The Relationship Between Unified Growth Theory, Demographic Transition and Population: Empirical Evidence from E-7 Countries

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Abstract

This study investigates the interaction of fertility, education, and long-run growth. In this context, the relationship between fertility, education, and long-run growth is analyzed using the "Panel ARDL Method PMG Estimator" with the help of the 2002-2022 data set for E-7 countries. The study's analysis includes GDP, life expectancy, mortality rate, population density, and rural areas. According to the results of the analysis, fertility has a direct and negative effect on education. In addition, GDP, life expectancy, mortality rate, population density, and rural population density significantly and positively affect education levels.

On the other hand, according to the study's findings, education has a direct and positive effect on fertility. There is also a significant and positive relationship between life expectancy, mortality rate, rural population rate, and fertility. In contrast, GDP and population density significantly but negatively affect fertility. The study's findings imply that factors such as income level, life expectancy, population density, urbanization, mortality rate, and birth rate affect the level of education and shape economic growth in the long run. Similarly, these findings confirm that social factors such as education and health shape the demographic structure while supporting economic growth.

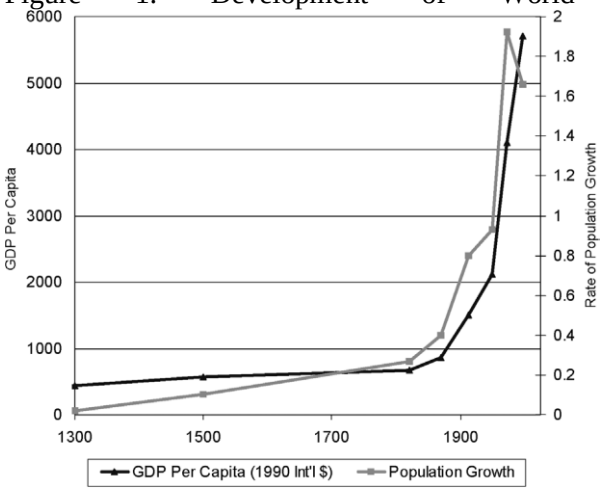
Keywords: Unified Growth Theory, Education, Fertility, Panel Data, Panel ARDL

1. Introduction

Regarding the demographic transition process, human history is divided into two periods: pre-industrial and post-industrial periods (Perrin, 2011). The main difference between the pre-and post-industrial periods stems from the different reflections of the relationship between fertility and income level. Although societies had high fertility rates in the pre-industrial period, there was a long period of stagnation in income levels (Clark, 2005). Malthus analyzed this relationship between population and economic growth in his work (1798), "An Essay on the Principle of Population as it Affects the Future Improvement of Society." In the study, it was argued that fertility increases as income increases that a constantly increasing population cannot adequately respond to the needs of society. That humanity will live in poverty forever.

The relationship between birth rates and economic growth, proposed by Malthus (1798), continues as an intellectual problem that remains topical for academics and economists today. Empirical evidence has been extensively documented in the literature that fertility has declined despite rising income levels in the West and developed countries since the industrial revolution (Tamura, 1988; Barro, 1991; Perrin, 2011).

Figure 1. Development of World Population and Per Capita Income



Resource: Maddison, 2001(trans:Galor,2005)

Figure 1 shows the relationship between world population and per capita income. According to Galor (2005), between 1000 and 1500, the world population increased from 268 million to 438 million (an average increase of 0.1% per year), and resources expanded rapidly, although not at the desired rate. Between 1500 and 1820, while resource expansion continued, the world population increased from 438 million to 1041 million (an average increase of 0.27% per year). Between 1870 and 1950, the per capita income rate increased and peaked between 1951 and 1973. Although the Industrial Revolution started the demographic transition process towards the end of the 19th century, especially in most Western countries, technological improvements, new product diversity, and changes in the demographic structure have prevented people from falling into poverty, even though the world population has increased about 6 times, especially in the last 200 years (Mankiw, 2010;241).

In light of all this information, the relationship between economic growth and birth rate has led a new generation of growth theorists (Galor and Moav, 2002; Hansen and Prescott, 2002; Strulik and Weisdorf, 2008) to develop new theories in all aspects. The Unified Growth Theory developed by Galor and Weil (1999) addresses the main features of the transition from the Malthusian era to the modern era and the related phenomena of the Great Divergence and Demographic Transition in a single framework. Therefore, this study aims to contribute to the literature by adopting the approach of the Unified Growth Theory pioneered by Galor (2002, 2010).

