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IS THERE A REVERSAL IN FERTILITY DECLINE? AN ECONOMIC ANALYSIS OF THE "FERTILITY J-CURVE"

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ABSTRACT. ***This paper aims to examine whether there exists the J-shaped relationship between development and fertility or the 'Fertility J-curve'. In other words, this study attempts to detect a turning point that marks the reversal of fertility decline. For this purpose, it uses threshold regression analysis to assess the relationship between the Human Development Index (HDI) and the Total Fertility Rate (TFR) in 172 countries over the period 1980-2009. The findings indicate that in the countries with a relatively low HDI, the level of HDI and the TFR have had a strong negative or a steeper-sloped relationship. On the other hand, in the countries with a relatively high HDI, the relationship between the HDI level and the TFR has been seen as negative but weak or flatter-sloped. While these results do not provide a significant empirical support to the existence of the Fertility J-curve they indicate an interesting new trend in demographic transformation.***

KEYWORDS: fertility decline, human development, demographic transformation, development economics, quantitative analysis.

JEL classification: J1, O1.

Introduction

Changes in the demographic situation in any country have far-reaching consequences on its economy and society (Dyson, 2010). Research studies have reported a global trend of convergence towards low fertility even in the previously high-fertility countries (Bongaarts, Watkins, 1996; Hirschman, Guest 1990; Kohler *et al*., 2002). This means that the distinction between developing and developed countries is being erased in terms of fertility rates (Wilson, 2001). The global average of the total fertility rate (TFR) in the year 2005 was 2.33 births per woman; by the year 2020, it is expected to plunge below the replacement level of 2.1. Currently, approximately three billion people are living in the countries where fertility rate is at or below the replacement level of 2.1 births per woman (The Economist, 2009a).

From the economic perspective, demographic transformation from a high-fertility regime to a low-fertility regime reduces the production output, diminishes the demand for goods and services, impacts the price level, decreases the rate of labour force participation, and so on. Much attention has been paid in research literature to the weakening economic dynamics in advanced countries due to the plunging fertility rates. [1] If the countries with rapidly declining fertility take no measures to replenish the diminishing labour force they will be unable to maintain the previous levels of the national production output (Donaldson, 1991). More importantly, the demand side of the economy suffers no less dramatic consequences from fertility decline. The plunging fertility rates result in an ageing and eventually shrinking population. This leads to an imbalance between the stable production supply and the waning demand for the goods, which causes deflation and cripples the economy (Motani, 2011).

In a reciprocative manner, socio-economic factors influence fertility rate and it has been argued that socio-economic situation is the main underlying factor in fertility transition (Becker, 1960; Notestein, 1953). Researchers have observed that fertility begins to decline during the transformation from the traditional rural and agrarian society to the modern industrial society (Andorka, 1978; Notestein, 1953). In the 20th century, the remarkable advances in socio-economic situation in many countries around the world were accompanied by sharp declines of fertility. This change in the fertility regime can be considered as one of the most dramatic social transformations in human history.

For several decades, the existence of the negative relationship between fertility and socio-economic situation has been a widely-accepted 'empirical law' in the field of social sciences (Myrskylä *et al*., 2009). However, in 2009, Mikko Myrskylä and his research team published the article titled "Advances in Development Reverse Fertility Rate" which challenged the previously held assumptions. In their paper, the researchers reported that they had detected a fundamental change in the empirical law of the negative association between fertility and development. The main finding of the study was that in the developed countries with a high Human Development Index (HDI) further socio-economic advancements halt and eventually reverse the declining fertility rates. Moreover, Myrskylä *et al*. have identified a threshold between the demographic regimes, i.e., the fertility-decline regime and the fertility-progress regime. They proposed that the 0.9 level of the HDI denotes the demarcation between the two fertility regimes. According to the researchers, the development-fertility relationship is negative when a country's HDI level is below 0.9. However, when the HDI

[1] It should be noted that 'advanced country' is not an unambiguous term in demographic research because 'advance' from an economic perspective may not necessarily coincide with 'advance' from a demographic viewpoint (Andorka, 1978). In the present paper, 'advance' or 'advancement' means an enhancement of important socio-economic indicators, such as income, life expectancy, literacy, standards of living as reflected in the Human Development Index (HDI).

level surpasses the 0.9 mark, the development-fertility association reverses and becomes positive. In their paper, Myrskylä *et al*. (2009) suggested that, in fact, the relationship between economic development and fertility is not negative but J-curved.

