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The Fertility-Development Relationship in the United States: New Evidence from Threshold Regression Analysis

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Abstract

This study employed a threshold regression analysis (Hansen, 2000) to examine the relationship between per capita Gross Domestic Product (GDP) and total fertility rate (TFR) in the United States. The United States is the only developed country where the declining fertility rate was reversed and recovered to the replacement level of 2.1. The findings indicate that there was a statistically significant threshold in the fertility-development relationship and a reverse in the fertility decline. The threshold value of real per capita GDP based on the Laspeyres index was US$22,267, while the threshold value of real capita GDP based on the Fisher index was US$21,264. This means that the decline in the fertility rate could be reversed when per capita income reached US$21,000-US$22,000. The empirical findings also indicate a significant negative relationship between per capita GDP and TFR when income level in the country was below the threshold value. This negative association between the two variables reversed to a positive relationship when income level had exceeded the threshold value. The findings of this study confirm the existence of a J-shaped fertility-development relationship in the United States.

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1. Introduction

A negative association between economic development and fertility rate is an accepted historical reality in social sciences disciplines. As Myrskylä *et al*. (2009) argue, unparalleled leaps that occurred in the twentieth century in many countries' social and economic development were accompanied by declines in their population and fertility rates. The researchers state that this negative association between economic and social development and human fertility is one of the most tenacious "empirical regularities" in social sciences (Myrskylä *et al*. 2009). In a similar vein, Doepke (2004) asserts that fertility decline is a universal trend, and that every industrialized country has experienced a demographic transition from high to low fertility.

Fertility decline in European countries has been an important research topic for demographic specialists and economists. Sobotka (2004) points out that, in 2002, more than half of Europe's population lived in countries with a fertility rate at or below 1.3. Kohler *et al*. (2002) argue that the lowest-low fertility, which is defined as a period of total fertility rate at or below 1.3, has been a constant feature of the demographic landscape in Europe in the 1990s. Among the factors that contribute to the reduced fertility rates the researchers mention increased returns to human capital and high economic uncertainty. Furthermore, not only developed countries but developing nations too began experiencing declining fertility rates. As a reputable international publication observes, "Fertility rate is falling and families are shrinking in places – such as Brazil, Indonesia, even parts of India – that people think of as teeming with children" (*The Economist* 2009a).

Exploring reasons for the fertility decline that various countries experience in the course of their economic development, Bryant (2007) proposes that not only socio-economic factors but also diffusion of new ideas have caused birth rates to fall. McDonald (2000) who specifically focuses on social causes of the fertility decline argues that this demographic trend is attributable to a low level of gender equality, such as a lack of support for women's employment, the absence of a proper tax system regarding the women's earnings, and the gender-oriented roles within the family.

Some economists attribute fertility decline to a hypothesis that there exists a trade-off relationship between the quantity and the 'quality' of children. Becker, Glaeser and Murphy (1999) defined the "quality" of children as a human-capital level of each child. In the course of economic development, parents tend to augment the 'quality' of their children while decreasing their quantity. According to Currais (2000), the first systematic analysis of the interaction between the quantity and quality of children was done by Gary S. Becker and H. Gregg Lewis (Becker and Lewis 1973).

According to the hypothesis on a trade-off relationship between the quantity and quality of children, there is a negative correlation between the number (or quantity) of children and their 'quality' as perceived by others. Parents maximize their utility subject to the budget constrains. The parental utility function can be expressed as

Max $U = U\ (n, q, y)$

where U is parental utility function, n is number of children, q is quality of children or a human-capital level of each child, and y is consumption. The budget constrains can be expressed as

$$I = nq\pi + y\pi_y$$

where I is income, π is the price of nq, and π_y is the price of y. This means that an increase in the quality of the children or the investment in the children's human capital would be more costly to the parents who have more children. This is because the increase in the investment will have to be applied to more 'units'. Furthermore, an increase in the quantity of children would be more costly to the parents if the children are of a higher 'quality' because 'higher quality' children cost more to the parents.

Recently, the entrenched assumptions at the core of the fertility-development discourse have been challenged. A study by Myrskylä *et al.* (2009) boldly proclaims a major shift in the negative relationship between fertility and development. The researchers contend that the development-fertility relationship is negative when the Human Development Index (HDI) is below the range of 0.85-0.9. However, when the HDI surpasses 0.9, as it has recently happened in some developed countries, the development-fertility association reverses to a positive one (Myrskylä *et al*. 2009). The significance of this finding is that a rule of demography that people in rich countries tend to have fewer children "no longer holds true", and the policy makers would need to change their present assumptions when devising the future models (*The Economist* 2009b).

