library(lmtest)

# Read the datasets
estonia_data <- read.csv("D:/EstoniaData.csv")
latvia_data <- read.csv("D:/LatviaData.csv")
lithuania_data <- read.csv("D:/LithuaniaData.csv")

# Exclude the Year column from the analysis
estonia_data_numeric <- estonia_data[, -which(names(estonia_data) == "Year")]
latvia_data_numeric <- latvia_data[, -which(names(latvia_data) == "Year")]
lithuania_data_numeric <- lithuania_data[, -which(names(lithuania_data) == "Year")]

# Compute descriptive statistics
estonia_stats <- describe(estonia_data_numeric)
latvia_stats <- describe(latvia_data_numeric)
lithuania_stats <- describe(lithuania_data_numeric)

# Print the results
print("Descriptive Statistics for Estonia:")

## [1] "Descriptive Statistics for Estonia:"

print(estonia_stats)

##       vars  n    mean     sd  median trimmed     mad     min      max
## ADR      1 34   51.30   2.30   50.98   51.00    1.71   48.67    57.84
## CBR      2 34   10.32   1.83   10.05   10.05    1.11    7.80    15.40
## FR       3 34    1.52   0.21    1.50    1.50    0.20    1.23     2.03
## PcGDP    4 34 9748.09 4021.64 9625.48 9585.70 5285.59 4274.08 16705.60
## NMR      5 34   -1.75   8.22   -2.20   -1.62    2.56  -24.93    29.44
## PGR      6 34   -0.73   0.77   -0.81   -0.78    0.48   -2.26     1.41
## UPGR     7 34   -0.69   0.84   -0.83   -0.75    0.38   -2.28     1.75
##          range skew kurtosis     se
## ADR       9.17 1.17     0.71   0.39
## CBR       7.60 1.39     1.54   0.31
## FR        0.80 0.82     0.23   0.04
## PcGDP 12431.52 0.27    -1.32 689.71
## NMR      54.37 0.75     5.46   1.41
## PGR       3.67 0.72     0.81   0.13
## UPGR      4.03 0.92     1.34   0.14

print("Descriptive Statistics for Latvia:")

## [1] "Descriptive Statistics for Latvia:"

print(latvia_stats)

##       vars  n    mean     sd   median trimmed     mad     min      max
## ADR      1 34   51.64   4.01    50.64   51.21    3.51   47.40    60.45
## CBR      2 34    9.79   1.51     9.70    9.66    1.48    7.60    14.20
## FR       3 34    1.46   0.22     1.46    1.45    0.21    1.09     2.02
## PcGDP    4 34 9499.09 3648.10 10004.09 9440.42 5078.98 4290.04 15335.22
## NMR      5 34   -5.52   5.72    -4.97   -5.36    2.89  -19.95    11.71
## PGR      6 34   -1.03   0.47    -0.97   -1.03    0.26   -2.08     0.13
## UPGR     7 34   -1.05   0.54    -1.03   -1.06    0.39   -2.05     0.32
##          range  skew kurtosis     se
## ADR      13.06  0.88    -0.52   0.69
```

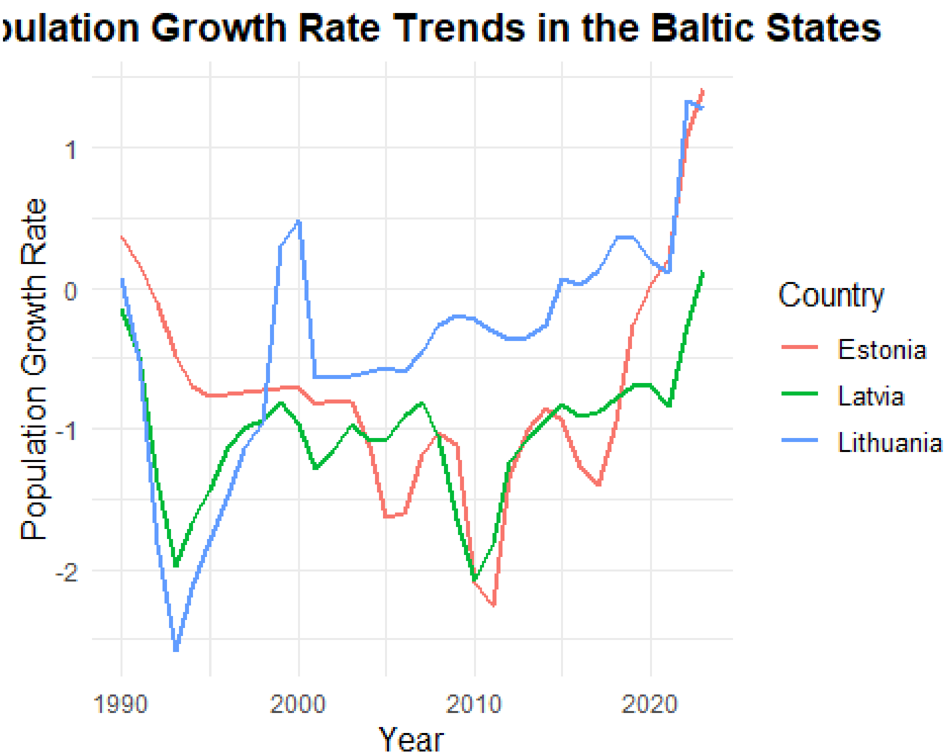
```
## CBR       6.60  0.83     0.61   0.26
## FR        0.93  0.35    -0.39   0.04
## PcGDP 11045.17  0.01    -1.45 625.64
## NMR      31.66  0.00     1.89   0.98
## PGR       2.21 -0.07     0.32   0.08
## UPGR      2.37  0.23     0.03   0.09