Myrskylä *et al*.'s (2009) findings have attracted the attention of the mass media. A reputable international publication, *The Economist*, has boldly proclaimed that a rule of demography that people in rich countries tend to have fewer children no longer holds true as in two dozen countries with the HDI levels above 0.9 a remarkable thing happened when fertility decline was reversed and began approaching two births per woman. The journal even suggested that in view of this new discovery, the policy makers would need to change the assumptions they hold in present when devising their models for the future (The Economist, 2009b).

Considering the importance of the findings by Myrskylä *et al*. (2009) and their implications, the present paper aims to empirically examine the relationship between the Human Development Index (HDI) and the total fertility rate (TFR) in 172 countries over the period between 1980 and 2009. The present research uses threshold regression analysis to assess the J-shaped relationship between fertility and development, or the 'Fertility J-curve'. The main objective of this paper is to explore whether there is a statistically significant turning point that marks the reversal in fertility decline.

Following this introductory section, Section Two offers a brief review of the influential literature on the demographic issue whether the expanding population has a positive or a negative impact on the economic and social well-being. Section Three gives an overview of the theory of fertility decline and highlights the previous research studies that have estimated the threshold for the two demographic regimes. Section Four explains the data collection and the data analysis method employed in the present paper while Section Five reports the empirical findings. Chapter Six offers concluding remarks.

1. Population, Fertility and Development

Numerous research studies have been devoted to the demographic transformations and their impact on the economy and society. Initially, the focus of attention and the main concern was not the declining fertility rates but, on the contrary, the danger of overpopulation. Thomas Malthus (1766-1834) was the first person who expressed such concerns. In 1798, he published the seminal book "*An Essay on the Principle of Population and a Summary View of the Principles of Population"* where he warned about the consequences of the population expansion. Malthus' arguments were based on the 'law of diminishing returns' on a fixed amount of land. He claimed that when fertility rate was excessively high there existed a tendency for the population growth to surpass the production growth. Malthus further asserted that the population increases in a geometric progression while the production increases in an arithmetic one; he concluded that an unencumbered population growth caused by a high fertility rate would result in the acute poverty of the population.

Despite the fact that the Malthusian and Neo-Malthusian theories have been a subject to ardent criticisms, Malthus' ideas and views have attracted many followers over the centuries and they remain influential until the present time. In the year 1972, a group of economists and intellectuals known as the Club of Rome published the book entitled "*The Limits to Growth*". The main thesis of this volume was that some preventive measures aimed at decreasing high fertility rates in the developing countries were much needed in order to prevent imminent economic and social disasters caused by overpopulation (Meadows *et al*., 1972). In a similar vein, in 1973, Robert McNamara, who was at that time the President of the World Bank, warned that the 'population explosion' posed a serious threat to the humankind

(Buchholz, 1999). Under the leadership of Robert McNamara and A.W. Clausen, the World Bank, together with the United States Agency for International Development (USAID) had been the driving force behind various programs aimed at reducing high fertility rates in poor aid-recipient countries (Simon, 1987). Furthermore, some of the aid donor countries and international organisations demanded that the aid recipients implement population control programmes and decrease their fertility rate as a condition for the provision of economic assistance.

Several prominent economists and the Nobel Prize laureates, among them James Meade, Paul Samuelson, and Jan Tinbergen, share the pessimistic attitude towards the consequences of overpopulation. Meade (1961), for example, concluded his analysis of the demographic situation in Mauritius with the assertion that the high fertility rate and rapid expansion of population had been at the root of the country's economic woes, such as a growing unemployment and declining per capita income. He suggested that the Mauritius government should introduce appropriate family planning policies to prevent an impending economic and social disaster. In a similar vein, Samuelson (1975) asserted that population growth caused by a high fertility rate would exhaust the available resources due to the law of diminishing returns. To concur, Tinbergen (1975) has argued that Malthus' warnings should be taken seriously because an unregulated population growth constitutes a global threat to the humankind. He went on further to suggest that population control should be practiced not only in the developing countries where fertility rates were high but also in the developed countries with moderate fertility rates.