Some researchers express doubts that high levels of development are able to reverse declining fertility rates. For example, Furuoka (2009) employed a threshold regression analysis to examine the fertility-development relationship in 176 countries. He found no empirical evidence to support the proposition that advances in development could reverse declining fertility rates. The results of Furuoka's cross-sectional study indicate that in countries with a low human development index, higher levels of the HDI tend to be associated with lower fertility rates. Likewise, in countries with a high human development index, higher levels of the HDI are associated with lower fertility rates, but the relationship is weak.

The present study aims to empirically examine the fertility-development relationship in the United States. Interestingly, while the European continent and even some developing countries have been experiencing plunging fertility rates, there had occurred a reverse in fertility decline in the United States. Until the 1980s, demographic trends in the United States were similar to those in other developed countries; the fertility rate in the United States kept falling and dropped below the replacement rate of 2.1. Then something unexpected happened: the American fertility rate reversed its decline and rose sharply (*The Economist* 2009c). In the year 2006, the fertility rate in the United States recovered to the replacement rate of 2.10 (World Bank 2010).

It should be noted that when per capita Gross Domestic Product (GDP) in the United States was lower than (approximately) US$22,000, there was a strong negative relationship between total fertility rate (TFR) and per capita GDP in the country (see Appendix 1, Figure 1 and Figure 2).[1] While the GDP kept increasing the fertility kept declining, as was the trend in other developed countries. In 1960, the TFR in the United States was relatively high at 3.65, and the country's per capita GDP amounted to US$14,736. The TFR rapidly declined to 2.91 in 1965 when per capita GDP was US$17,700. In 1970, TFR dropped to 2.48 (per capita GDP US$19,696). The country's fertility rate became lowest at 1.78 in the year 1976, when the per capita GDP amounted to US$22,602.

Remarkably, decline in the fertility rate in the United States seemed to stop and reverse when per capita GDP reached US$22,000. In 1980, when per capita GDP amounted to US$24,640, the country's fertility rate increased to 1.84. It climbed to 2.01 in 1989, when the country's per capita GDP was US$30,838. In 2006, with per capita GDP at US$42,683, fertility rate in the United States recovered and reached 2.1, or the level of replacement.

To empirically examine the fertility-development relationship in the United States in the period 1960-2007, the present study employs threshold regression analysis (Hansen, 2000). There are two advantages to employing this method. Firstly, the threshold regression can be used to determine whether there was a statistically significant reverse in the decline of the fertility rate in the United States. Secondly, it can detect the exact threshold value or a watershed when a demographic transition from fertility decline to fertility rise had occurred.

Following this introductory section, Section Two offers a brief explanation of Hansen's threshold regression model. Section Three reports the empirical findings, and Section Four is a conclusion.

2. Hansen's threshold regression method

Hansen (1996, 1997, 2000) developed a new and highly functional empirical test for threshold effect that constructs asymptotic confidence intervals for the threshold parameter. According to Hansen, an exogenously given variable, which is called threshold variable, is used to split a sample into two regimes.

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

$$y_t = \theta_1 x_t + e_{1t} \qquad \text{if } q_t \le \gamma \qquad (1)$$

$$y_t = \theta_2 x_t + e_{2t} \qquad \text{if } q_t > \gamma \qquad (2)$$

[1] The graph reports real per capita GDP based on the Laspeyres fixed-weighted index that is derived from the growth rates of consumption (C), investment (I) and government expenditure (G). Per capita GDP is codified as "RGDPL" in the Penn World Table (CICUP 2010).

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

The threshold value is unknown *a priori.* Therefore, it should be estimated together with other parameters. When the threshold variable is smaller than the threshold value, the model proceeds to estimate 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 can be expressed as

$$TFR_t = \beta_0+\beta_1 GDP_t + \varepsilon \qquad (3)$$

where β_0 is an intercept, β_1 is a slope coefficient, ε is an error term, TFR_t is total fertility rate in the United States in the year t, GDP_t is a natural log of per capita Gross Domestic Product (GDP) in the United States in the year t.

Data on total fertility rates were obtained from the World Bank (2010). Data on per capita GDP were obtained from CICUP (2010).

