Does higher longevity harm economic growth?

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Summary: This study contributes to economic growth literature by providing new evidence on the relationship between life expectancy and economic growth utilising the recently developed dynamic panel threshold estimator. The sample of this study contains a total of 112 developed and developing countries covering the period from 1981 to 2010. The findings indicate the existence of a non-linear relationship between life expectancy and economic growth. In particular, life expectancy is useful for economic growth but only up to a certain threshold level; any further increase in longevity above the threshold would adversely affect growth. These findings emphasise the role of demographic transition in explaining the relationship between health and economic growth.

Keywords: life expectancy, demographic transition, growth, dynamic panel threshold.

JEL classification: O47, J11, C23.

1. Introduction

Life expectancy has shown a dramatic increase in recent years, which mainly results in a high percentage of an ageing population and a low fertility rate. The improvement in life expectancy emerges mainly from the declining mortality rate and at the same

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time, demographic transition states the adverse effect on the fertility rate. In developed countries, 21% of the total population is aged 60 years and above with the expectation that it will reach a level of 33% by 2050. In developing countries, the percentage of the population 60 years and above is about 8% of the total population, but this number is expected to reach approximately 20% of the entire population by 2050. Globally, the number of the population aged 60 years or more is projected to triple and reach almost 2 billion by the year 2050. Moreover, the world's population aged 80 years and above is also expected to reach 395 million in 2050 (United Nations 2009). These numbers, in fact, raise many questions about the possibilities of an economic growth slowdown as a result of the increasing trend of the ageing population, which may induce more social expenditure on the elderly. Therefore, it draws some doubts on the linear relationship between health and economic growth (Lars Kunze 2014).

In the existing literature, the life expectancy-growth nexus has been the subject of a series of debates. Many studies indicate that higher life expectancy plays a positive role in stimulating economic growth (Robert J. Barro 1996; Robert J. Barro and Xavier Sala-i-Martin 2004; David E. Bloom et al. 2004). On the other hand, various empirical studies point out that the relationship between life expectancy and economic growth might have a non-linear pattern especially when demographic changes are taken into account (Chong-Bum An and Seung-Hoon Jeon 2006; Rodolphe Desbordes 2011; Matteo Cervellati and Uwe Sunde 2011a).

The main purpose of this study is to investigate the possibility of an inverted-U shaped relationship between life expectancy and economic growth. Specifically, we explore whether there exists a threshold level of life expectancy in the longevity-growth nexus, where life expectancy promotes growth up to a certain threshold level and then impedes growth after it exceeds the threshold. The non-linear relationship may better be estimated using a more appropriate estimating procedure, namely the dynamic panel threshold developed by Stephanie Kremer, Alexander Bick, and Dieter Nautz (2013). This paper is organised as follows: Section 2 presents the theoretical, as well as the empirical literature; Section 3 explains the empirical model, the estimation methodology and the data; Section 4 contains the results and a discussion, and Section 5 forms the conclusion of the study.

2. Literature review

Many studies discuss the role of life expectancy on economic growth while considering the demographic transition that has taken place in many countries around the world. The demographic transition leads to changes in the population structure and it is normally measured by the mortality rate or the life expectancy and fertility rate (Isaac Ehrlich and Francis T. Lui 1991; Jie Zhang, Junsen Zhang, and Ronald Lee 2003; Cervellati and Sunde 2011a; Cervellati and Sunde 2011b; Desbordes 2011). During the early stages of demographic transition, the level of the mortality rate tends to be high (low longevity), while a lower mortality rate (high longevity) is associated with the later stages of the demographic transition (Cervellati and Sunde 2011a). The demographic transition has three stages. The first stage is characterised by high birth and mortality rates. The second is characterised by a high birth rate and a low mortality rate. The third stage is characterised by low birth and mortality rates. Many countries around the globe have been through the various stages of demographic transition, which may likely affect how longevity influences the GDP growth rate. When longevity changes with respect to the various stages of demographic transition, its effect on economic growth is more likely to be changed. There are various channels through which longevity affects economic growth. First, longevity leads to a higher saving rate, hence, a higher rate of physical capital accumulation. In addition, it reduces the number of accidental bequests, decreases investment, and therefore reduces physical capital accumulation. Moreover, with lower longevity, the tax rate for education tends to increase, but beyond a certain threshold level; further longevity may lower the tax rate, thus human capital accumulation increases initially but declines eventually. Overall, the effect of a further increase in longevity in developing countries (low longevity) results in a higher growth rate; however, its effect in developed countries (high longevity) seems to reduce economic growth (Zhang, Zhand, and Lee 2003; Raouf Boucekkine, Bity Diene, and Theophile Azomahou 2007). Similarly, Kunze (2014) explains that the relationship between life expectancy and growth follows a non-linear pattern, which confirms the existence of an inverted-U shaped relationship. Kunze shows that the intergenerational transfers in the form of family altruism lead to an inverted-U shaped relationship between longevity and growth when bequests are inoperative.

