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Population growth and standard of living: A threshold regression approach

Fumitaka Furuoka
Universiti Malaysia Sabah

Qaiser Munir
Universiti Malaysia Sabah

Abstract

This study employs Hansen's (2000) threshold regression analysis to examine the relationship between population growth and per capita GDP in 117 countries. Threshold regression analysis allows controlling the quality of population when examining the relationship between the quantity of population and per capita income in a country. The paper uses Human Development Index (HDI) value as the threshold regression variable. In the course of the analysis, a sample of 117 countries was split twice and separated into four sub-samples. The threshold regression analysis revealed that there was a significant negative relationship between population growth and per capita GDP only in the countries with a low level of human development. In other words, quantitative expansion of population would have negative impact on standard of living only in the countries with low quality of population. The empirical findings of this paper support a proposition that the quality of population aspect should be included in the debate on the relationship between population expansion and economic development.

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Introduction

Relationship between the expanding world population and the standard of living or income level has generated a considerable interest among researchers, policymakers, and the general public. A number of factors, such as the "oil shock" in the 1970s, and the more recent warnings of an impending food crisis have exacerbated the worries about negative impacts of the rapidly growing population on the world economy and the quality of life. New forms of the Malthusian idea of limited resources, especially food supplies and energy, have appeared.

The relationship between the upward demographic trend and the income level has been described as "a complex one, and the historical evidence is ambiguous, particularly concerning what is cause and what is effect" (Thirlwall 1994:143). No consensus has been achieved as to whether population expansion is beneficial or detrimental to the living standard or the per capita income. The relationship between population growth and per capita income could be considered as positive when the expanding population in a country propels its economic development, encourages competition in business activities and stimulates the market growth. On the other hand, the relationship could be considered as negative when the increase of population becomes an impediment to the country's economic development because the rapid expansion of population increases dependency burden (i.e., the number of people who are considered to be economically unproductive, such as children and the elderly). The view that the increasing world population has a negative impact on living standards has been prevailing since Thomas Malthus (1798) warned about the calamitous consequences of "over-population" more than two centuries ago. However, not all modern scholars share this opinion. For example, Simon (1996:589) points out that human beings is "the ultimate resource" that contributes to economic development.

Numerous research studies have been done on a long-run relationship between population growth and income level (e.g., Ahlburg 1996; Bucci and La Torre 2007; Dawson and Tiffin 1998; Easterlin 1967; Kelley and Schmidt 1996; Kuznets 1967; Simon 1992; Thirlwall 1972; Thornton 2001). A majority of the earlier studies used cross-section regression analysis, and established a negative relationship between population expansion and income level. However, considerable methodological problems arise from the use of the cross-section regression. For example, such analyses tended to suffer from the problem of heteroskedasticity. On the other hand, the main problem in the earlier research studies that used time-series regression analysis is a lack of adequate data sets.

In recent years, the availability of reliable data sets has promoted further research on the relationship between population growth and economic development. Dawson and Tiffin (1998) employed time-series data to examine a long-run relationship between population growth and living standard in India. They used augmented Dickey-Fuller (ADF) unit root test and Johansen co-integration test to analyze the co-integrating relationships between the two variables. As the findings indicated, no long-run equilibrium relationship could be detected between population expansion and income level in India. The researchers concluded that "…Population growth neither causes per capita income growth nor is caused by it" (Dawson and Tiffin 1998:154).

John Thornton (2001) examined a long-run relationship between population expansions and economic growth in seven Latin American countries, i.e. Argentina, Brazil, Chile, Colombia, Mexico, Peru, and Venezuela. The findings of the study supported the conclusion reached by Dawson and Tiffin (1998). As Thornton (2001:466) maintained, "A long-run relation between population and real per capita GDP does not appear to exist; hence, population growth neither causes growth of per capita GDP nor is caused by it".

A more recent research study by Bucci and La Torre (2007) employed a two-sector endogenous growth model. The researchers contended that population growth mignt have either a negative or an ambiguous effect on economic development. The former would be in evidence when physical capital and human capital are substitute. On the other hand, when physical capital and human capital are complementary, the effect of the population growth on economic development becomes ambiguous. Turnemaine (2007) developed a model in which technical progress, human capital, and population interact endogenously to analyze the relationship between population growth and per capita growth. He concluded that population growth could have both positive and negative impacts on the economic development; the outcome would depend on the relative contribution of the population and human capital to the economy.