The present study used two types of per capita GDP, namely, *LGDP* and *FGDP*. The *LGDP* is a real per capita GDP based on the Laspeyres fixed-weighted index derived from the growth rates of domestic absorption (*DA*). The *FGDP* is a real per capita GDP based on the chain Fisher volume index derived from the growth rate of *DA* for each year.[2] For the purpose of the analysis, all the data were transformed into a log form.

The threshold regression can be expressed as

$$TFR_t= (\beta_{10}+\beta_{11}GDP_t)d\{GDP_t\leq\gamma\} + (\beta_{20}+\beta_{21}GDP_t)d\{GDP_t>\gamma\}+ \varepsilon \qquad (4)$$

where $d\{.\}$ is the indicator function, $d\{GDP_t\leq\gamma\}$ equals to 1, and $d\{GDP_t>\gamma\}$ equals to 0 if GDP_t is equal to or less than the threshold value, which indicates a regression estimate of the first regime. On the other hand, $d\{GDP_t\leq\gamma\}$ equals to 0, and $d\{GDP_t>\gamma\}$ equals to 1 if GDP_t is greater than the threshold value, which indicates a regression estimate of the second regime.

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

[2] In the Penn World Table, *LGDP* is codified as *RGDPL2* and *FGDP* is codified as *RGDPCH*. For a more detailed description of the data, see CICUP (2010).

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

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

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:

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

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

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

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 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

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

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.

3. Empirical Findings

The current study employed a threshold regression analysis to examine the fertility-development relationship in the United States in the period 1960-2007, and used per capita GDP as the threshold variable to split time-series data into two regimes. As the first step of the empirical analysis, this study employed OLS analysis to examine the relationship between the total fertility rates and per capita GDP without the threshold.

As Table 1 and Table 2 (see Appendix 2) report, the OLS estimation without the threshold value shows that there existed a strong negative relationship between fertility rates and the standard of living or per capita GDP in the United States. In other words, as the country's economic development progressed and its people became wealthier, the total fertility rates declined.

Secondly, the heteroskedasticity-consistent Lagrange multiplier (LM) test was used to examine whether there was a sample split based on the two types of per capita GDP (i.e. *LGDP* and *FGDP*). One thousand bootstrap replications were run to estimate *p*-values for test statistic.

Figure 3 (see Appendix 1) shows that, upon running 1000 bootstrap replications, the LM statistic for *LGDP* was 25.66, and its *p*-value was 0.001. This means that there could have existed a sample split based on the *LGDP*. In other words, according to real per capita GDP based on the Laspeyres index, there occurred a significant reverse in the fertility decline in the United States.

As Figure 4 (see Appendix 1) shows, the LM statistic for *FGDP* was 25.81, and its *p*-value was 0.001. This finding indicates that there could have existed a sample split based on the *FGDP*. This means that the empirical findings on real per capita GDP based on the Fisher Index confirmed that there was a statistically significant reverse in the negative association between fertility and per capita income in the United States.

Thirdly, the likelihood ratio (LR) test was used to detect the exact threshold value and to construct the confidence interval. Figure 3 (see Appendix 1) is a graph featuring the normalized likelihood ratio (LR) as a function of the threshold in the level of per capita GDP based on the Laspeyres index (*LGDP*). As the figure shows, the least square (LS) estimation of *γ*, which minimizes the residual variance as well as the LR statistic, was 10.010 while the confidence interval was [9.972, 10.106]. These findings indicate that the threshold estimation was precise and the confidence interval was tight.

Figure 4 (see Appendix 1) is a graph representing a normalized likelihood ratio (LR) as a function of the threshold in the level of per capita GDP based on the Fisher index (*FGDP*). As the Figure shows, the least square (LS) estimation of *γ* was 9.964 while the confidence interval was [9.916, 10.028]. These findings indicate that the threshold estimation was precise and the confidence interval was tight.

Table 1 (see Appendix 2) reports that there was a significant negative relationship between income level and fertility rate in the United States when the natural log of real per capita GDP based on the Laspeyres index was equal to or less than 10.011. On the other hand, standard of living and fertility rate in the country had a significant positive relationship when the natural log of real per capita GDP was greater than the threshold value. In other words, when real per capita GDP based on the Laspeyres index had reached US$22,267 the fertility decline reversed. This means that the fertility-development relationship in the United States became J-shaped.