Transition from Malthusian Growth Theories to Unified Growth Theory

In the literature, the regimes countries' economies are assumed to have experienced historically are categorized under the Malthusian regime, post-Malthusian regime, and modern growth regime.

Malthusian Regime: Malthus stated that the population change in the USA increased at a geometric rate, and the resources that feed the population increased at an arithmetic rate following the conditions of his period. He argued that improvements in the income level of individuals increased birth rates, that the rapid increase in population would lead to famine in the future, and that the fertility rate should be slowed down. In his speech titled "The Wheat Problem" in 1898, Sir William Crookes warned that the world would face a great famine by 1930 if natural resources were not increased and argued that Malthus' theory was valid (Dyson, 1996).

Post-Malthusian regime: In the 19th century, while the rapid population growth in the big cities of Great Britain continued, increasing real incomes were directed towards consumption. Population growth continues to occur when it is less costly to have children (İçer, 2017). However, while the unemployment problems brought about by this period showed that the Malthusian regime was valid, the decline in the fertility rate in France led to major criticism of Malthusian theory, and the theory began to lose its effect towards the end of the 19th century (Karaca, 2022). The gradual increase in population and education

led to a rise in income and fertility rates during the post-Malthusian regime (Galor, 2024). However, investment in education is still zero.

Modern Growth Regime: The Malthusian era, which for the last 200 years has recognized a positive relationship between income and fertility, has gradually given way to the Modern Growth Regime, marked by sustained economic growth and declining fertility rates (demographic transition) (Strulik and Weisdorf, 2008). The term "Demographic Transition" used by demographers refers to the shift from high fertility and high mortality rates to low fertility and low mortality rates in many countries around the world (Behar et al., 1999: 21; Lee, 2003; Sertkaya Doğan, 2018: 29).

Population growth ceased to be positively correlated with per capita income, and the relationship reversed with sharp declines in fertility rates (Doepke et al., 2022). During this period, technological advances expanded education and affected the fertility rate, leading individuals to have fewer children and parents to invest more in child education. In addition to the decline in population growth, the educated labor market increases economic growth. It ultimately leads to a stable pattern of high, human capital-oriented growth (Madsen and Strulik, 2023). There is strong empirical evidence of a complex but robust relationship between the fertility rate and many economic variables, with causal relationships running in both directions (d'Albis et al., 2018).

Unified Growth Theory: The development process is a complex process that has been going on for thousands of years. Therefore, constructing a unified theory of economic growth that can explain this development process has become one of the most important research challenges facing researchers. The theory developed by Galor and Weil (2000) and extended by Galor and Moav (2002) conceptualizes the economic history of humanity as a phase transition between three regimes (Malthusian Regime, Post-Malthusian Regime, and Modern Growth Regime) (Madsen and Strulik, 2023).

Unified Growth Theory (UGT) proposed by Galor (2005);
i) The endogenous evolution of technology, population, and per capita income throughout human history;
ii) the Malthusian stagnation period;
iii) The endogenous transition from the Malthusian trap;
iv) The beginning of the demographic transition
v) It refers to growth models that integrate the entire growth process into a unified framework by capturing the emergence of sustainable economic growth.

The Unified Growth Theory developed by Galor and Weil (2000) and Galor and Moav (2002) aims to test the effects of GDP, life expectancy, mortality, population density, and rural population on education and fertility in E7 countries and to identify the mechanisms that trigger the fertility and education transition. Accordingly, this study aims to test the transition of fertility and education rates in E7 countries between 2002 and 2022. The contribution of the study to the literature is quite broad. The first developing countries' demographic transition process differs from that of the developed countries. Therefore, the study of E7 countries will greatly contribute to the literature. When other studies on the Unified Growth Theory are examined, it is seen that most of the analyses are focused on economic growth. Fertility and education, the most important demographic transition elements, constitute this study's focus. In particular, it is seen that the majority of the studies analyzed in this study are based on the level of female education. However, male education level is also thought to affect fertility significantly. Finally, the study is expected to fill a large part of the gap in the literature by revealing the effects of GDP, life expectancy, mortality, population density, and rural population on education and fertility rates.

2. Literature Review

Studies on economic growth have been conducted in the literature for many years. The Unified Growth Theory is the most recent theory explaining the relationship between population and economic growth (Galor, 2005, 2011). Therefore, this study investigates the relationship between fertility, life expectancy, mortality, population density, and rural population variables on GDP and education. This study analyzes the effects in the context of E7 countries with high growth rates.