Klasen and Lawson (2007) used cross-country data and panel data in their analysis. The findings indicate a negative relationship between population expansion and economic performance. According to the researchers, all of the regressions of per capita economic growth indicated that "population growth has a highly significant negative influence on per capita economic growth" (Klasen and Lawson 2007:11). Thus, the findings of the previous cross-sectional research studies tended to indicate that the relationship between population growth and living standard was negative. In other words, in countries with a low population growth the per capita income was higher while in countries with a high population growth the per capita income was lower (see Figure 1).

An important aspect omitted from the debate on the expansion of the world population is population quality. A Nobel Prize laureate, Theodore Schultz, argued that mainstream economists tended to put stress on the issue of the finite resources rather than to consider the value of the population quality. He highlighted the measurable gains that the improvements in the population quality could bring to the economic development in developing nations (Schultz 1979). Becker and Tomes (1976) maintained that the quality of population or human capital could eventually substitute the quantity of population. In a long run, as a country becomes more prosperous the increase in demand for a high quality human resource would lead to the reduction of the population quantity. In other words, as a country develops economically people tend to have fewer children which means that economic development could offer a solution for over-population.

The present study focuses on the quality of population aspect. It examines the relationship between population growth and living standard or per capita GDP in 117 countries using the threshold regression analysis (Hansen 2000). The threshold regression analysis allows controlling the *quality* of population when running a regression that investigates the relationship between the *quantity* of population and economic development. This study employs Human Development Index (HDI) value as a proxy to measuring the quality of population. Following the introductory section, Section two briefly explains Hansen's threshold regression model. Section three reports the empirical findings while Section four offers concluding remarks.

Hansen's threshold regression method

Hansen (2000) developed a new statistical analysis for threshold effect and constructed asymptotic confidence intervals for the threshold parameters. According to Hansen, an exogenously given variable, called the threshold variable, is used to split a sample into two regimes. The current paper employed the threshold regression analysis to examine the relationship between population expansion and standard of living. The source of data was the United Nations Development Program's *Human Development Report 2007/2008* (UNDP 2009).

Hansen's threshold estimation is based on a two-regime structural equation as follows

$$y_i = \theta_1 x_i + e_{1i} \qquad \text{if } q_i \le \gamma \qquad (1)$$

$$y_i = \theta_2 x_i + e_{2i} \qquad \text{if } q_i > \gamma \qquad (2)$$

where γ denotes threshold value, y is dependent variable, x is independent variable, q is threshold variable, θ is slope coefficient, and e is error term.

Since the threshold value is unknown *a priori,* it should be estimated in addition to the other parameters. In cases when the threshold variable is smaller than the threshold value, the model estimates equation 1. On the other hand, when the threshold variable is larger than the threshold value, the model estimates equation 2.

In the current study the OLS regression without the threshold value could be expressed as

$$GDP_i=\beta_0+\beta_1 POP_i+\beta_2 Infant_i+\beta_3 Gini_i+\varepsilon \qquad (3)$$

where β_0 is intercept, β_1, β_2 and β_3 are slope coefficients, ε is error term, GDP_i is a natural log of the per capita Gross Domestic Product (GDP) at Purchasing Power Parity (PPP) in country i; POP is annual growth rate of population from 1975 to 2005 in country i; $Infant$ is infant mortality rate in country i in the year 2005; $Gini$ is the Gini coefficient in country i.