As Table 2 (see Appendix 2) shows, per capita GDP and fertility rate in the United States had a negative relationship when the natural log of real per capita GDP based on the Fisher index was equal to or less than 9.965. On the other hand, when the natural log of real capita GDP was greater than the threshold value, the relationship between per capita GDP and fertility rate became positive. In other words, when real per capita GDP based on the Fisher index had approached US$21,264, the negative fertility-development relationship reversed to positive. The empirical findings on per capita GDP based on the Fisher index confirmed the findings on per capita GDP based on the Laspeyres index, which supports the existence of a J-shaped fertility-development relationship in the United States.

In short, the findings indicate that there was a statistically significant threshold in the fertility-development relationship. A significant reverse of the fertility decline occurred in the United States. Furthermore, the threshold value of real per capita GDP based on the Laspeyres index was US$22,267, while the one based on the Fisher index was US$21,264. These results indicate that the demographic transition or the reverse in the fertility decline occurred when real per capita GDP in the United States approached US$21,000-US$22,000 level. The empirical findings also indicate a significant negative relationship between per capita GDP and TFR when income level in the country was below the threshold value. This negative association between the two variables reversed to positive when income level exceeded the threshold value. These findings firmly establish the existence of a J-shaped development-fertility relationship in the United States.

4. Conclusion

The present paper aimed to empirically examine the fertility-development relationship in the United States, and employed a threshold regression analysis for this purpose. A justification for the choice of the United States as a case study is that it is the only developed country that has successfully recovered its fertility rate to the replacement rate of 2.1.

Empirical findings from the threshold regression analysis indicate that there existed a statistically significant threshold in the fertility-development relationship in the United States. This means that there had occurred a significant reverse in the country's plunging fertility rate. Furthermore, the threshold value of the real per capita GDP based on the Laspeyres index was US$22,267, while the real per capita GDP based on the Fisher index was US$21,264. These findings indicate that the fertility decline began to reverse when the real per capita GDP had approached US$21,000-US$22,000.

The empirical findings also indicate that there was a significant negative relationship between per capita GDP and TFR when income level in the United States was below the threshold value. However, this negative association reversed to a positive relationship when the country's per capita GDP was above the threshold value. The findings support the existence of a J-shaped development-fertility relationship in the United States.

As a conclusion, the findings of the present study suggest a possibility that advances in a country's economic development are able to reverse the declining fertility rate provided that income level in the country reaches a certain threshold. However, income level or standard of living is only one of many other interrelated factors that influence fertility rate. Not all countries that reach a threshold value would necessarily experience a reverse in the fertility rate. For example, a number of European countries and some Asian countries have a high per capita income but do not experience a reverse in the fertility rates. This is due to a complexity of the development-fertility relationship and the existence of numerous other factors that can affect the relationship between economic development and human fertility. Future studies need to explore what are the other factors that could stop and reverse fertility decline. Until more research is done on the J-shaped fertility-development relationship and a better understanding of a possible reverse in the global demographic trend is achieved, old assumptions on the fertility-development relationship might as well remain a guide to decision-makers in devising future policies.