These alarmist views about a rapid population growth are not universally shared. Repetto (1985) has pointed out that many of the empirical studies that claimed that a rapid expansion of population impeded economic development were not reliable. This is because the statistical correlation between population expansion and economic growth in these studies did not address the causal relationship between the two (Repetto, 1985). Furthermore, a prominent population economist Julian Simon (1996) has regarded human capital as the crucial element for economic growth and the ultimate resource. He argued that population growth was beneficial for the economic development because skilled and hopeful people would exert their will and imaginations for their economic benefit and as a result of their efforts the whole society would benefit (Simon, 1996). Simon described population control programs as downright harmful. He argued that some aspects of US Foreign Aid Programmes aimed at family planning were wasteful because these programs distracted from addressing other important economic and social issues in the aid-receiving countries (Simon, 1987).

2. Fertility Decline and Reversal: The "Fertility J-curve"

Myrskylä *et al*. (2009) have argued that the remarkable progress in social and economic development in many countries during the 20th century was accompanied by a decline in fertility rate. To concur, Doepke (2004) has asserted that fertility decline is a universal trend and that every industrialized country undergoes a demographic transition from a high to a low fertility. The negative association between human fertility and socio-economic development has been an established and widely-accepted view in social sciences. However, there is no consensus among the researchers as to how or why this fertility decline occurs. This can be partially attributed to methodological difference in demographic and economic research and also to a fact that demographic and economic transformations are examined in isolation (Doepke, 2004). Through a deductive approach demographers tend to focus on identifying various socio-economic and demographic determinants of fertility decline.

Economists, on the other hand, prefer to explore macroeconomic factors and they use abstract economic models to deductively establish the reasons for the plunging fertility rates.

Another difference in approaches between demographic and economic research studies is that the former use demographic data to detect the underlying structures and patterns of demographic transformation. They place emphasis on the complexity of a demographic system that undergoes fertility transition. By contrast, economists begin their analysis with some ready assumptions and they proceed to explain various demographic phenomena theoretically. In economic research, complex elaborations not based on the actual data are avoided. Due to these differences in research methods, demographers often question the depth of the analysis and the validity of the findings reported in economic research studies. Economists, among them Bryant (2007), argue in response that economic theories are indeed applicable to the demographic data and that they are able to explain demographic transitions better than it is generally believed. Bryant (2007) has pointed out that the relationship between fertility rate and the development indicators is strong enough and that a simple statistical model based on the development indicators can predict transitions in fertility for many countries.

The basic economic hypothesis to explain fertility decline is the existence of a trade-off relationship between the quantity and the 'quality' of children.[2] Nobel Prize laureate Gary Becker who published his influential paper "An economic analysis of fertility" in 1960 was among the first researchers to look at the importance of the 'quality' of children. Becker (1960) viewed the relationship between human fertility and economic development from the perspective of utility maximization. He pointed out that utility-maximization decisions made by the parents take into account not only the number of the children but also their 'quality', which is strongly influenced by education that the children receive.

The first systematic formal analysis of the interaction between the quantity and the quality of children was carried out one decade later by Becker and Lewis (Currais, 2000). According to Becker and Lewis (1973), decline of human fertility can be explained by a trade-off relationship between the quantity and the quality of children. In other words, there is a negative correlation between the number (or quantity) of children and their 'quality' as perceived by the others. The parents maximize their utility subject to the budget constraints, and the function can be expressed as

$$\text{Max } U = U(n, q, y) \qquad (1)$$

where: U is the parental utility function, n is the number of children, q is the quality of children or the human-capital aspect of each child, and y is the consumption.