The threshold regression can be expressed as

$$GDP_i=(\beta_{10}+\beta_{11}POP_i+\beta_{12}Infant_i+\beta_{13}Gini_i)d\{HDI_i\le\gamma\}+(\beta_{20}+\beta_{21}POP_i+\beta_{22}Infant_i +\beta_{23}Gini_i)\, d\{HDI_i>\gamma\} +\varepsilon \qquad (4)$$

where $d\{.\}$ is the indicator function; $d\{HDI_i \leq \gamma\}$ equals to 1, and $d\{HDI_i > \gamma\}$ equals to 0. If HDI_i is equal to or less than the threshold value, this indicates a regression estimate of the "first regime". On the other hand, if $d\{HDI_i \leq \gamma\}$ equals to 0, and $d\{HDI_i > \gamma\}$ equals to 1 if HDI_i is greater than the threshold value which indicate the regression estimate of the "second regime". Further, in equation (4), HDI_i is the human development index in country *i* in the year 2005.[1]

As the first step, this study examined whether there was a threshold effect in equation (4). According to Hansen (1996, 1997, 2000), the threshold effect is defined as the difference in the slope coefficients between the first and the second regimes. The null hypothesis is there is no threshold (i.e., no difference in the slope coefficients between the two regimes). The heteroskedasticity-consistent Lagrange multiplier (LM) test can be used to test this hypothesis.

As the next step, this study proceeded to examine the threshold value. Hansen (1996, 1997, 2000) suggests that an appropriate estimation method for this purpose is the Least Square (LS). Under an assumption that the residual is *iid* $N(0, \sigma^2)$, Least Square is equivalent to the Maximum Likelihood Estimation (MLE). The LS estimate of the residual variance or $\hat{\sigma}_T{}^2(\gamma)$ can be expressed as

$$\hat{\sigma}_T{}^2(\gamma) = \frac{S_T(\gamma)}{T} = \frac{1}{T}\sum_{t=1960}^{2007}\hat{e}_t(\gamma)^2 \qquad (5)$$

where T is number of observations in the time-series data, $S_T(\gamma)$ is the residual sum of squares, and e is the residual. The LS estimate of γ or $\hat{\gamma}$ is the value that minimizes the residual variance:

$$\hat{\gamma} = \text{argmin}\, \hat{\sigma}_T{}^2(\gamma) \qquad (6)$$

where *argmin* stands for the argument of the minimum. The null hypothesis of no threshold effect is tested by the standard F-statistic. The F-statistic can be calculated as follows

$$F_T = T\frac{S_T^0 - S_T^1(\hat{\gamma})}{S_T^1(\hat{\gamma})} \qquad (7)$$

where S_T^0 is the residual sum of squares based on equation (3), and $S_T^1(\hat{\gamma})$ is the residual sum of squares based on equation (4). If the residual is conditionally heteroskedastic, a heteroskedastic-consistent Lagrange multiplier (LM) statistic can be used to test the null

[1] Human Development Index (HDI) is a comprehensive and also a composite socio-economic development indicator, which is used to rank countries by the level of human development. On the other hand, per capita GDP is employed to rank countries merely by the income level, without paying attention either to the levels of heath and longevity or to the education and knowledge levels.

hypothesis. However, the asymptotic distribution of the LM statistic is not a chi-squared distribution. The bootstrap procedure was used to approximate its asymptotic distribution and to obtain the critical values.

As the third step, this study proceeded to form a confidence level for γ. According to Hansen (1996, 1997, 2000), a common method to form a confidence level is through inversion of the Wald statistic. The threshold regression is an example when the Wald statistic has poor finite sample behaviour. This is because asymptotic sampling distribution depends on an unknown parameter. Therefore, Hansen suggested employing the likelihood ratio (LR) statistic to form the confidence level for γ. The LR statistic can be calculated as

$$LR_T(\gamma_0) = \frac{S_T(\lambda_0) - S_T(\hat{\gamma})}{S_T(\hat{\gamma})} \tag{8}$$

where γ_0 is the actual or specific threshold value, and $\hat{\gamma}$ is an estimated threshold value. The confidence interval can be constructed as

$$\hat{\Gamma} = \{\gamma : LR_T(\gamma) \leq c\} \tag{9}$$

where $\hat{\Gamma}$ is an asymptotic C-level confidence region for γ, and c is the $100 \times C$ percentile of the asymptotic distribution of the LR statistic.

Empirical Findings

The present study examined the relationship between population growth and economic development using the HDI value as the threshold variable. In other words, the HDI was used to split the countries into several groups.

First of all, the heteroskedasticity-consistent Lagrange multiplier (LM) test was carried out to examine whether there were sample splits based on the HDI value. Upon running 1000 bootstrap replications, the LM statistic was 43.72, and its p-value was 0.01. This means that the LM test strongly rejected the null hypothesis of no threshold, which suggests that there might be a sample split based on the HDI value.