The initial work of Ehrlich and Lui (1991) explains the role of demographic transition through the impact of longevity and fertility on economic growth. Although the ageing population is expected to rise, the model predicted that the increase in longevity may dramatically increase the growth rate and reduce the fertility rate. The positive impact of life expectancy on growth is a reflection of the abilities and high skills of workers, which improve their productivity (Barro and Sala-i-Martin 2004).

Barro (2013) develops an extension to the neoclassical growth theory that incorporates the concept of health capital expressed by life expectancy. The model predicts that health affects economic growth in various ways. First, in a direct way, an improvement in health increases labour productivity. In addition, an improvement in health reduces mortality and morbidity, thus lowering the human capital depreciation rate. Through this indirect channel, rising life expectancy enhances the demand for human capital in the form of education, which increases productivity. However, the model predicts diminishing returns to health investment due to the declining productivity of the elderly.

Many have argued that longer life expectancy has a linear effect on economic growth, thus using linear regressions to estimate their empirical analyses. In general, high life expectancy enhances economic growth, which in turn tends to increase longevity. For example, Declan French (2012) shows that there is a bidirectional causality between life expectancy and income in the OECD countries. Although a higher level of life expectancy tends to increase the share of the ageing population and the dependency ratio, Jie Zhang and Junsen Zhang (2005) emphasise that an increase in longevity enhances the economic growth rate and also shifts the behaviour of other growth determinants such as reducing fertility, increasing saving and schooling time, which refer to the potential demographic changes. Whereas, Daron Acemoglu and Simon Johnson (2007) indicate that an increase in life expectancy has no impact on the GDP per capita growth.

On the other hand, other empirical works continue the argument regarding the non-linearity between life expectancy and growth. For example, An and Jeon (2006) show that there is an inverted-U shaped relationship between demographic transition and growth, especially due to the increase in the ageing population. It is worth mentioning that changes in life expectancy are highly associated with demographic transition (Jesus Crespo Cuaresma, Martin Lábaj, and Patrik Pružinský 2014). Applying the same idea, Cervellati and Sunde (2011a) split their sample of study into two groups, depending on the stage of demographic transition, considering that life expectancy and mortality change are negatively related. The result shows a non-linear effect of life expectancy on growth. Another study by Desbordes (2011) also divided the sample in the same manner and investigated the non-linear relationship between longevity and growth. The author argues that the assumption made by Acemoglu and Johnson (2007) regarding the linear relationship between life expectancy and growth is highly misleading, that their model suffers from functional form mis-specification, and that the impact of longevity on economic growth is conditional on each country's initial life expectancy. The study indicates that above the threshold, which is equal to 53 years of age, an increase in life expectancy enhances economic growth. In addition, life expectancy is also expected to have a non-linear effect on education and population growth. The demographic transition is one of the main reasons behind the non-linear relationship between life expectancy and education, and between life expectancy and population growth (Cervellati and Sunde 2014), and also between life expectancy and economic growth (Cervellati and Sunde 2011b).

Since many empirical studies have addressed the non-linear effect of life expectancy on growth, it is possible to point out gaps in the existing literature. First, the lack of a theoretical base is a common aspect among the majority of the previous literature. The growth theories must be adopted in order to explain the relationship between life expectancy and growth. Second, to estimate the non-linear relationship, a robust technique such as the dynamic panel threshold model should be used instead of the quadratic form to explain the non-linear effect of life expectancy on growth. Various studies have pointed out the methodological limitations of using quadratic form equations to test for non-linearity (see Paresh K. Narayan and Seema Narayan 2010; Abdalla Sirag et al. 2018), thus, more appropriate estimation technique should be used. Therefore, this study relies on the economic growth theory developed by Zhang, Zhang, and Lee (2003) in order to build the empirical model. Additionally, this study adopts a more innovative technique, developed by Kremer, Bick, and Nautz (2013), called the dynamic panel threshold model to estimate the non-linear effect of life expectancy on growth.

3. Methodology and the data

3.1 Empirical model

The empirical model of this study is based on the neoclassical growth model of Zhang, Zhang, and Lee (2003), whilst also adopting the dynamic technique proposed by Kremer, Bick, and Nautz (2013) as an extension of Bruce E. Hansen's (1999) static technique, to examine the non-linear linkages between life expectancy and economic growth:

$$GDPG_{it} = \beta LE_{it} + \pi Z_{it} + \varepsilon_{it} \quad (1)$$

where $GDPG_{it}$ is the GDP per capita growth rate, LE_{it} is the life expectancy at birth as a human capital in the form of health, similarly to Siong H. Law and Nirvikar Singh (2014) Z_{it} is a vector of explanatory variables: INI_{it} is the log of initial income, ED_{it} is human capital in the form of education, K_{it} is the capital as a share of the GDP, PG_{it} is the population growth rate, INS_{it} is the quality of institutions, ε_{it} is the error term, i= 1, …, N denotes the country and t= 1, …, T denotes the time.