Looking at the literature, it is seen that the majority of studies have been conducted on economic growth and fertility. Economic growth and demographic transition (Essien (2016; Cervellati et al., 2019; Li & Zhang, 2007; Bloom & Finlay, 2009; Bloom et al., 2000; Mierau &Turnovsky, 2014; Essien, 2016), the relationship between economic growth and fertility and life expectancy (Munir & Shahid, 2021), the relationship between mortality and fertility and wages (Hondroyiannis & Papapetrou; 2002), the demographic transition with income (Mason & Kinugasa, 2008; Munir &Arshad, 2018), the effect of the working population and schooling rate on economic growth (Cuaresma et al, 2014; Cruz &Ahmed, 2018), the relationship between life expectancy, healthy population, working population and economic growth (Frimpong & Adu, 2014; Iqbal et al. 2015).

Table 2. Literature Review

Author/s	Period	Country	Method	Variables	Result
Madsen & Strulik (2023)	1750-2000	21 OECD countries	2SLS Regressions	technological progress as patents per capita, R&D intensity, and investment in machinery, equipment, and intellectual property products.	Technological progress has a positive effect on education but a negative effect on fertility.
Murtin (2013)	1870-2000	70 countries	GMM	Birth rate, mortality, GDP	Primary schooling is a robust determinant of fertility.
Weinberg (1987)		38 countries	World Fertility Surveys	Scholing rate and fertility	When the number of years of primary schooling increases to six years, fertility declines by about 40% to 80%.
Strulik (2024)	1950-2010	The U.S.	sensitivity analysis	Education and fertility	People with higher education have fewer children, but controlling the level of education and increasing income leads to higher fertility.
Hazan & Zoabi (2014)	2001-2011	The U.S.	Cross-sectional	Education, fertility	Highly educated women can have more children and work longer hours, substituting their time with market services to raise children and manage their households.
Arif & Chaudhry (2008)	1990-2003	Pakistan	Demographic Surveys and Labour Force Surveys	demographic transition and educational attainment with youth employment	An increase in the working-age population and a decline in fertility significantly contributed to productivity.

D'Albis et al (2018)	1906-1975	28 countries	OLG Model	Fertility, education, human capital,	In Regime I, there is no education, and fertility is high. In Regime II, when human capital reaches a threshold, the economy starts to invest in education for individuals, and fertility declines. In Regime III, higher incomes now lead to postponing births.
Bittencourt (2018)	1980-2009	Southern Africa	Panel Time Series	Fertility, education, GDP, life expectancy, gender gap, agriculture	Primary education is associated with lower fertility in the SADC
İçer (2017)	1960-2010	27 Sub-Sahra African Countries	OLS - GMM	Education and fertility	Education is a strong but negative determinant of fertility.
Okoye & Pongou (2023)	Different years	Nigeria	2SLS	Schooling rate, total number of children, number of living, and ideal children	It supports the predictions of the unidirectional economic growth theory that technological progress leads to a demand for more education, triggering fertility decline and resulting in higher incomes.
Lehr (2009)	1960-1999	95 countries	GMM Estimation	Enrollment rates, fertility, education levels	Increases in the secondary sector demand for education will lead to fertility declines regardless of the stage of fertility.
DeCicca & Krashinsky (2023)	1981-1991	Canada	OLS	Education and fertility	education level has a negative effect on fertility.
Afreen et al. (2024)	2017-2018	Pakistan	Poisson regression	Education and fertility	education level has a negative effect on fertility.
Kebede et al. (2022)	1972-2014	34 sub-Saharan African countries	Multilevel analysis	Women's education, fertility, household wealth, and area of residence	women's level of education is the factor that has the most significant impact on fertility.

Angko et al. (2022)	2014	Ghana	Poisson regression	Child mortality, fertility, population, public health	education level has a negative effect on fertility.
Wusu&Isiugo-Abanihe (2019)	2003, 2008 and 2013	Nigeria	survey	Women's education, fertility, area of residence	education level has a negative effect on fertility.
Samari (2019)	2006-2012	Egypt	survey	Education, instrumental agency, and number of birth	Women who received more support had higher fertility than women who did not receive support.

3. Data Description and Empirical Model

3.1. Data Source

The dataset used in the study covers 2002-2022, and China, India, Russia, Mexico, Indonesia, Brazil, and Türkiye considered E-7 countries. The reason for choosing this period is that these are the commonly accessible years for the variables. On the other hand, E-7 countries are thought to come to the fore in producing and consuming renewable energy in the coming years with their increasing share in world trade volume, high population, and technological breakthroughs. For this reason, E-7 countries were selected in the study sample. In this study, the two main variables of interest are education and fertility. We use school enrollment data to represent education.