Figure 2 displays a graph featuring the normalized likelihood ratio (LR) as a function of the threshold in the HDI values. As the Figure shows, the least squares (LS) estimate of γ, which minimizes the residual variance as well as the LR statistic, was 0.804. The confidence interval was [0.804, 0.804]. This may indicate that the threshold estimate was very precise and the confidence interval was very tight.

The threshold value of 0.804 separated the 117 countries in the data into two subsamples, namely, into 39 countries with a high level of human development, and 78 countries with a low level of human development. The HDI value was used as the threshold variable to analyze each of these two subsamples. The heteroskedasticity-consistent LM test was used to examine whether there was a sample split in the first subsample of 39 countries.

Upon running 1000 bootstrap replications, the LM statistic was 18.34, and its *p*-value was 0.01. Thus, the LM test rejected the null hypothesis of no threshold which means that, in the first subsample, there might be a sample split based on the HDI value.

As Figure 3 shows, the LS estimate of γ, which minimizes the residual variance as well as the LR statistic, was 0.921. The confidence interval was [0.870, 0.935] and it contained 9 out of the 39 countries. This finding indicates that the threshold estimate was precise and the confidence interval was tight.

The threshold value of 0.921 divided the 39 countries with a high level of human development into two subsamples, namely, 22 countries with a very high level of human development, and 17 countries with a high level of human development.

Next, the heteroskedasticity-consistent LM test was used to examine whether there was a sample split in the subsample of the 78 countries with a low level of human development. After running 1000 bootstrap replications, the LM statistic was 13.39, and its *p*-value was 0.02. Thus, the LM test rejected the null hypothesis of no threshold. This means that there might be a sample split based on the HDI value in this subsample of countries.

Figure 4 shows that the estimate of the threshold value, which minimizes the residual variance as well as the LR statistic, was 0.534. The confidence interval was [0.534, 0.534], and it contained 9 out of the 78 countries. This indicates that the threshold estimate was very precise and the confidence interval was very tight. The threshold value of 0.534 further separated the 78 countries into two subsamples, namely, 28 countries with a very low level of human development and 50 countries with a low level of human development.

To summarize, the threshold variable (i.e., HDI) significantly split the sample of 117 countries into two regimes. In the two-regime model, the first regime consisted of 78 countries with a low level of human development (i.e., where the HDI value was equal to or less than 0.804) while the second regime consisted of 39 countries with a high level of human development (i.e., where the HDI value was greater than 0.804).

Furthermore, the threshold variable significantly split these two subsamples into four regimes. For the four-regime model, the first regime consisted of 28 countries with a very low level of human development (i.e. where the HDI value was less than or equal to 0.534); the second regime consisted of 50 countries with a low level of human development (i.e., where the HDI value was greater than 0.524 but less than or equal to 0.804). The third regime consisted of 17 countries with a high level of human development (i.e., where the HDI value was greater than 0.804 but less than or equal to 0.921); the fourth regime consisted of 22 countries with a very high level of human development (i.e., where the HDI value was greater than 0.921).

This study proceeded to analyze the relationship between population growth and per capita GDP in the different regimes. Table 1 reports the empirical results of the threshold regression analysis of the two-regime model, namely, Regime 1 which included 78 countries with a low level of human development, and Regime 2 which included 39 countries with a high level of human development.

As Table 1 indicates, infant mortality had a significant negative relationship with the per capita GDP in these two regimes. Infant mortality rate can indicate the level of medical care and the public heath condition in a country. Countries with an inferior medical care and a poor public health condition tend to be in a lower income level bracket. On the other hand, as seen in the table the Gini coefficient, which can be used to measure income inequality in a country, had a significant positive association with living standard only in the countries with a low level of human development. This means that among these 78 nations, the countries with a relatively high income disparity tended to have a higher living standard.

Further, as Table 1 shows, the threshold regression analysis revealed that there was a significant negative relationship between population growth and per capita GDP only in the countries with a low level of human development. In the countries with a high level of human development, the relationship between population growth and the per capita income level was positive but nonsignificant. In other words, a large quantitative expansion of population in the countries with a low level of human development tended to be associated with a lower per capita income. However, there was no such an association in the countries with a high level of human development.