To estimate the non-linear relationship between the exogenous changes in longevity and growth in developed and developing countries, we utilise the dynamic panel threshold technique developed by Kremer, Bick, and Nautz (2013). For that, let us consider the following threshold model:

$$GDPG_{it} = u_i + \beta_1 LE_{it} I(LE_{it} \leq \gamma) + \delta_1 I(LE_{it} \leq \gamma) + \beta_2 LE_{it} I(LE_{it} > \gamma) + \pi Z_{it} + \varepsilon_{it} \quad (2)$$

where u_i is the country-specific effect, and ε_{it} is the error term which is assumed to be ε_{it} ~ (0, σ^2). The indicator function $I(\cdot)$ indicates the regime or group according to the threshold variable LE_{it}, and γ denotes the impact of life expectancy, depending on whether LE_{it} lies below or above the threshold level. Z_{it} contains a vector of control variables that are partially endogenous, where the slope parameter is assumed to be regime independent. Z_{1it} contains a set of exogenous variables (ED_{it}, K_{it}, PG_{it}, INS_{it}), while Z_{2it} contains endogenous variables such as the initial GDP INI_{it}. The estimator allows different regime intercepts (δ_1). Thus, the impact of life expectancy on economic growth can be explained by $\hat{\beta}_1(\hat{\beta}_2)$, which denotes the marginal effect of life expectancy on growth in the low (high) life expectancy regime, i.e. when life expectancy is below (above) the threshold.

3.2 Estimation

Following Mehmet Caner and Bruce E. Hansen (2004), first, we estimate the reduced form regression for the endogenous variables Z_{2it} as a function of the instrument X_{it}, by using the least squares method to obtain the predicted values $\hat{Z}_{2it}$. Second, we substitute the predicted values of Z_{2it} into Eq. (2) and estimate the threshold coefficient γ via the least squares method, denoting the resulting sum of the squared residuals as S(γ). The previous step is repeated for a strict subset in support of the threshold variable LE in Eq. (2). Third, the estimation of the threshold value γ is chosen as the one that has the smallest sum of the squared residuals, i.e. $\hat{\gamma}$ = argmin $S_n(\gamma)$.

Similarly to Hansen (1999) and Caner and Hansen (2004), the threshold critical values at the 95% confidence interval are given by:

$$\Gamma = \{\gamma : LR(\gamma) \leq C(\alpha)\}$$

where $C(\alpha)$ is the 95% percentile of the asymptotic distribution of the likelihood ratio $LR(\gamma)$. The underlying likelihood ratio has been adjusted to account for the number of time periods used for each cross-section (Hansen 1999). Once the threshold $\hat{\gamma}$ is determined, the generalized method of moments GMM estimator can be used to estimate the slope parameters for the previous instruments and the estimated threshold

$\hat{\gamma}$. In line with Manuel Arellano and Olympia Bover (1995), Kremer, Bick, and Nautz (2013) and Law and Singh (2014), the lagged dependent variable is used as an instrument.

3.3 The data

This study uses panel data to estimate the model for 112 countries over the period of 1981 to 2010. In line with economic growth literature, the data is based on 5-year averages where a small number of time series observations (T) and a large number of cross-sectional observations (N) are more applicable to the GMM estimators. Additionally, averaging the data tends to smooth the effect of the business cycle (Law and Singh 2014). For each country, there is a maximum of six observations.

The health measurement is through life expectancy at birth, which is the number of years that newborns are expected to live. This indicator is widely used in economic literature and the majority of studies have neglected its potential non-linear effect on economic growth. The datasets of life expectancy, the GDP per capita growth rate, the initial GDP per capita (US$ 2005 constant prices), capital formation as a share of the GDP, and the population growth rate are obtained from the World Development Indicators, compiled by the World Bank. The average years of secondary schooling are retrieved from the Robert J. Barro and Jong W. Lee (2013) dataset. The degree of institutions' corruption is obtained from the International Country Risk Guide (ICRG). We expect a large variation in the values of life expectancy across the 112 countries, therefore, in addition to the main sample, we will divide the countries into two sub-samples namely: developed and developing countries. As suggested by an anonymous reviewer, we estimated Eq. (2) for three samples: Sample 1 contains all countries, Sample 2 contains 23 developed countries, and Sample 3 contains 89 developing countries. Tables 1.a, 1.b, 1.c, and 2 present the descriptive statistics for all countries (Sample 1), developed countries (Sample 2), developing countries (Sample 3) and the correlation matrix of the variables used in the analysis, respectively. It is interesting to note that after averaging the data, Israel has the highest life expectancy at 82.85 years between 2006 and 2010. This can be explained by life expectancy in 2006 and 2007 in Israel being recorded at 85.16 years and 85.12 years, respectively, but declined to 80.9 years, 81.4 years and 81.6 years in 2008, 2009, and 2010, respectively. Nonetheless, Japan represents the highest and most consistent life expectancy. In 1990, Japan's life expectancy was 78.39 years; in 2000 it reached 81.1 years and 82.8 years in 2010. Sierra Leone, however, recorded the lowest life expectancy of about 36 years in the 1990s.