On the other hand, we use the fertility rate to represent fertility. The study uses GDP per capita, life expectancy, mortality, population density and urban population as control variables. The variables are obtained from the World Bank database. Table 1 presents the variables used in the model and their explanations.

Table 1: Variables Used in the Model and Their Explanations

Variables	**Explanations**	**Resource**	
EDU	Education Index	https://www.sustainabledevelopmentindex.org/	
FERTILITY	Fertility rate, total (births per woman)	World Bank	
LIFE	Life expectancy at birth, total (years)	World Bank	
GDP	GDP per capita (constant 2015 US$)	World Bank	
MORTALITY	Mortality rate, infant (per 1,000 live births)	World Bank	
POP	Population density (people per sq. km of land area)	World Bank	
URBAN	Urban population (% of total population)	World Bank	

Summary information, statistics, and data sources regarding the variables used in the analysis are presented together in Table 2.

Table 2: Summary Statistic

	Education	Fertility	Life	GDP	Mortality	Pop	Urban
Mean	10.60330	2.050988	71.75171	6637.817	20.83540	126.5872	62.81232
Median	10.50715	2.086000	72.57900	7862.871	17.40000	96.44066	71.40200
Maximum	14.24812	3.350000	78.58700	14055.10	66.40000	479.4255	87.55500
Minimum	6.189921	1.164000	62.66900	756.7041	3.800000	8.716096	27.66700
Std. Dev.	1.923745	0.446605	3.777408	3482.106	13.39628	130.9611	18.26716
Skewness	0.055099	0.317651	-0.332515	-0.295916	1.386016	1.540808	-0.531520
Kurtosis	2.410813	2.929587	2.233741	1.769818	4.757041	4.279561	1.917391
Jarque-Bera	2.410205	2.740793	6.905687	12.50174	72.25781	74.68812	15.44323
Probability	0.299661	0.254006	0.031655	0.001929	0.000000	0.000000	0.000443
Sum	1707.132	330.2090	11552.03	1068688.	3354.500	20380.54	10112.78
Sum Sq. Dev.	592.1274	31.91298	2283.010	1.94E+09	28713.65	2744128.	53390.24
Observations	161	161	161	161	161	161	161

The study consists of two stages. In the first stage, model 1, where education is the dependent variable, is tested. The second stage, where fertility is the dependent variable, is tested. Accordingly, the first and second models created are presented in equation 1 and equation 2:

Model 1: $EDU_{it} = \alpha_1 + \beta_1 FER_{it} + \beta_2 LnGDP_{it} + \beta_3 LIFE_{it} + \beta_4 MRTL_{it} + \beta_5 LnPOP_{it} + \beta_6 URBAN_{it} + \varepsilon_{it}$ (1)

Model 2: $FER_{it} = \alpha_1 + \beta_1 EDU_{it} + \beta_2 LnGDP_{it} + \beta_3 LIFE_{it} + \beta_4 MRTL_{it} + \beta_5 LnPOP_{it} + \beta_6 URBAN_{it} + \varepsilon_{it}$ (2)

The basic hypothesis regarding the model to be estimated with the help of equations 1 and 2 is expressed below:

H1: Fertility level has a direct impact on education level.

H2: Education level has a direct effect on fertility.

The steps to be followed to reach the long-term equation and parameter coefficients in the study through the model are expressed below:

1. Cross-section dependency test and Heterogeneity test
2. Unit root tests to determine the stationarity of the series
3. Kao (1999) Cointegration Test
4. PMG Estimator proposed by Pesaran et al. (2007)

In econometric studies, three types of data are used: time series data, cross-section data, and mixed data, a combination of time series data and cross-section data. If the same cross-sectional unit is examined

within a certain time, such mixed data is called panel data (Gujarati, 1999; Afşar and Özarslan Doğan, 2021).

In this study, The panel ARDL method developed by Pesaran and Shin (1995, 1999), Pesaran and Smith (1998), and Pesaran et al. (2001) was preferred. The most important feature of the model in question is that it has two advantages. The first of these advantages is that it provides superiority in reaching long and short-term results together. The second advantage is that it can be used to strengthen the data set for economies such as Türkiye, where data is scarce (Şengönül ve Tekgün, 2021).