As a next step, the study carried out the threshold regression analysis of all the four regimes. As Table 2 shows, infant mortality rate had a significant negative relationship with per capita GDP in all regimes except Regime 4 which included the countries with a very high level of human development.[2] This finding indicates that countries with a substandard medical care and an inferior public health condition tended to have a sluggish economic growth.

Further, as shown in Table 2, the Gini coefficient had a significant positive association with per capita income only in the countries with a low level of human development. This means that among the 50 countries with a low level of human development, the nations with a relatively high income inequality tended to have a higher living standard.

More importantly, as Table 2 reports, a significant negative relationship between population growth and per capita GDP was detected only in the countries with a low level of human development. In support to the findings from the two-regime model, the relationship was nonsignificant in the countries with a high and a very high level of human development.

[2] In all of the 22 countries with a very high level of human development infant mortality rate was very low. The highest mortality rate of 6 deaths per 1000 live births was in the USA while the lowest infant mortality rate of 3 deaths per 1000 live births was in Norway, Sweden, Finland, Japan, and Singapore. A relatively small variance in the infant mortality rate (between 6 to 3 deaths per 1000 live births) in these countries prevented the analysis from capturing the relationship between the infant mortality and the per capita income.

However, contradicting the findings from the two-regime model, no significant relationship between the two variables was found in the countries with a very low level of human development. An explanation for this could be that all of the 28 countries with a very low level of human development are among the poorest developing countries in the world. They are plagued by serious social, economic and political problems, such as famine, political instability, or the war. Thus, in these countries, a low population growth rate does not seem to be associated with standard of living.

To summarize, the threshold regression analysis done in this study revealed that there was a significant negative relationship between population growth and per capita GDP only in the countries with a low level of human development. In other words, these findings indicate that quantitative expansion of population combined with a relatively low quality of population had a negative association with living standard.

Conclusion

The current paper employed Hansen's threshold regression method to examine the relationship between population growth and per capita GDP in 117 countries. The threshold regression analysis allows researchers to control the quality of population when running a regression on the relationship between the quantity of population and per capita income in a country. The study used the Human Development Index (HDI) value as the threshold variable which is a proxy to measuring the quality of population.

The threshold regression analysis revealed that there was a significant negative relationship between population growth and per capita GDP only in the countries with a low level of human development. In other words, quantitative expansion of population would have negative impact on standard of living only in the countries with a low quality of population. The empirical findings of this paper support a proposition that the quality of population aspect should be included in the debate on the relationship between population expansion and economic development.

Though this study used Human Development Index to gauge the quality of population, other variables can be used for this purpose, such as educational level, skill development level, health condition, etc. Future research studies on this topic may want incorporate one or more of these variables as a control variable.

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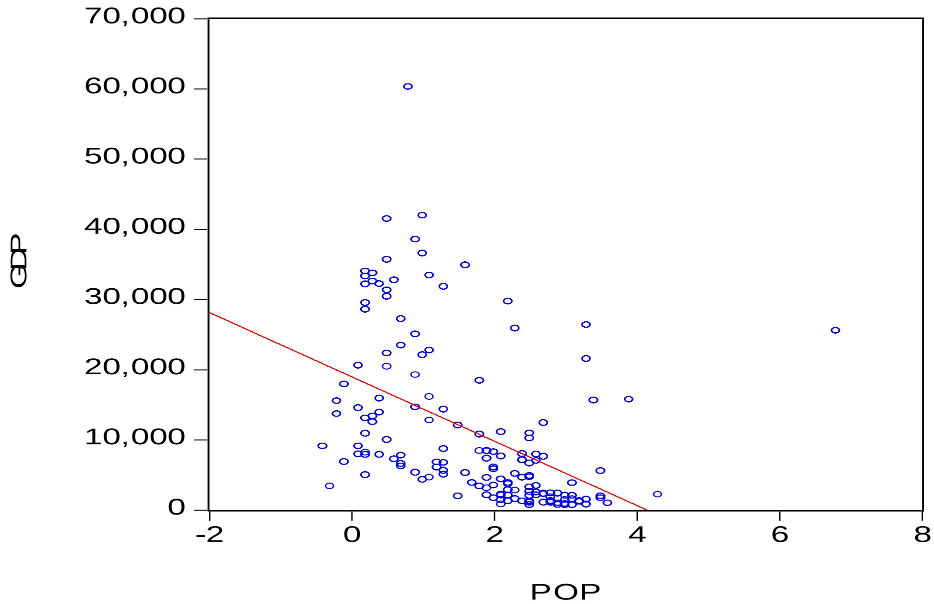
Appendix