print("Descriptive Statistics for Lithuania:")

## [1] "Descriptive Statistics for Lithuania:"

print(lithuania_stats)

##       vars  n     mean      sd   median  trimmed     mad     min      max
## ADR      1 34    51.57    3.73    51.38    51.30    4.63   46.88    59.16
## CBR      2 34    10.36    1.30    10.30    10.31    1.26    7.50    14.20
## FR       3 34     1.53    0.18     1.55     1.53    0.21    1.20     2.05
## PcGDP    4 34 12565.20 4339.52 13166.69 12577.12 6014.70 6016.43 19400.12
## NMR      5 34    -4.67    8.70    -6.47    -5.48    3.05  -25.47    25.59
## PGR      6 34    -0.41    0.85    -0.33    -0.37    0.59   -2.57     1.34
## UPGR     7 34    -0.47    1.01    -0.44    -0.45    0.83   -2.84     1.62
##          range  skew kurtosis     se
## ADR      12.28  0.58    -0.85   0.64
## CBR       6.70  0.51     0.64   0.22
## FR        0.85  0.44     0.24   0.03
## PcGDP 13383.69 -0.08    -1.44 744.22
## NMR      51.06  1.28     3.49   1.49
## PGR       3.91 -0.47     0.36   0.15
## UPGR      4.45 -0.25    -0.05   0.17

# Add a 'Country' column
estonia_data$Country <- "Estonia"
latvia_data$Country <- "Latvia"
lithuania_data$Country <- "Lithuania"

# Combine the datasets
combined_data <- bind_rows(estonia_data, latvia_data, lithuania_data)

#Graph showing trends in Fertility rates

# Filter the data for Fertility Rate
fertility_rate_data <- combined_data %>%
  select(Year, Country, FertilityRate = FR)  # Replace "FR" with the actual column name for fe
rtility rate if different