The budget constraints can be expressed as

$$I = nq\pi + y\pi_y \qquad (2)$$

where: I is the income, π is the price of nq, and π_y is the price of y.

As follows from these formulas, an increase in the quality of children would be more costly to the parents who have more children. This is because an 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 whose children are of a higher 'quality' because they cost more to the parents. Becker, Tomes (1976) have argued that in a prosperous economy the demand for the population quality will grow. This will lead to a reduction in the population

[2] In a later study, Becker, Glaeser, Murphy (1999) viewed the 'quality' as the human capital aspect of a child.

quantity and in a long run the quality of population, or human capital will become a substitute to its quantity. To respond to the new economic reality and social demands, people will choose to have fewer children but they will try to enhance their 'quality' by giving the children better education.

For several decades, such theories formed the core of the fertility-development discourse and they provided a satisfactory explanation for the plunging fertility rates in the developed countries. However, recently, these entrenched assumptions have been challenged. Myrskylä *et al*. (2009) have detected a major shift in the negative relationship between human fertility and economic development, which can be described as the 'Fertility J-curve'. According to their findings, the development-fertility relationship is negative when the Human Development Index (HDI) is below the range of 0.85-0.9. But when the HDI surpasses the 0.9 level, as it has recently happened in some developed countries, the development-fertility association reverses to a positive one. In other words, there exists a threshold value, such as the HDI value of 0.9, which demarcates the two demographic regimes (i.e. the fertility-decline regime and the fertility-progress regime). The significance of Myrskylä *et al*. (2009) finding is that a basic demographic maxim that people in the rich countries tend to have fewer children has lost its validity.

Subsequent to the ground-breaking study by Myrskylä *et al*. (2009), Furuoka (2009) retested the existence of the fertility J-curve using the same data. His study did not detect a statistically significant threshold value or the 'Fertility J-curve' to demarcate the two fertility regimes. Furuoka's (2009) findings, however, did indicate that in the countries with a low HDI, higher levels of the HDI tended to be associated with lower fertility rates. Likewise, in the countries with a high HDI, higher levels of the HDI were associated with lower fertility rates, but the relationship was not statistically significant. Some interesting findings were reported in the following research study, however, when Furuoka (2010) examined the relationship between the total fertility rate and GDP per capita in the context of the United States. The results indicated a statistically significant threshold in the fertility-development relationship and a reverse in the fertility decline. In other words, in the case of the United States the findings validated the existence of the fertility J-curve. The results indicated that the threshold value of real GDP per capita based on the Laspeyres index was I$22,267, while the threshold value of real GDP per capita based on the Fisher index was I$21,264 (Furuoka, 2010)[3]. These findings suggest that fertility decline could be reversed when income reaches I$21,000-I$22,000 per capita. At the same time, the analysis detected a significant negative relationship between GDP per capita and the total fertility rate when the income level in the USA was below the threshold value; this negative association between GDP per capita and the TFR reversed to a positive one when the income level began exceeding the threshold value.

3. Research Method and Data

This study examines the relationship between the human development index (HDI) and the total fertility rate (TFR) in 172 countries over the period between 1980 and 2009. The source of the data on the Human Development Index (HDI) is the United Nations Development Program (UNDP, 2012). The data on Total Fertility Rate (TFR) are acquired from the World Bank (2012). It should be noted that between 1980 and 2000, the data on the HDI were reported at a five-year intervals (i.e. the data is available for the years 1980, 1985, 1990, 1995, and 2000). From 2005 until 2009, the annual data on the HDI were provided. The

[3] The "I$" sign stands for "International Dollar", a hypothetical currency used in the Penn World Table. The "I$" has equal purchasing power with the US Dollar.

present paper examines the relationship between the HDI and the TFR only for the years with the available data on the HDI.

Bruce Hansen's threshold regression method is used in this study to identify the exact value of the threshold for the J-shaped relationship between fertility and development or the 'Fertility J-curve'.[4] Hansen (2000) has developed a highly functional empirical test for the threshold effect that allows constructing asymptotic confidence intervals for the threshold parameter. According to Hansen, an exogenously given variable, which is called "the threshold variable", is used to split the sample into two regimes. In the present study, the HDI level is used as the threshold variable to split the countries in the data into two demographic regimes. The first demographic regime (Fertility Regime 1) includes the countries with a low HDI. In these countries, the HDI level is equal to or lower than the threshold value. The second demographic regime (Fertility Regime 2) comprises the countries with a high HDI, i.e. where the HDI level is greater than the threshold value.