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Appendices

Appendix 1

Figure 1: Total fertility rate (TFR) in the United States from 1960 to 2007

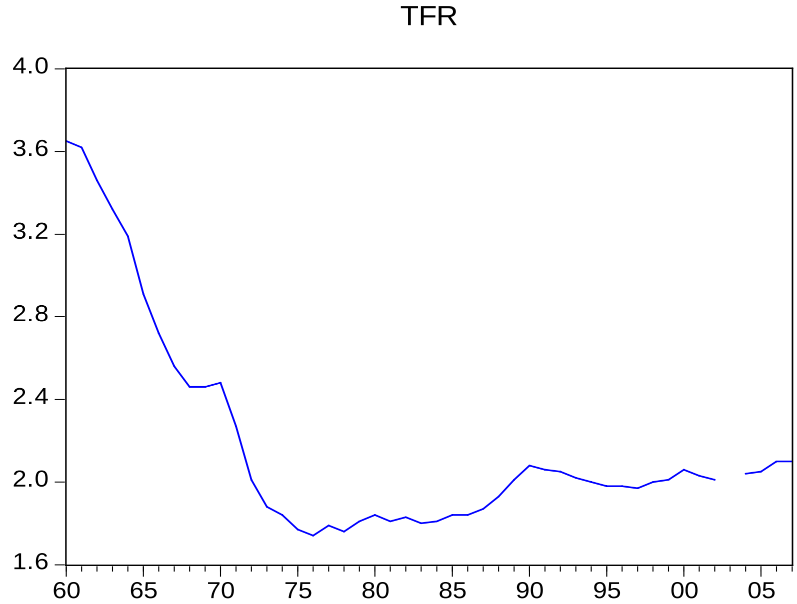
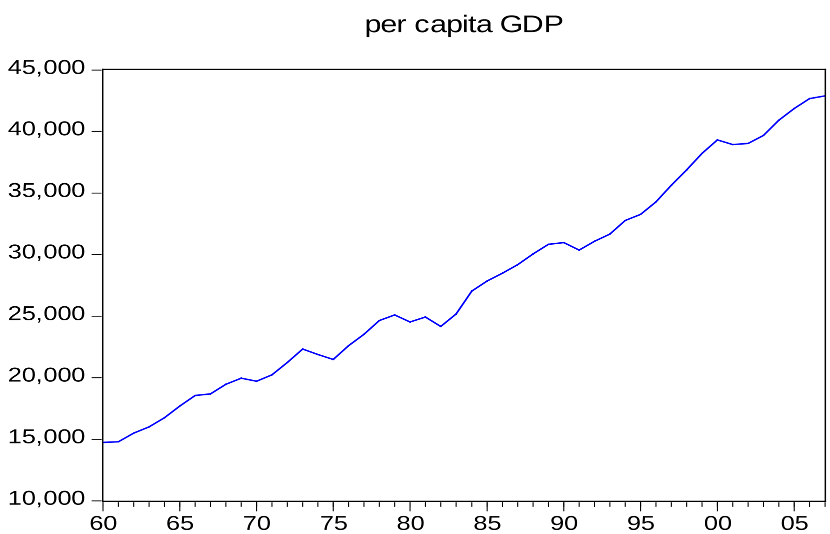


Figure 2: Per capita gross domestic product (GDP) in the United States from 1960 to 2007



Note: Data on total fertility rate were obtained from the World Bank (2010). Data on the per capita GDP were obtained from CICUP (2010).