# Create the plot
ggplot(fertility_rate_data, aes(x = Year, y = FertilityRate, color = Country, group = Countr
y)) +
  geom_line(size = 1) +
  labs(
    title = "Fertility Rate Trends in the Baltic States",
    x = "Year",
    y = "Fertility Rate",
    color = "Country"
  ) +
  theme_minimal() +
  theme(
    plot.title = element_text(size = 14, face = "bold", hjust = 0.5),
    axis.title = element_text(size = 12),
    legend.title = element_text(size = 12),
    legend.text = element_text(size = 10)
  )
```



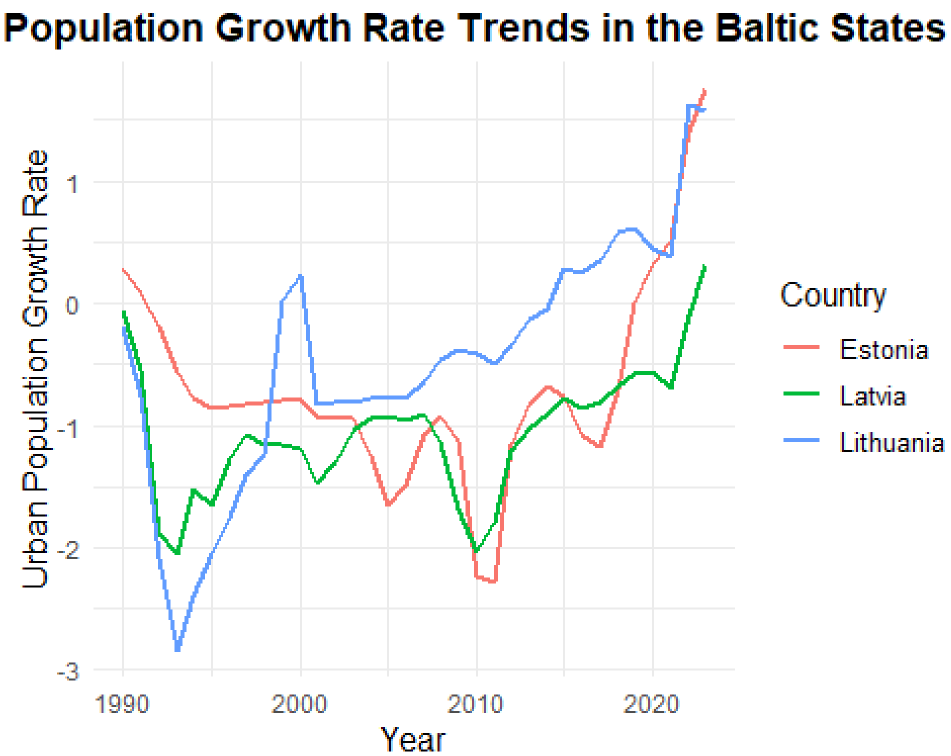

```
#Graph Showing trends in Crude Birth Rates

# Filter the data for Crude Birth Rate
crude_birth_rate_data <- combined_data %>%
  select(Year, Country, CrudeBirthRate = CBR)  # Replace "CBR" with the actual column name for
crude birth rate if different

# Create the plot
ggplot(crude_birth_rate_data, aes(x = Year, y = CrudeBirthRate, color = Country, group = Count
ry)) +
  geom_line(size = 1) +
  labs(
    title = "Crude Birth Rate Trends in the Baltic States",
    x = "Year",
    y = "Crude Birth Rate",
    color = "Country"
  ) +
  theme_minimal() +
  theme(
    plot.title = element_text(size = 14, face = "bold", hjust = 0.5),
    axis.title = element_text(size = 12),
    legend.title = element_text(size = 12),
    legend.text = element_text(size = 10)
  )
```



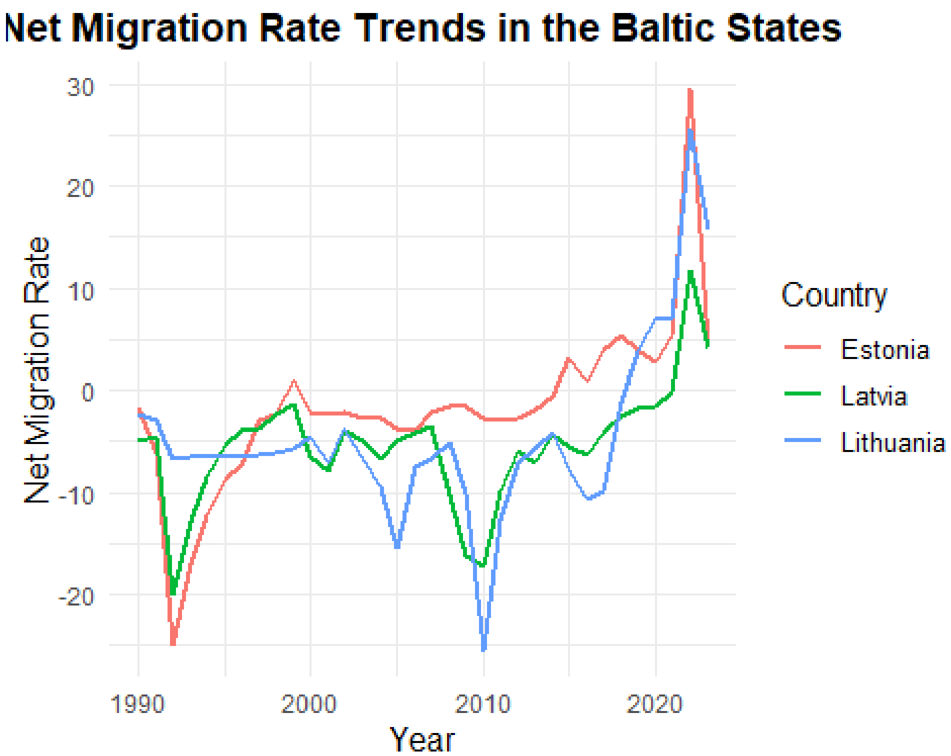