4. Empirical Findings

As the first step, this study employed the Ordinary Least Squares (OLS) test to examine the development-fertility relationship without the threshold. As *Table 1* reports, there existed a significant negative relationship between the HDI and the TFR in the period from 1980 to2000, which means that the fertility rates were declining. It is interesting to note that the slope coefficient was -9.052 in the year 1980, and it gradually decreased to-7.969 in 2000. This result indicates that fertility declined at a faster pace in the 1980s compared to the 2000s. On average, in the 1980s, an increase of 0.1 point in the HDI was accompanied by a decrease of 0.91 point in the TFR. By contrast, in the 2000s, an increase of 0.1 point in the HDI coincided with an approximately 0.8 point decrease in the TFR.

Table 2 reports the findings on the fertility-development relationship over the period 2005-2009. The results indicate the presence of a negative relationship between fertility and socio-economic development, which means that socio-economic advancements were accompanied by fertility decline. In 2005, the slope coefficient was -7.571, and it decreased to -6.970 in 2009. The results also indicate that the TFR decline was slower between 2005 and 2009. Thus, in 2005, an increase of 0.1 point in the HDI value coincided with a decrease of 0.76 point in the TFR. However, in 2009, the same increase of 0.1 point in the HDI was accompanied by a smaller decline of 0.7 point in the TFR.

Table 1. OLS analysis without threshold, 1980-2000

	1980	*1985*	*1990*	*1995*	*2000*
Constant	9.388*** (0.342)	9.315*** (0.323)	8.774*** (0.278)	8.351*** (0.266)	8.105*** (0.244)
HDI	-9.052*** (0.610)	-9.168** (0.556)	-8.535*** (0.460)	-0.278*** (0.425)	-7.969*** (0.381)
R-squared	0.679	0.707	0.739	0.738	0.746
Number of Observations	106	114	123	136	150

Notes: Figures in the round brackets under the slope coefficients indicate standard errors.
*** indicates significance at 1% level
** indicates significance at 5% level
* indicates significance at 10% level

Source: own calculations.

[4] For a detailed explanation of Hansen's method adopted in this study see Appendix I.

Table 2. OLS analysis without threshold, 2005-2009

	2005	*2006*	*2007*	*2008*	*2009*
Constant	7.829*** (0.225)	7.735*** (0.225)	7.649*** (0.225)	7.536*** (0.228)	7.461*** (0.229)
HDI	-7.571*** (0.342)	-7.406*** (0.338)	-7.247*** (0.336)	-7.059*** (0.338)	-6.970*** (0.339)
R-squared	0.742	0.737	0.731	0.719	0.714
Number of Observations	172	172	172	172	171

Notes: Figures in the round brackets under the slope coefficients indicate standard errors. *** indicates significance at 1% level; ** indicates significance at 5% level; * indicates significance at 10% level.

Source: own calculations.