Based on Model 1 and Model 2 created to be estimated with Panel Data analysis, the Panel ARDL equation can be expressed as in Equation 3 and Equation 4:

$$EDU_{it} = \alpha_0 + \delta t + \sum_{i=1}^{n-1}(\beta_{1i}EDU_{t-i}) + \sum_{i=0}^{n-1}(\beta_{2i}FER_{t-i}) + \sum_{i=0}^{n-1}(\beta_{3i}\,LnGDP_{t-i}) + \sum_{i=0}^{n-1}(\beta_{4i}LIFE_{t-i}) + \sum_{i=0}^{n-1}(\beta_{5i}MRTL_{t-i}) + \sum_{i=0}^{n-1}(\beta_{6i}LnPOP_{t-i}) + \sum_{i=0}^{n-1}(\beta_{7i}URBAN_{t-i}) + (\emptyset_{1i}EDU_{t-i}) + (\emptyset_{2i}FER_{t-i}) + (\emptyset_{3i}LnGDP_{t-i}) + (\emptyset_{4i}LIFE_{t-i}) + (\emptyset_{5i}MRTL_{t-i}) + (\emptyset_{6i}LnPOP_{t-i}) + (\emptyset_{7i}URBAN_{t-i}) + \varepsilon_t \quad (3)$$

$$FER_{it} = \alpha_0 + \delta t + \sum_{i=1}^{n-1}(\beta_{1i}FER_{t-i}) + \sum_{i=0}^{n-1}(\beta_{2i}EDU_{t-i}) + \sum_{i=0}^{n-1}(\beta_{3i}\,LnGDP_{t-i}) + \sum_{i=0}^{n-1}(\beta_{4i}LIFE_{t-i}) + \sum_{i=0}^{n-1}(\beta_{5i}MRTL_{t-i}) + \sum_{i=0}^{n-1}(\beta_{6i}LnPOP_{t-i}) + \sum_{i=0}^{n-1}(\beta_{7i}URBAN_{t-i}) + (\emptyset_{1i}FER_{t-i}) + (\emptyset_{2i}EDU_{t-i}) + (\emptyset_{3i}LnGDP_{t-i}) + (\emptyset_{4i}LIFE_{t-i}) + (\emptyset_{5i}MRTL_{t-i}) + (\emptyset_{6i}LnPOP_{t-i}) + (\emptyset_{7i}URBAN_{t-i}) + \varepsilon_t \quad (4)$$

In Equality 3 and 4, The terms α_0, δt and ε_t represent the constant, trend, and error term, respectively. The terms ∅ and β in the equation refer to the short-term and long-term coefficients of the variables in the model.

In the panel ARDL analysis, cross-sectional dependency was examined before investigating stationarity. In this way, it will be determined whether the shock occurring in one of the series has the same level of effect on other variables. For this purpose, a CD-LM test was performed in the study. In addition, Swammy (1970) and Pesaran and Yamagata Delta (2008) conducted heterogeneity tests to determine the study's homogeneity, and the results are given in Table 3. Table 3 below presents the cross-sectional dependency results and heterogeneity test results.

Table 3: Cross-Section Dependency and Heterogeneity Test Results

	Model 1	**Model 2**
Test	**Statistic value (Prob)**	**Statistic Value (Prob)**
LMadj testi Test	**0.1666 (0.8677)**	**-0.439 (0.6356)**
Swammy(1970) Test	**-0.16(0.86)**	**0.12(0.90)**
Pesaran ve Yamagata	**-0.21 (0.83)**	**0.15 (0.87)**

Pesaran, Ullah, and Yagamata's (2008) LMadj test eliminates the deviations in the LM test and the possibility of the correlation sum being 0 in the Pesaran CD test. It is used in cases where the T dimension is larger than the N dimension. According to the cross-sectional dependency test results in Table 3, the null hypothesis stating that no cross-sectional dependency exists in the E-7 countries included in the panel data set was accepted, and the alternative hypothesis was rejected. Accordingly, there is no cross-sectional dependency in the model considered in the countries in the sample group, meaning that the effect that will emerge in one of the E-7 countries will not be reflected in the other

countries. In other words, according to this result, other countries will not be affected by a macroeconomic shock experienced in one of the E-7 countries. Since there is no cross-sectional dependency after this stage, it is more appropriate to use first-generation unit root tests in the stationarity analysis of the variables.

On the other hand, according to the test results conducted to investigate the heterogeneity given in Table 3, the null hypothesis regarding the homogeneity of the parameters of the variables and the estimated model is accepted in Model 1 and Model 2. According to this finding, it is concluded that the parameters of the models are homogeneous. This result also implies that the interaction between the E-7 countries considered in the study does not differ.