Table 1.a. Descriptive statistics (All countries)

	Mean	Std. Dev.	Min	Max
GDP growth	1.74	2.63	-8.97	10.66
Initial income	8.22	1.59	4.75	11.33
Life expectancy	67.88	10.08	36.12	82.85
Education	2.54	1.37	0.07	6.84
Capital	22.03	6.37	3.06	47.67
Population growth	1.56	1.24	-1.40	7.05
Institutions	2.92	1.42	0	6

Table 1.b. Descriptive statistics (Developed Countries)

	Mean	Std. Dev.	Min	Max
GDP growth	1.79	1.55	-1.68	9.14
Initial income	10.31	0.37	9.24	11.33
Life expectancy	77.49	2.25	72.32	82.64
Education	3.87	0.95	1.55	6.84
Capital	22.14	3.03	16.41	30.26
Population growth	0.62	0.45	-1.69	1.84
Institutions	4.36	1.46	0	6

Table 1.c. Descriptive statistics (Developing Countries)

	Mean	Std. Dev.	Min	Max
GDP growth	1.73	2.87	-8.97	10.66
Initial income	7.62	1.27	4.75	10.45
Life expectancy	65.15	9.76	36.12	82.85
Education	2.16	1.22	0.07	6.02
Capital	21.99	7.04	3.06	47.67
Population growth	1.83	1.26	-1.40	7.05
Institutions	2.51	1.10	0.02	6

Table 2. Correlation matrix

	GDPG	INI	LE	ED	K	PG	INS
GDPG	1.00						
INI	-0.03	1.00					
LE	0.10	0.80	1.00				
ED	0.09	0.73	0.72	1.00			
K	0.13	0.15	0.28	0.20	1.00		
PG	-0.20	-0.45	-0.50	-0.58	-0.12	1.00	
INS	0.08	0.54	0.43	0.43	0.03	-0.24	1.00

Note: GDPG = is GDP growth rate. INI = is initial GDP per capita. LE = is life expectancy. ED = is human capital in form of education. K = is capital formation as physical capital. PG = population growth rate. INS = institutions quality measured by corruption index. Here, we presented only the correlation matrix of all countries.

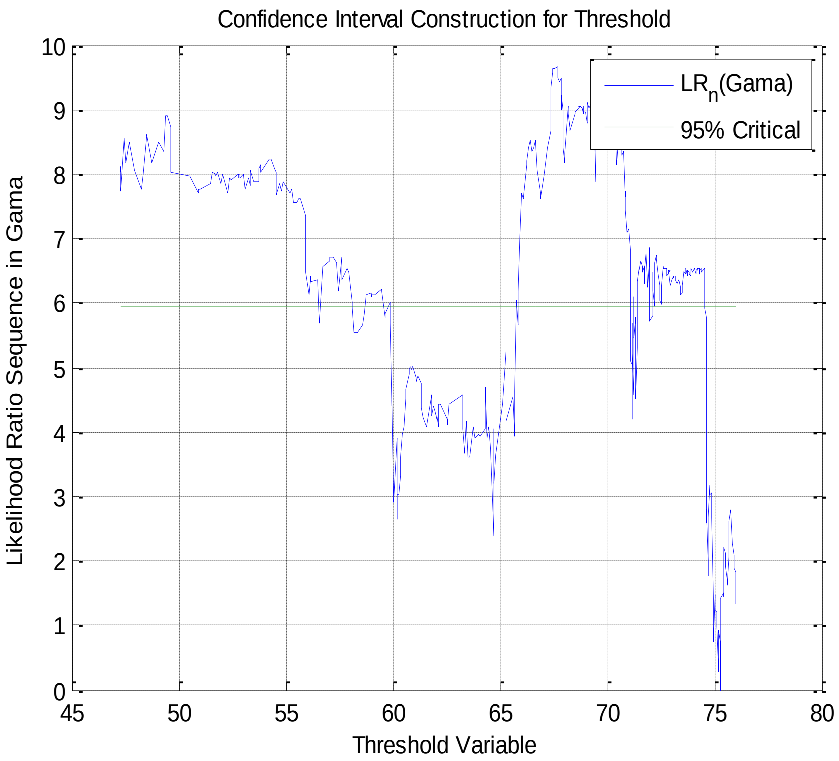
4. Results and discussion

4.1 The threshold value

Figure 1 shows the normalised likelihood ratio sequence $LR_n(\gamma)$ as a function of the threshold variable of life expectancy for Sample 1 that contains 112 developed and developing countries. The least-squares estimation of γ occurs when the $LR_n(\gamma)$ is minimised at $\hat{\gamma}$ = 75.29 years. The 95% critical value shown by the green line is about 5.9, and the asymptotic confidence intervals Γ =[56.61-76.00].