```
#Graph Showing trends in Population growth rate
# Filter the data for Population Growth Rate
population_growth_rate_data <- combined_data %>%
  select(Year, Country, PopulationGrowthRate = PGR)  # Replace "PGR" with the actual column na
me for population growth rate if different

# Create the plot
ggplot(population_growth_rate_data, aes(x = Year, y = PopulationGrowthRate, color = Country, g
roup = Country)) +
  geom_line(size = 1) +
  labs(
    title = "Population Growth Rate Trends in the Baltic States",
    x = "Year",
    y = "Population Growth Rate",
    color = "Country"
  ) +
  theme_minimal() +
  theme(
    plot.title = element_text(size = 14, face = "bold", hjust = 0.5),
    axis.title = element_text(size = 12),
    legend.title = element_text(size = 12),
    legend.text = element_text(size = 10)
  )
```



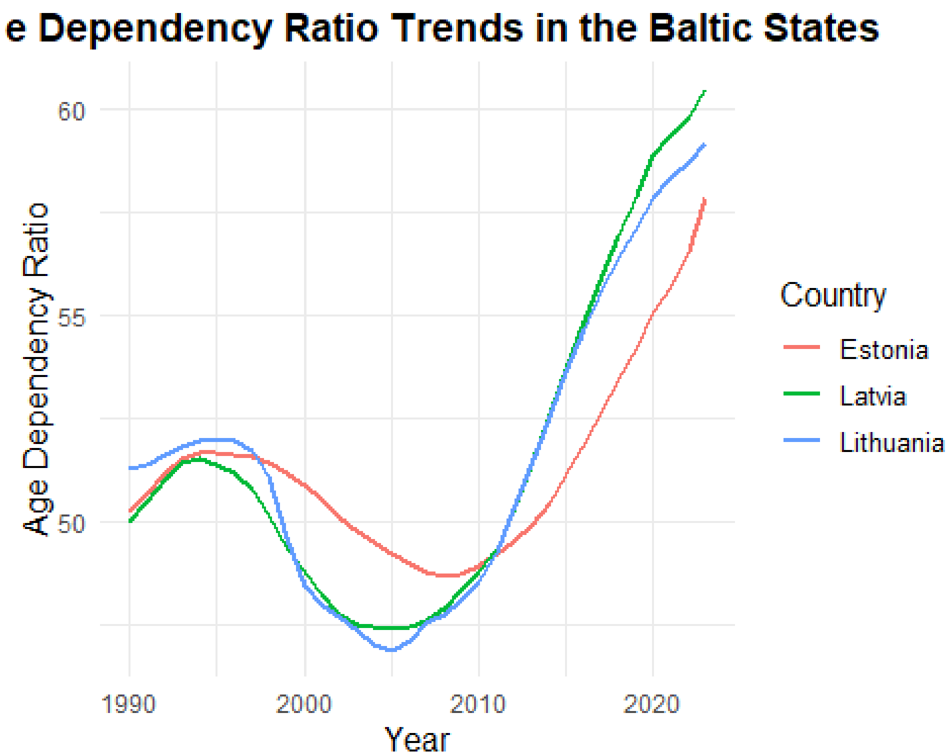

```
#Graph Showing trends in Urban Population Growth RateS

# Filter the data for Urban Population Growth Rate
urban_population_growth_rate_data <- combined_data %>%
  select(Year, Country, UrbanPopulationGrowthRate = UPGR)  # Replace "UPGR" with the actual co
lumn name for urban population growth rate if different