Table 3. Threshold regression analysis, 1980-2000

1980	**Threshold Value** 0.688** [0.174, 0.850]	
	Demographic Regime 1 ($HDI \leq 0.688$)	*Demographic Regime 2* ($HDI < 0.688$)
Constant	8.565*** (0.437)	6.790** (3.130)
HDI	-6.907*** (0.927)	-6.144 (4.132)
R-squared	0.421	0.078
Number of Observations	78	28
1985	**Threshold Value** 0.668 [0.178, 0.859]	
	Demographic Regime 1 ($HDI \leq 0.668$)	*Demographic Regime 2* ($HDI > 0.668$)
Constant	8.672*** (0.447)	6.883*** (2.237)
HDI	-7.525*** (0.935)	-6.274** (2.950)
R-squared	0.459	0.117
Number of Observations	78	36
1990	**Threshold Value** 0.697 [0.697, 0.697]	
	Demographic Regime 1 ($HDI \leq 0.697$)	*Demographic Regime 2* ($HDI > 0.697$)
Constant	8.535*** (0.389)	3.833** (1.629)
HDI	-7.901*** (0.768)	-2.357 (2.095)
R-squared	0.562	0.033
Number of Observations	84	39
1995	**Threshold Value** 0.674** [0.322, 0.822]	
	Demographic Regime 1 ($HDI \leq 0.674$)	*Demographic Regime 2* ($HDI > 0.674$)
Constant	8.831*** (0.379)	4.224*** (1.307)
HDI	-9.306*** (0.743)	-2.934* (1.669)
R-squared	0.653	0.059
Number of Observations	85	51
2000	**Threshold Value** 0.527*** [0.527, 0.527]	
	Demographic Regime 1 ($HDI \leq 0.527$)	*Demographic Regime 2* ($HDI > 0.527$)
Constant	8.951*** (0.637)	5.494*** (0.515)
HDI	-9.664*** (1.618)	-4.485*** (0.707)
R-squared	0.431	0.289
Number of Observations	49	101

Notes: Figures in the round brackets under the slope coefficients indicate standard errors. Figures in the square brackets next to the threshold values indicate confidence interval. *** indicates significance at 1% level; ** indicates significance at 5% level; * indicates significance at 10% level.

Source: own calculations.

In the second step of the analysis, this study employed the heteroskedasticity known as consistent Lagrange multiplier (LM) test to examine whether there was a sample split based on the HDI level. As *Table 3* shows, upon running 1000 bootstrap replications for the period 1980-2000, the LM test strongly rejected the null hypothesis of no-threshold for three years, namely, the years 1980, 1995, and 2000. At the same time, the LM test failed to reject the null hypothesis of no-threshold for two years (i.e., 1985 and 1990). These findings suggest the presence of a sample split based on the HDI level in the beginning of 1980s, and also in the period from the mid-1990s to the beginning of the 2000s. On the other hand, there occurred no significant demographic transformation in the period from the mid-1980s to the early 1990s.

The findings indicate a possibility of a demographic regime change during this period but the change was not statistically significant. It is interesting to note that upon running 1000 bootstrap replications for the period 2005-2009, the LM test strongly rejected the null hypothesis of no-threshold for each of the five years (i.e., 2005, 2006, 2007, 2008 and 2009) (see *Table 4*). These findings indicate that there could be a significant sample-split based on the HDI value between the mid- and the late-2000s, which means that there occurred a significant demographic transformation during this period.

As the third step, this study used the likelihood ratio (LR) test to detect the threshold value and to construct the confidence intervals. The results reported in *Table 3* suggest that, in 1980, there was a significant demographic regime change when the HDI was 0.688, and the confidence interval was [0.174, 0.850]. There also occurred a demographic regime change in 1995, when the HDI level was 0.674 and the confidence interval was narrower at [0.322, 0.822]. By contrast, the threshold value decreased to 0.527 in 2000, and the confidence interval became very tight at [0.527, 0.527].

The findings reported in *Table 4* indicate that there was a transformation in the demographic regime in the year 2005, when the HDI reached 0.702, and the confidence interval was very tight at [0.702, 0.703]. In 2006, the threshold value slightly increased to 0.706, and the confidence interval widened to [0.557, 0.798]. In the following year, there occurred another significant demographic regime transformation with the HDI 0.704, and a narrower confidence interval [0.698, 0.819]. In 2008, the threshold value increased slightly to 0.714, and the confidence interval was [0.568, 0.804]. However, in 2009, the threshold value decreased to 0.562, and the confidence interval widened [0.534, 0.837].