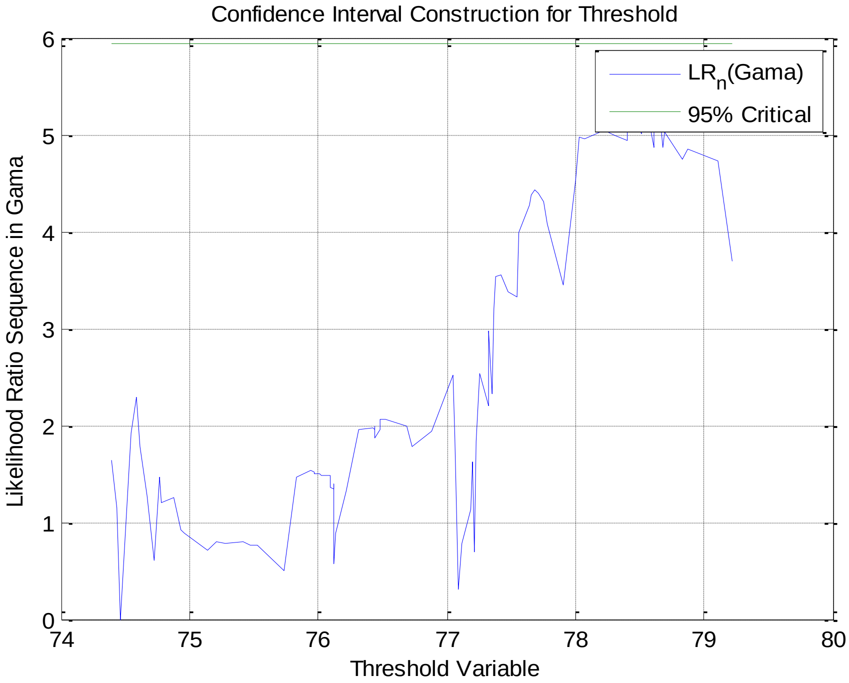
Figures 2 and 3 display the normalised likelihood ratio sequence $LR_n(\gamma)$ as a function of life expectancy for Sample 2 and Sample 3 that contain 23 developed and 89 developing countries, respectively. The least-squares method estimates γ as the value that minimises these graphs, which occurs at $\hat{\gamma}$ = 74.47 years and $\hat{\gamma}$ = 64.68 years for the developed and developing countries, respectively. The asymptotic confidence intervals are Γ =[74.39-79.22] for the developed countries and Γ =[46.48-69.45] for the developing countries. The findings reveal different and higher values for the turning point of life expectancy to the one found by Desbordes (2011), which is 53 years.

Figure 1. Threshold value of life expectancy (All Countries)



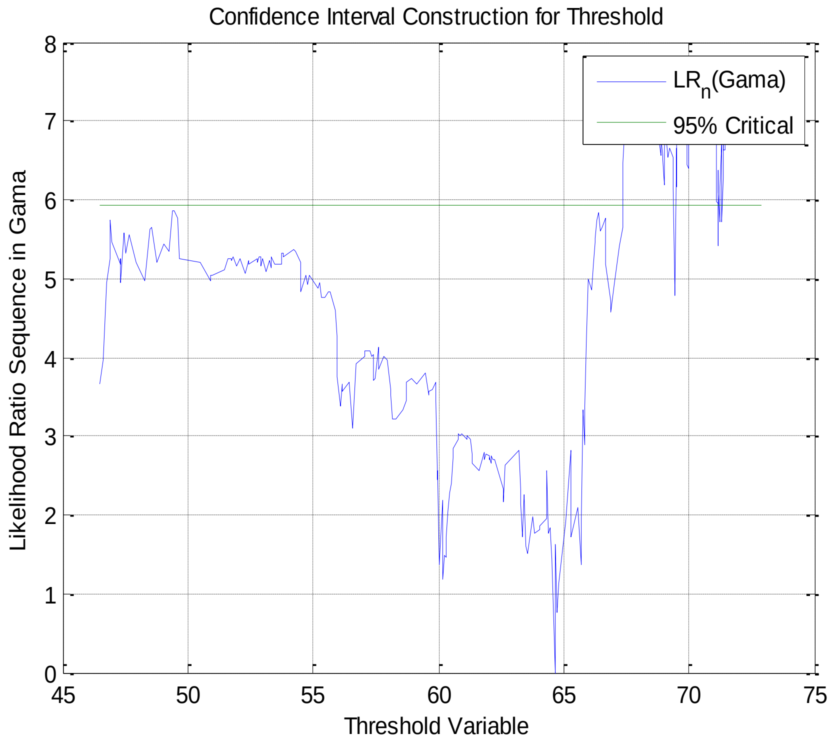
Source: Authors' calculation for Eq. (2).

Figure 2. Threshold value of life expectancy (Developed Countries)



Source: Authors' calculation for Eq. (2).

Figure 3. Threshold value of life expectancy (Developing Countries)



Source: Authors' calculation for Eq. (2).

4.2 Empirical findings

Table 3 reports the findings of estimating Eq. (2) using life expectancy as a threshold variable to assess the effect of longevity on economic growth in the 112 developed and developing countries (Model 1). The results show that the effect of life expectancy on growth is contingent on its threshold value, which is estimated at about 75.3 years. This result indicates that only 164 out of 623 or 26.3% of the observations in our sample exceed the threshold level of life expectancy. The findings reveal that the two regimes of the life expectancy coefficients $\hat{\beta}_1$ and $\hat{\beta}_2$ are statistically significant, however, it is positive below the threshold and negative above the threshold.