Figure 1: GDP per capita and population growth



Source: UNDP, 2009

Figure 2: First sample split, using HDI 2005

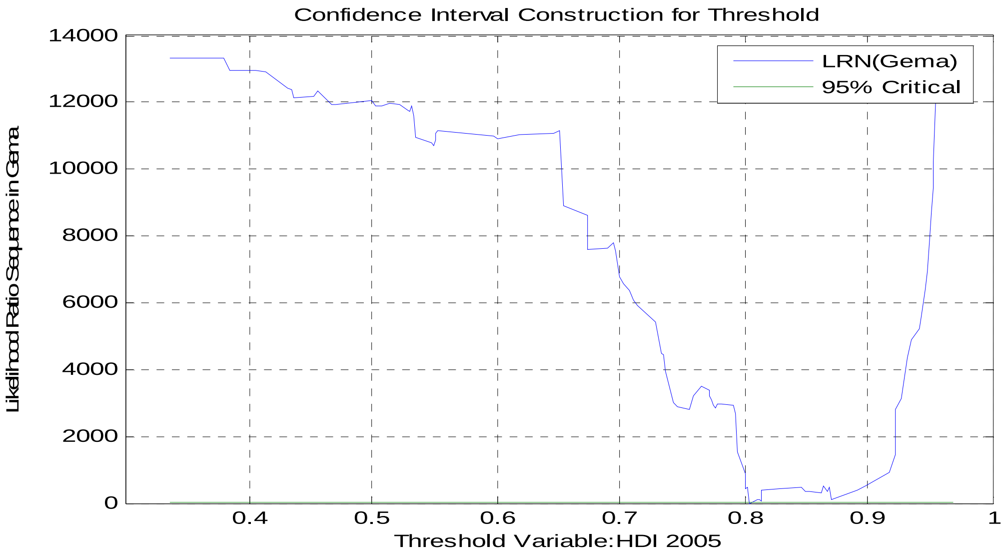


Figure 3: Second sample split (HDI2005>0.804) based on HDI 2005

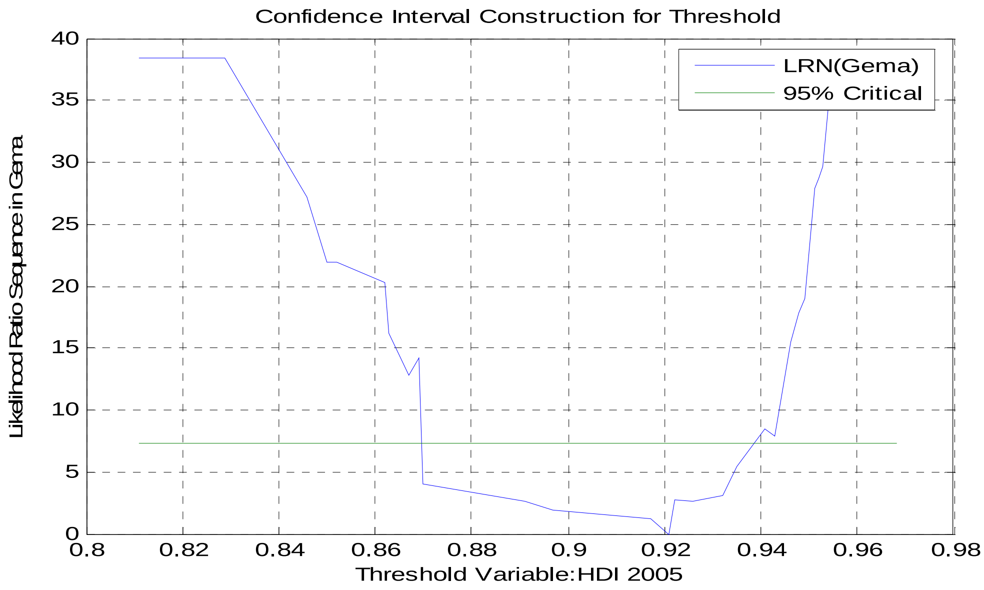


Figure 4: Second sample split (HDI2005 ≤ 0.804), using HDI 2005

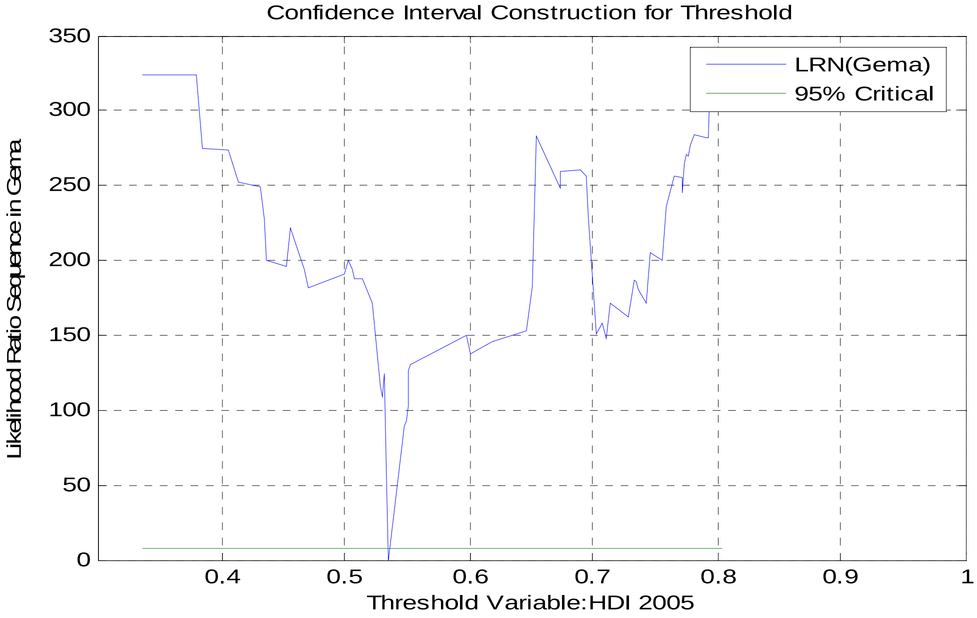


Table 1: Threshold regression analysis of the two-regime model

	Regime 1 Countries with a low level of human development ($HDI \leq 0.804$)	**Regime 2** Countries with a high level of human development ($HDI > 0.804$)
Constant	8.414** (0.267)	10.876** (0.251)
Population growth	-0.290** (0.078)	0.071 (0.092)
Infant Mortality	-0.013** (0.001)	-0.062** (0.013)
Gini Coefficient	0.023** (0.005)	-0.013 (0.009)
Observation	78	39
R-squared	0.665	0.633

Table 2: Threshold regression analysis of the four-regime model

	Regime 1 Countries with a very low human development ($HDI \le 0.534$)	**Regime 2** Countries with a low human development ($0.534 < HDI \le 0.804$)
Constant	7.211** (0.741)	8.024** (0.294)
Population growth	-0.011 (0.152)	-0.240* (0.091)
Infant Mortality	-0.007** (0.002)	-0.006* (0.002)
Gini Coefficient	0.015 (0.008)	0.025** (0.006)
Observation	28	50
R-squared	0.268	0.401
	Regime 3 Countries with a high human development ($0.804 < HDI \le 0.921$)	**Regime 4** Countries with a very high human development ($HDI > 0.921$)
Constant	10.221** (0.221)	10.490** (0.244)
Population growth	0.018 (0.085)	-0.016 (0.055)
Infant Mortality	-0.031** (0.011)	0.052 (0.046)
Gini Coefficient	-0.010 (0.007)	-0.010 (0.007)
Observation	17	22
R-squared	0.614	0.118

Notes: Figures in parentheses indicate standard error
** indicates significance at 1% level, * indicates significance at 5% level