In the study, the Maddala and Wu (1999) unit root test, one of the first-generation unit root tests, was used, and the test statistics obtained are shown in Table 4.

Table 4: Maddala and Wu (1999) unit root test result

Variables	**Test Statistic**	**Probability Value**
EDU	12.775	0.544
D(EDU)	75.993	0.000***
FER	5.804	0.971
D(FER)	70.141	0.000***
LnGDP	9.831	0.774
D(LnGDP)	87.626	0.000***
LIFE	26.969	0.019**
MRTL	203.799	0.000***
LnPOP	4.035	0.995
d(LnPOP)	41.683	0.000***
URBAN	70.442	0.000***

*0.10, **0.05 and ***0.01 indicate significance levels.

Tablo 4'te yer alan Maddala ve Wu (1999) birim kök test sonucuna göre LIFE, MRTL, LnPOP ve URBAN değişkenlerinin seviyede durağan olduğu yani I(0), EDU, FER ve LnGDP değişkenlerinin ise birinci farkı alındıktan sonra durağanlaştığı yani I(1) düzeyinde durağan olduğu görülmektedir.

As the next step, after performing unit root tests, the Kao Panel Cointegration Test was applied to test a long-term cointegration relationship between the variables. According to the Kao Cointegration test result in Table 5, findings regarding a long-term relationship between the estimated Model 1 and Model 2 variables were obtained.

Table 5: Kao Panel Cointegration Results

	Test	**Model 1**	**Model 2**
Kao Test	Modified Dickey-Fuller t	-4.99***	-6.19***
	Dickey-Fuller t	-6.69***	-7.72***
	Augmented Dickey-Fuller t	-4.63***	-3.95***
	Unadjusted modified Dickey-Fuller t	-13.38***	-13.97***
	Unadjusted Dickey-Fuller t	-9.03***	-9.47***

Note: *** 0.01 indicates significance levels.

After the cointegration in the panel data used in the study was obtained, Model 1, expressed in Equation 3, was estimated with the help of Panel ARDL, and these results are given in Table 6. According to Table 6, the fact that the ECT error term coefficient in the error correction model is negative and significant at 10% indicates that the deviations in the period under consideration are being corrected. The error term coefficient obtained shows that if any shock situation occurs in the current period, this shock effect is eliminated 58% quickly in the next period.

According to the Panel ARDL estimation results given in Table 6, the first of the variables used in the long-term estimation results obtained, the fertility variable, affects the education index statistically significantly and negatively. This result is evaluated as high birth rates will lead to a low level of education at the social level. In this case, it may have negative effects on economic growth. This result is consistent with the results obtained by Barro & Lee (2013) and Götmark & Andersson (2020).

Another variable considered in the study is the income (GDP) variable. According to the results obtained, the direction of the effect of income on education is positive and statistically significant. It states that income level increases in E-7 countries positively contribute to education. In other words, countries with increasing income bring about an increase in living standards. This increases the investments and expenditures to be made in the field of education, strengthens the educational infrastructure, positively affects the quality of education, and contributes to growth in the long term. Studies conducted by Barro (2001) and Sala-i-Martin (2004) support the finding that higher income levels increase education success, which positively affects economic growth and development.

The life expectancy variable is another variable considered according to the panel ARDL estimation results. According to the findings obtained in the study, there is a positive and statistically significant relationship between life expectancy and education. In this context, this result can be evaluated as the high life expectancy in E-7 countries, allowing more people to receive education and improved educational opportunities.

Another variable considered in the study, the mortality rate variable, was found to have a positive and statistically significant effect on education. As stated by Becker (1960) and Becker-Tomes (1976), this finding indicates that in countries with high mortality rates, there is the opportunity to allocate more resources to education, and that resources increase investments in education, thus positively affecting the level of education. Therefore, in countries with high mortality rates, since more importance is given to education to solve this problem, it can be emphasized that the increase in mortality rate contributes positively to education. According to the panel ARDL estimation results, the population density variable also has a positive and statistically significant effect on the education index. The finding can be evaluated as positively affecting the level of education in countries with high population density due to the ease of access to educational opportunities. In addition, the increase in population density positively affects education through factors such as strengthening infrastructure investments, competitive environment, ease of access, and increase in social capital.