Table 4 presents the findings of the impact of life expectancy on economic growth contingent on its threshold value for the 23 developed countries (Model 2), and the 89 developing countries (Model 3). The estimated threshold is about 74.5 years for the sub-sample of developed countries. The number of observations laying above the threshold is 124 out of 138 or about 89.9% of the observations are above the threshold. Once more, the estimated life expectancy coefficient below the threshold of 74.5 years enhances economic growth, whereas the coefficient above the threshold indicates that higher life expectancy tends to reduce economic growth. For the sub-sample of developing countries, the estimated threshold is 64.7 years. The number of observations above the threshold for the developing countries is 293 out of 485, which represents approximately 60.4% of the observations. The estimated parameters of life expectancy have positive effects below and above the threshold. In particular, life expectancy is found to have a positive and statistically significant impact on economic growth below the threshold, whereas above the threshold level it has a positive but insignificant impact on economic growth.

Table 3. Results of dynamic panel threshold

	Model 1 (All countries)
Threshold estimates	
$\hat{\gamma}$	75.30
Confidence interval (95%)	[56.61-76.00]
Impact of life expectancy	
$\hat{\beta}_1$	0.137 ***
	(0.054)
$\hat{\beta}_2$	-0.338*
	(0.194)
Impact of covariates	
INI_{it}	-0.999
	(2.732)
ED_{it}	0.157
	(0.499)
K_{it}	0.0003
	(0.036)
PG_{it}	-0.526***
	(0.197)
INS_{it}	0.186*
	(0.097)
$\widehat{\delta_1}$	-36.781***
	(12.521)
Observation	623
N	112
Observation below $\hat{\gamma}$	459
Observation above $\hat{\gamma}$	164

Notes: The standard errors are reported in parentheses. The sample period: 1981–2010 (5-year average).
*indicates significant at 1% level.
** indicates significant at 5% level.
*** indicates significant at 10% level.

Table 4. Results of dynamic panel threshold

	Model 2 (Developed)	Model 3 (Developing)
Threshold estimates		
$\hat{\boldsymbol{\gamma}}$	74.47	64.68
Confidence interval (95%)	[74.39-79.22]	[46.48-69.45]
Impact of life expectancy		
$\hat{\boldsymbol{\beta}}_1$	1.185***	0.254***
	(0.477)	(0.091)
$\hat{\boldsymbol{\beta}}_2$	-0.798**	0.087
	(0.371)	(0.249)
Impact of covariates		
$\boldsymbol{INI_{it}}$	7.517**	-12.387**
	(3.589)	(5.967)
$\boldsymbol{ED_{it}}$	-0.027	3.739***
	(0.273)	(1.297)
$\boldsymbol{K_{it}}$	0.197**	0.086
	(0.077)	(0.064)
$\boldsymbol{PG_{it}}$	-2.730***	-0.658*
	(0.742)	(0.347)
$\boldsymbol{INS_{it}}$	0.195**	0.107
	(0.097)	(0.228)
$\widehat{\boldsymbol{\delta_1}}$	-146.85***	-9.256
	(25.94)	(17.018)
Observation	138	485
N	23	89
Observation below $\hat{\boldsymbol{\gamma}}$	14	192
Observation above $\hat{\boldsymbol{\gamma}}$	124	293

Notes: The standard errors are reported in parentheses. The sample period: 1981–2010 (5-year average).
*indicates significant at 1% level.
** indicates significant at 5% level.
*** indicates significant at 10% level.

In the three samples, the estimated parameters of initial income, human capital, physical capital, population growth, and institutions are in agreement with the theoretical expectation. The initial income coefficients' are negative which fulfil the convergence condition except in the case of Model 2, but it is only negative and significant in Model 3. The population growth coefficients' are negative and significant in all models. Likewise, the institution indicator coefficients' are significant, but positive in two out of the three models, indicating that the economic growth process relies on the good quality of institutions. However, the coefficients of human capital and physical capital are significant in explaining economic growth only in Model 3 and Model 2, respectively.

The results of this study reveal that life expectancy has a non-linear effect on economic growth. Specifically, life expectancy stimulates growth up to a certain threshold level, and above this threshold, the effect of life expectancy tends to be negative. The findings of the current study are consistent with the theoretical expectation of Zhang, Zhang, and Lee (2003) and Kunze (2014), but contradict the findings of some empirical works, such as Cervellati and Sunde (2011a, b) and Desbordes (2011), which indicate that in countries where life expectancy is high and further improvement in life expectancy promotes growth and the opposite is true. When we split the sample into developed and developing countries, our findings show a relatively lower threshold in the group of developing countries compared to the other two samples, however, we found evidence of a non-linear effect of life expectancy on growth since the coefficients are positive and significant below the threshold and positive and insignificant with a lower magnitude above the threshold. This may suggest that the developing countries are yet to reach the turning point beyond which the impact of life expectancy on economic growth is negative. Nonetheless, the insignificant impact of life expectancy the GDP growth rate above the threshold raises a real concern for the near future. For the developed countries, the findings are similar to those of the full sample, since a non-linear relationship between life expectancy and economic growth is detected. Notwithstanding, below the threshold, the effect of life expectancy on growth is positive and significant, and the effect is negative and significant above the threshold, only a few countries have a life expectancy that is less than the threshold. As presented in Table 4, the number of observations below the threshold is 14 out of 138 (only 10% of the observations).