Figure 3: Sample split based on *LGDP*

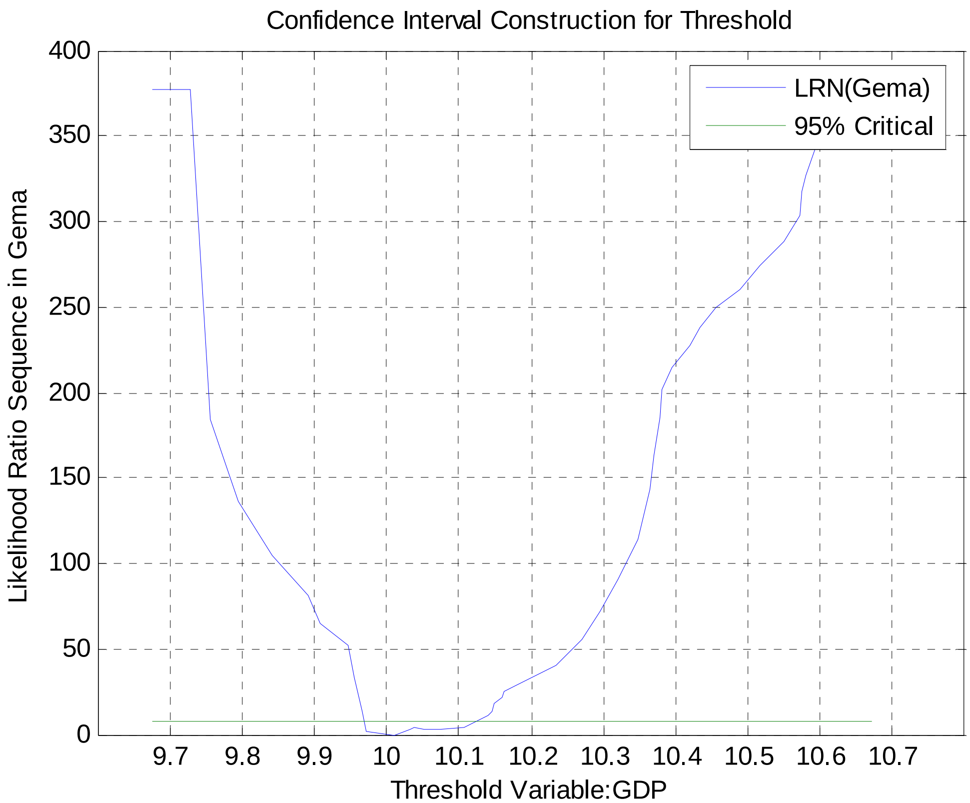
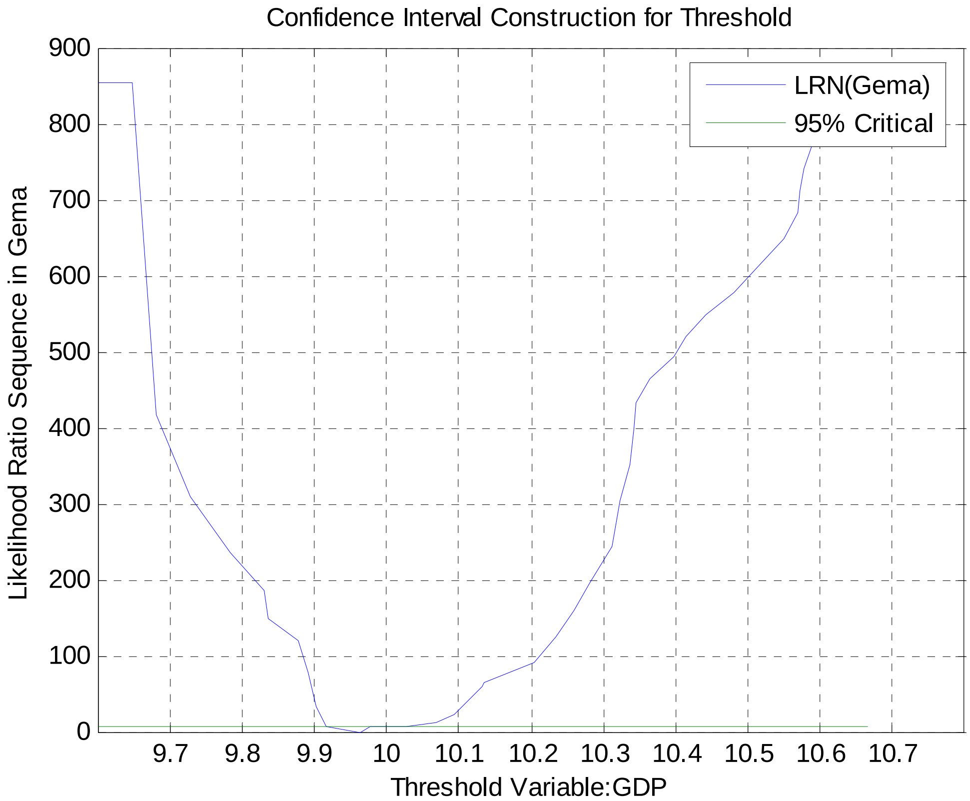


Figure 4: Sample split based on *FGDP*



Appendix 2

Table 1: Empirical results without and with threshold estimation (*LGDP*)

	Without threshold estimation	**With threshold estimations**	
		Regime 1 ($LGDP \leq 10.010$)	Regime 2 ($LGDP > 10.010$)
Constant	14.123** (6.828)	48.609** (29.675)	-3.289** (-6.588)
LGDP	-1.168** (-5.772)	-4.609** (-27.923)	0.504** (10.461)
R-squared	0.425	0.986	0.773
Adjusted R-squared	0.412	0.984	0.766
Number of observations	47	13	34

Figures in the parentheses indicate t-statistics
** indicates significance at 1% level
* indicates significance at 5% level

Table 2: Empirical results without and with threshold estimation (*FGDP*)

	Without threshold estimation	**With threshold estimations**	
		Regime 1 ($FGDP \leq 9.965$)	Regime 2 ($FGDP > 9.965$)
Constant	13.209** (6.942)	45.053** (33.0617)	-2.850** (-5.991)
FGDP	-1.083** (-5.795)	-8.072** (-12.354)	0.463** (10.055)
R-squared	0.427	0.988	0.759
Adjusted R-squared	0.414	0.987	0.752
Number of observations	47	13	34

Figures in parentheses indicate t-statistic
** indicates significance at 1% level
* indicates significance at 5% level