Similarly, it was concluded that the urbanization variable, the last variable in model 1, has a positive and statistically positive effect on the education index. This result indicates that the increase in urbanization positively contributes to education, with the effect of factors such as providing wider infrastructure opportunities and the potential to reduce regional and gender inequalities in education. This result is similar to the results reached by Glaeser & Maré (2001).

Table 6: ARDL (2,2,2,2,2,2,2) PMG Estimation Results (Model 1)

Dependent Variables: EDU		**Long Run Equation**		
Variables	**Coefficient**	**Std. Error**	**T-Statistic**	**Prob.**
FER	-1.899525	0.149802	-12.68024	0.0000***
Ln(GDP)	0.814856	0.145508	5.600093	0.0000***
LIFE	0.081997	0.006545	12.52917	0.0000***
MRTL	0.059382	0.011909	4.986427	0.0000***
Ln(POP)	2.37658	0.735920	3.229410	0.0022***
URBAN	0.13264	0.025333	5.235782	0.0000***
	Short Run Equation			
D(EDU(-1))	0.159884	0.158600	1.008097	0.3183
D(FER)	2.038167	0.556162	3.664699	0.0006
D(FER(-1))	1.722914	1.143093	1.507238	0.1380
DLN(GDP)	-1.690273	1.279243	-1.321307	0.1924
DLN(GDP(-1))	-1.280478	1.636560	-0.782421	0.4377
D(LIFE)	-0.015688	0.088034	-0.178202	0.8593
D(LIFE(-1))	-0.084954	0.102768	-0.826662	0.4124
D(MRTL)	-0.424759	0.381230	-1.114181	0.2705
D(MRTL(-1))	0.300819	0.450637	0.667543	0.5075
DLN(POP)	69.70234	146.4482	0.475952	0.6362
DLN(POP(-1))	29.34678	118.4446	0.247768	0.8053
D(URBAN)	-4.440574	6.880919	-0.645346	0.5217
D(URBAN(-1))	2.137007	1.711654	1.248504	0.2177
ECM(-1)	-0.583392	0.321327	-1.815574	0.0754*

Note: *** 0.01 indicates significance levels.

After the cointegration in the panel data used in the study was obtained, Model 2 expressed in Equation 4 was estimated with the help of Panel ARDL, and these results are given in Table 6. According to Table 6, the fact that the ECT error term coefficient in the error correction model is negative and significant at 5% indicates that the deviations in the period under consideration are being corrected. The error term coefficient obtained shows that if any shock situation occurs in the current period, this shock effect is eliminated 59% quickly in the next period.

According to the Panel ARDL estimation results given in Table 6, the first of the variables used in the long-term estimation results obtained, the education index, affects the fertility variable statistically significantly and positively. This finding implies that the increase in the education level positively affects the fertility. In countries such as E-7, where the education level increases, the increase in the education level of women makes them economically stronger. Thus, they can make more flexible decisions when planning their families. Moreover, women with higher social status tend to have better health status and are physically able to have more children. This result is also supported by Lutz and Skirbekk (2013).

Another variable considered in the study is the income (GDP) variable. According to the results obtained in the study, the direction of the effect of income on the fertility is negative and statistically significant. This result indicates that increases in income levels in E-7 countries have a decreasing effect on fertility. This result shows that fertility decreases with the increase in economic development and social welfare in E-7 countries. This result is consistent with Becker (1960), Becker & Lewis (1973), and Schultz (2005).

The life expectancy variable is another variable considered according to the panel ARDL estimation results. According to the findings obtained in the study, there is a positive and statistically significant relationship between life expectancy and fertility rate. This finding supports the view that, as stated by Aghion et al. (2016), especially in developing countries such as E-7, the increase in life expectancy due to the development of the health system may also lead to a rise in fertility rates.

Another variable examined in the study, the mortality rate variable, has been found to have a positive and statistically significant effect on the fertility rate. Since access to health services is limited in developing countries such as E-7, especially child deaths are accompanied by a tendency to increase the fertility in parallel with the mortality rate in these countries. Therefore, it can be emphasized that there is a positive relationship between mortality rates and fertility in E-7 countries. This result is parallel to Aghion et al. (2016).

According to the panel ARDL estimation results, the population density variable has a negative and statistically significant effect on the education index. The finding can be evaluated as the increase in education level, the improvement in the quality of life, and the rise in population density, which affects fertility rates in a decreasing way. Bongaarts (2001) also found similar findings to those of this study.

It was concluded that the last variable considered in model 2, urbanization, had a positive and statistically positive effect on the fertility. This result can be evaluated as the emergence of more job opportunities and social security opportunities with urbanization, which encourages low-income families to have more children.