Although very little is found in the existing literature on the question of the non-linear effect of longevity on economic growth, the relationship between the two can be explained in various ways. First, longevity affects saving positively, thus increases physical capital accumulation. Second, it is an inevitable fact that the demand for medical care (health investment) rapidly increases with old age and towards the end of life (Titus Galama 2011). Therefore, as old-age consumption becomes relatively more important, and thus longevity reduces investments into younger generations' education and, thereby, human capital accumulation. Third, investment in health would have diminishing returns due to the decreasing productivity of the ageing population (Barro 2013). Fourth, demographic transition has an outstanding effect on health expenditure policies. Niklas Potrafke (2010) argued that in most of the OECD countries, the increasing size of the ageing population puts greater pressure on public health systems while the size of the younger population, who contribute to the public health system through taxes or social health insurance compulsory contributions declines. The public health systems in developed countries, therefore, require reform to ensure their sustainability and to avoid slowing down the economic growth rate.

4.3 Robustness analysis

In this study, we conduct some robustness analysis. First, we remove the countries that have the highest and lowest life expectancy and re-estimate the three samples. Table 5 displays the findings of the dynamic panel threshold estimation. It reveals that the life expectancy threshold values are 75.30 years, 74.47 years, and 64.68 years for all countries, the developed countries, and the developing countries, respectively. This shows that the values of the life expectancy threshold remain unchanged after we remove the countries with the highest and lowest longevity in each sample. Moreover, the regime dependent regressors are similar to those of the main estimation. In particular, for the all-countries sample, $\hat{\beta}_1$is positive and statistically significant, whereas $\hat{\beta}_2$ is negative and significant, which confirms the existence of an inverted-U shaped relationship between longevity and economic growth. Also, for the developed countries, $\hat{\beta}_1$ is positive and statistically significant, but $\hat{\beta}_2$ is negative and significant. While for the developing countries the coefficients below and above the threshold are positive but $\hat{\beta}_2$ appears to be insignificant. In general, the findings of the robustness analysis seem to provide strong support to the main results reported in this study that life expectancy enhances economic growth only up to a certain threshold level beyond which it reduces growth.

Second, we employ the generalized method of moments (system-GMM) estimator introduced by Arellano and Bover (1995) and Richard Blundell and Stephen Bond (1998) as a robustness test, and we include the quadratic form of life expectancy. Although this quadratic form has limitations, since it may suffer from collinearity or multicollinearity, we estimated it to test for non-linearity between longevity and growth (see David I. Stern 2004; Narayan and Narayan 2010; Martin Wagner 2012). The threshold value can be calculated as $\hat{\gamma} = \left|\frac{\hat{\beta}_1}{2\hat{\beta}_2}\right|$ similarly to Desbordes (2011) and Sirag et al. (2016). Table 6 reports the results of the system-GMM estimator. The findings reveal that the threshold value is about 73.91 years, which is almost the same as the threshold produced by the dynamic panel threshold estimation that is reported in Table 3. The findings of the system-GMM estimation also indicate that further increase in life expectancy initially enhance growth but eventually, above a turning point, it reduces growth. The results of other controlling variables in Model 7 have almost the same pattern as the findings in Model 1 estimated by the dynamic panel threshold estimator. Finally, the diagnostic tests reveal that the instruments are valid since the Sargan test p-value is greater than 0.05. Moreover, the model fails to pass the first order autocorrelation test after the rejection of the null hypothesis; however, it fails to reject the null hypothesis of no second-order autocorrelation.

Table 5. Results of dynamic panel threshold (robustness)

	Model 4 (All countries)	Model 5 (Developed)	Model 6 (Developing)
Threshold estimates			
$\hat{\gamma}$	75.30	74.47	64.68
Confidence interval (95%)	[56.10-75.97]	[74.49-78.68]	[47.91-69.45]
Impact of life expectancy			
$\hat{\beta}_1$	0.134**	1.778***	0.238***
	(0.054)	(0.438)	(0.061)
$\hat{\beta}_2$	-0.368*	-0.789**	0.059
	(0.198)	(0.353)	(0.154)
Impact of covariates			
INI_{it}	-0.842	8.305**	-1.759
	(2.655)	(3.478)	(4.324)
ED_{it}	0.153	-0.137	0.718
	(0.497)	(0.256)	(1.022)
K_{it}	-0.002	0.156**	-0.001
	(0.036)	(0.071)	(0.045)
PG_{it}	-0.523**	-3.229***	-0.691***
	(0.214)	(0.772)	(0.345)
INS_{it}	0.192**	0.157*	0.253*
	(0.097)	(0.087)	(0.145)
$\widehat{\delta_1}$	-38.850***	-190.52***	-9.906
	(12.974)	(28.85)	(11.305)
Observation	611	126	461
N	110	21	85
Observation below $\hat{\gamma}$	452	12	180
Observation above $\hat{\gamma}$	159	114	281

Notes: The standard errors are reported in parentheses. The sample period: 1981–2010 (5-year average). Here, we removed the highest and lowest countries with life expectancy from each sample.
*indicates significant at 1% level.
** indicates significant at 5% level.
*** indicates significant at 10% level.