# Create the plot
ggplot(urban_population_growth_rate_data, aes(x = Year, y = UrbanPopulationGrowthRate, color =
Country, group = Country)) +
  geom_line(size = 1) +
  labs(
    title = "Urban Population Growth Rate Trends in the Baltic States",
    x = "Year",
    y = "Urban Population Growth Rate",
    color = "Country"
  ) +
  theme_minimal() +
  theme(
    plot.title = element_text(size = 14, face = "bold", hjust = 0.5),
    axis.title = element_text(size = 12),
    legend.title = element_text(size = 12),
    legend.text = element_text(size = 10)
  )
```



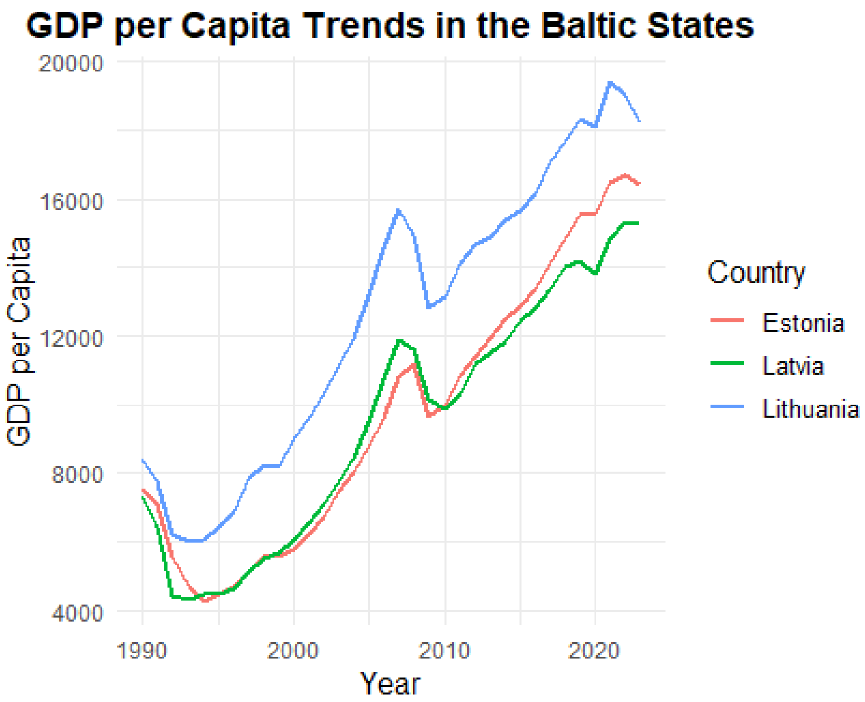

```r
#Graph Showing trends in Net Migration Rates
# Filter the data for Net Migration Rate
net_migration_rate_data <- combined_data %>%
  select(Year, Country, NetMigrationRate = NMR)  # Replace "NMR" with the actual column name f
or net migration rate if different

# Create the plot
ggplot(net_migration_rate_data, aes(x = Year, y = NetMigrationRate, color = Country, group = C
ountry)) +
  geom_line(size = 1) +
  labs(
    title = "Net Migration Rate Trends in the Baltic States",
    x = "Year",
    y = "Net Migration Rate",
    color = "Country"
  ) +
  theme_minimal() +
  theme(
    plot.title = element_text(size = 14, face = "bold", hjust = 0.5),
    axis.title = element_text(size = 12),
    legend.title = element_text(size = 12),
    legend.text = element_text(size = 10)
  )
```




```
#Graph Showing trends in Age Dependance Ratios

# Filter the data for Age Dependency Ratios
age_dependency_ratio_data <- combined_data %>%
  select(Year, Country, AgeDependencyRatio = ADR)  # Replace "ADR" with the actual column name
for age dependency ratios if different

# Create the plot
ggplot(age_dependency_ratio_data, aes(x = Year, y = AgeDependencyRatio, color = Country, group
= Country)) +
  geom_line(size = 1) +
  labs(
    title = "Age Dependency Ratio Trends in the Baltic States",
    x = "Year",
    y = "Age Dependency Ratio",
    color = "Country"
  ) +
  theme_minimal() +
  theme(
    plot.title = element_text(size = 14, face = "bold", hjust = 0.5),
    axis.title = element_text(size = 12),
    legend.title = element_text(size = 12),
    legend.text = element_text(size = 10)
  )
```




```
#Graph Showing trends in GDP per Capita
# Filter the data for GDP per Capita
gdp_per_capita_data <- combined_data %>%
  select(Year, Country, GDPPerCapita = PcGDP)  # Replace "PcGDP" with the actual column name f
or GDP per capita if different

# Create the plot
ggplot(gdp_per_capita_data, aes(x = Year, y = GDPPerCapita, color = Country, group = Country))
+
  geom_line(size = 1) +
  labs(
    title = "GDP per Capita Trends in the Baltic States",
    x = "Year",
    y = "GDP per Capita",
    color = "Country"
  ) +
  theme_minimal() +
  theme(
    plot.title = element_text(size = 14, face = "bold", hjust = 0.5),
    axis.title = element_text(size = 12),
    legend.title = element_text(size = 12),
    legend.text = element_text(size = 10)
  )
```