Table 7: ARDL (2,2,2,2,2,2,2) PMG Estimation Results (Model 2)

Dependent Variables: FER		**Long Run Equation**		
Variables	**Coefficient**	**Std. Error**	**T-Statistic**	**Prob.**
EDU	0.168572	0.007828	21.53363	0.0000***
Ln(GDP)	-0.447910	0.039445	-11.35539	0.0000***
LIFE	0.067542	0.003251	20.77340	0.0000***
MRTL	0.009104	0.001613	5.643177	0.0000***
Ln(POP)	-6.920491	0.406745	-17.01432	0.0000***
URBAN	0.042118	0.005642	7.465012	0.0000***
	Short Run Equation			
D(FER(-1))	-0.593703	0.255819	-2.320795	0.8206
D(EDU)	0.070484	0.071815	0.981467	0.3311
D(EDU(-1))	-0.050747	0.043846	-1.157398	0.2526
DLN(GDP)	0.590707	0.426459	1.385145	0.1722
DLN(GDP(-1))	0.471796	0.400089	1.179228	0.2439
D(LIFE)	-0.029580	0.016882	-1.752143	0.0859
D(LIFE(-1))	-0.031410	0.022596	-1.390078	0.1707
D(MRTL)	0.063839	0.063856	0.999726	0.3223
D(MRTL(-1))	-0.013562	0.058289	-0.232665	0.8170
DLN(POP)	46.48232	26.82118	1.733045	0.0893
DLN(POP(-1))	-44.36659	18.46895	-2.402226	0.0201
D(URBAN)	0.951691	1.028663	0.925173	0.3593
D(URBAN(-1))	-0.429578	1.179316	-0.364260	0.7172
ECM(-1)	-0.593703	0.255819	-2.320795	0.0244**

Note: **0.05 and ***0.01 indicate significance levels

Conclusion and Discussions

Unified Growth Theory (UGT) develops alternative endogenous and exogenous elements that can capture the key features of the development process in a single framework. UGT guides by shedding light on the driving forces that enable countries with a Malthusian approach to move from stagnation to sustainable economic development.

This article aims to determine the mechanisms that trigger the fertility and education transition by testing the effects of the Unified Growth Theory developed by Galor and Weil (2000) and Galor and Moav (2002) on life expectancy, mortality, population density, and rural population on education and fertility in E7 countries. In this context, this study aims to test the transition of fertility and education rates in E7 countries between 2002 and 2022. This was achieved with the help of the Panel ARDL method developed by Pesaran et al. (2001).

The study consists of two different hypotheses. The first hypothesis is that fertility has a direct effect on the level of education. According to the results of the analysis, fertility has a direct and negative impact on education. This result indicates that high birth rates lead to low education levels at the social level, which can negatively affect economic growth. High birth rates generally reduce the capacity to create an educated workforce and limit the potential for economic growth. This issue is also consistent with the literature emphasizing the effect of human capital and demographic factors on growth in the theory of combined growth. Therefore, increasing fertility in E7 countries decreases the education rate, confirming the first hypothesis.

At this stage, the effects of the independent variables GDP, life expectancy, mortality rate, population density, and rural population on fertility were also analyzed. According to the analysis results, GDP, life expectancy, mortality rate, population density, and rural population density significantly and positively affect education levels.

The second hypothesis was determined as the education level directly affects fertility. At this stage, the effects of the education rate on fertility were investigated. According to the results of the analysis, education directly and positively impacts fertility. According to this result, increasing the education rate in E7 countries increases fertility. There is a significant and positive relationship between life expectancy, mortality rate, rural population rate, and fertility, while GDP and population density have a significant but negative effect on fertility.

The findings obtained in the study reveal the multidimensional structure of the unified growth theory and the mutual relationships between economic growth and education. Factors such as income level, life expectancy, population density, urbanization, mortality rate, and birth rate affect the level of education and shape economic growth in the long term. Improvements in education both increase social welfare and encourage economic growth in the long term. At the same time, variables related to health and demographic factors, such as fertility, interact with investments in education in a way that supports economic growth. In this context, the long-term growth process in E-7 countries can enter a more sustainable and balanced growth path with advances in education and improvements in health conditions.

As a result, it can be concluded that education investments, population policies, and social policies should be shaped in line with economic growth targets. The findings of this study are expected to provide an important guide in shaping education policies, population policies, economic growth, and development strategies in the E-7 countries.

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