Table 6. Findings of system GMM estimations

	Model 7 ($\boldsymbol{LE}$ threshold)
Threshold estimates	
$\hat{\gamma} = \left\lvert \frac{\hat{\beta}_1}{2\hat{\beta}_2} \right\rvert$	73.91
$\boldsymbol{LE_{it}}(\widehat{\boldsymbol{\beta}}_1)$	0.619 ***
	(0.220)
$\boldsymbol{LE^2_{it}}(\widehat{\boldsymbol{\beta}}_2)$	-0.0042**
	(0.002)
$\boldsymbol{INI_{it}}$	-0.474
	(0.357)
$\boldsymbol{ED_{it}}$	-0.237
	(0.287)
$\boldsymbol{K_{it}}$	0.042
	(0.030)
$\boldsymbol{PG_{it}}$	-0.433***
	(0.146)
$\boldsymbol{INS_{it}}$	0.299*
	(0.170)
Sargan test	[0.18]
AR (1) p-value	[0.00]
AR (2) p-value	[0.99]

Notes: The standard errors are reported in parentheses, and between [ ] are the p-values of Sargan test and serial correlation tests. The sample period: 1981–2010 (5-year average).
*indicates significant at 1% level.
** indicates significant at 5% level.
*** indicates significant at 10% level.

This study contributes to the existing literature in the following ways. First, the non-linear effect of demographic transition, expressed by life expectancy, on economic growth is addressed. Further, the study adopts the dynamic panel threshold estimator developed by Kremer, Bick, and Nautz (2013) which is an extension of Hansen's (1999) static technique. This is the first study that uses this method to address the non-linear effect of longevity on economic growth. Using dynamic panel threshold models is more appropriate to explain the economic growth process than using static threshold models. In addition, Kremer, Bick, and Nautz (2013)'s model is superior to the threshold model of Caner and Hansen (2004) and Hansen (2000) which only capture cross-sectional data. The majority of studies that have adopted a non-linear framework to explain the relationship between life expectancy and growth have used the quadratic form of life expectancy (see Desbordes 2011) or through splitting the sample of the study between pre- and post-demographic transition to find non-linearity (see Acemoglu and Johnson 2007; Cervellati and Sunde 2011a; Cervellati and Sunde 2011b). Therefore, the dynamic panel threshold model fills the methodological gap in the growth literature. Second, the study adopts the neoclassical growth model, contrary to most of the other studies that have used non-linear modelling without theoretical support (Zhang, Zhang, and Lee 2003; Kunze 2014). Finally, the study uses a sufficiently large dataset in order to draw a reliable conclusion. The sample size of the study consists of annual data for 112 developed and developing countries from 1981 to 2010.

5. Conclusion

The current study has provided new evidence of an inverted-U shaped relationship between life expectancy and economic growth in 112 countries during the period 1981 to 2010. The paper adopted a relevant econometric estimation method, the dynamic panel threshold model, developed by Kremer, Bick, and Nautz (2013), to capture the dynamics of the growth model. The empirical findings revealed that there is an inverted-U shaped relationship conditional upon a life expectancy threshold in the life expectancy-growth nexus. On the one hand, when life expectancy is below the threshold, longevity would positively accelerate economic growth. This suggests that the improvement in life expectancy leads to further increments in the economic growth rate. On the other hand, when life expectancy is greater than the threshold, the impact of longevity on growth will be negative. This indicates that any further increase in life expectancy will not necessarily be translated to a higher growth rate.

The study showed that the impact of life expectancy on economic growth is contingent on its threshold level in both developed and developing countries. For developed countries, the results revealed that the impact of life expectancy below the threshold is positive and significant, but above the threshold of 74.47 years, the impact of life expectancy on economic growth will be negative. However, in the case of the developing countries, the impact of life expectancy on the GDP growth was positive both below and above the threshold level, but the impact was insignificant above the threshold of 64.7 years. The empirical evidence from this study has suggested that the impact of life expectancy on growth in the developed countries is negative (Models 1 and 2) compared to the developing countries, where it is positive (Models 1 and 3).

The findings of this study have a number of important implications for future research and practice. When studying the impact of life expectancy on economic growth, especially for those who use panel data analysis, the stage of demographic transition of particular countries should be taken into account. In addition, it is very important to address the relationship between longevity and economic growth within the economic development level framework. The growing size of the ageing population is putting too much pressure on the health systems of many countries. Therefore, the health systems could focus more on improving the efficiency and diversification of health financing sources. Adjusting the population’s age structure by encouraging reproduction in order to increase fertility rate, may bring a better balance in the long term. A further empirical investigation is required and future research may wish to consider treating longevity as an endogenous factor.

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