```
#Combining the three data sets to have Panel data
# Load the Combined dataset
data1 <- read.csv("D:/Combinedbalticdata.csv")

#Multicollinearity Tests

# Fit the full linear regression model with all variables, including UPGR
model <- lm(PcGDP ~ ADR + CBR + FR + NMR + PGR + UPGR, data = data)

# Calculate VIF for the full model
vif_values <- vif(model)

# Display VIF results
print(vif_values)

##       ADR       CBR        FR       NMR       PGR      UPGR
##  2.595132 19.112296 17.075025  2.142514 37.955552 42.075840

#Transform data to panel data
pdata <- pdata.frame(data, index = c("Country", "Year"))

# Fit the Pooled OLS model
pooled_model <- plm(PcGDP ~ ADR + CBR + NMR + UPGR, data = pdata, model = "pooling")

# Summarize the Pooled OLS results
summary(pooled_model)

## Pooling Model
##
## Call:
## plm(formula = PcGDP ~ ADR + CBR + NMR + UPGR, data = pdata, model = "pooling")
##
## Balanced Panel: n = 3, T = 34, N = 102
##
## Residuals:
##     Min.  1st Qu.   Median  3rd Qu.     Max.
## -5668.57 -2646.68   698.04  2641.79  6294.32
##
## Coefficients:
##             Estimate Std. Error t-value  Pr(>|t|)
```

```
## (Intercept) 2277.112   6942.719  0.3280   0.74363
## ADR          240.931    119.143  2.0222   0.04591 *
## CBR         -207.592    235.807 -0.8803   0.38085
## NMR           34.436     57.732  0.5965   0.55224
## UPGR        2495.344    492.849  5.0631 1.962e-06 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Total Sum of Squares:    1791500000
## Residual Sum of Squares: 980360000
## R-Squared:      0.45279
## Adj. R-Squared: 0.43022
## F-statistic: 20.0653 on 4 and 97 DF, p-value: 4.5881e-12

# Perform Breusch-Pagan LM test
plmtest(pooled_model, type = "bp")

##
##  Lagrange Multiplier Test - (Breusch-Pagan)
##
## data:  PcGDP ~ ADR + CBR + NMR + UPGR
## chisq = 9.2224, df = 1, p-value = 0.002391
## alternative hypothesis: significant effects

# Fit the Fixed Effects model
fixed_effects_model <- plm(PcGDP ~ ADR + CBR + NMR + UPGR, data = pdata, model = "within")

# Summarize the Fixed Effects results
summary(fixed_effects_model)

## Oneway (individual) effect Within Model
##
## Call:
## plm(formula = PcGDP ~ ADR + CBR + NMR + UPGR, data = pdata, model = "within")
##
## Balanced Panel: n = 3, T = 34, N = 102
##
## Residuals:
##     Min.  1st Qu.   Median  3rd Qu.     Max.
## -5022.97 -2857.91   927.83  2366.15  4947.81
##
## Coefficients:
##      Estimate Std. Error t-value  Pr(>|t|)
## ADR   240.641    116.531  2.0650   0.04164 *
## CBR  -143.748    230.576 -0.6234   0.53450
## NMR    79.152     58.167  1.3608   0.17680
## UPGR 2059.202    492.079  4.1847 6.371e-05 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Total Sum of Squares:    1594400000
## Residual Sum of Squares: 871480000
## R-Squared:      0.45339
## Adj. R-Squared: 0.41887
## F-statistic: 19.6999 on 4 and 95 DF, p-value: 7.806e-12

# Test for heteroscedasticity
bptest(fixed_effects_model)

##
##  studentized Breusch-Pagan test
##
## data:  fixed_effects_model
## BP = 15.878, df = 4, p-value = 0.003187

# Apply robust standard errors
fixed_effects_robust <- coeftest(fixed_effects_model, vcov = vcovHC(fixed_effects_model, type
= "HC1"))
print(fixed_effects_robust)
```

```
##
## t test of coefficients:
##
##      Estimate Std. Error t value Pr(>|t|)
## ADR   240.641    118.352  2.0333  0.04481 *
## CBR  -143.748    166.296 -0.8644  0.38954
## NMR    79.152    118.601  0.6674  0.50615
## UPGR 2059.202   1089.609  1.8899  0.06183 .
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```