According to the results reported in Table 3, in the year 1980, there existed a strong, negative, and statistically significant relationship between fertility and development in the countries with a relatively low HDI (Fertility Regime 1). At the same time, in the countries with a relatively high HDI (Fertility Regime 2) the relationship between fertility and development was strong and negative but not statistically significant. Interestingly, in the years 1995 and 2000, the empirical analysis detected a strong, negative, and statistically significant relationship between the HDI and the TFR in the countries with a relatively low HDI (Fertility Regime 1) and also in the countries with a relatively high HDI (Fertility Regime 2). This suggests that a demographic transformation was taking place in both Fertility Regime 1 and Fertility Regime 2 countries. However, fertility decline in Fertility Regime 2 countries was much smaller compared to that in Fertility Regime 1 countries. In 1995, the slope coefficient in Fertility Regime 1 countries was -9.306, while in Fertility Regime 2 countries it was -2.934. This means that, on average, in Fertility Regime 1 countries an increase of 0.1 in the HDI level was accompanied by a decrease of 0.93 in the TFR. In Fertility Regime 2 countries, an increase in the HDI level by 0.1 point was matched by a decrease of 0.29 in the TFR.

Furthermore, in 2000, the slope coefficient for Fertility Regime 1 countries became -9.664 while in Fertility Regime 2 it was -4.485. This means that in the countries with a relatively low HDI (Fertility Regime 1), an increase of 0.1 point in the HDI level was accompanied by a decrease of 0.97 point in the TFR. In the countries with a relatively high HDI (Fertility Regime 2), an increase of 0.1 point in the HDI level coincided with a decrease of only 0.45 point in the TFR.

Table 4. Threshold regression analysis, 2005-2009

2005	**Threshold Value** 0.702*** [0.702, 0.703]	
	Demographic Regime 1 $(HDI \leq 0.702)$	*Demographic Regime 2* $(HDI > 0.702)$
Constant	8.497*** (0.356)	2.548*** (0.708)
HDI	-8.884*** (0.671)	-1.004 (0.876)
R-squared	0.639	0.018
Number of Observations	101	71
2006	**Threshold Value** 0.706*** [0.557, 0.798]	
	Demographic Regime 1 $(HDI \leq 0.706)$	*Demographic Regime 2* $(HDI > 0.706)$
Constant	8.441*** (0.360)	2.539*** (0.689)
HDI	-8.787*** (0.673)	-0.966 (0.848)
R-squared	0.634	0.018
Number of Observations	100	72
2007	**Threshold Value** 0.704*** [0.698, 0.819]	
	Demographic Regime 1 $(HDI \leq 0.704)$	*Demographic Regime 2* $(HDI > 0.704)$
Constant	8.381*** (0.371)	2.573*** (0.667)
HDI	-8.668*** (0.689)	-0.978 (0.819)
R-squared	0.622	0.019
Number of Observations	98	74
2008	**Threshold Value** 0.714*** [0.568, 0.804]	
	Demographic Regime 1 $(HDI \leq 0.714)$	*Demographic Regime 2* $(HDI > 0.714)$
Constant	8.277*** (0.378)	2.486*** (0.663)
HDI	-8.489*** (0.695)	-0.843 (0.811)
R-squared	0.607	0.014
Number of Observations	98	74
2009	**Threshold Value** 0.562*** [0.534, 0.837]	
	Demographic Regime 1 $(HDI \leq 0.562)$	*Demographic Regime 2* $(HDI > 0.562)$
Constant	8.023*** (0.781)	4.855*** (0.407)
HDI	-7.847*** (1.776)	-3.644*** (0.533)
R-squared	0.269	0.290
Number of Observations	55	116

Notes: Figures in the round brackets under the slope coefficients indicate standard errors. Figures in the square brackets next to the threshold values indicate confidence interval. *** indicates significance at 1% level; ** indicates significance at 5% level; * indicates significance at 10% level.

Source: own calculations.

Table 4 shows that between 2005 and 2008, there existed a strong, negative and statistically significant relationship between fertility and development in Fertility Regime 1 countries. In Fertility Regime 2 countries the relationship was negative but not statistically significant. Only in the year 2009, the relationship between fertility and development in both Fertility Regime 1 and Fertility Regime 2 countries was strong, negative, and statistically significant. As the results show, in 2009, the slope coefficient was -7.847 in Fertility Regime 1 countries and -3.644 in Fertility Regime 2 countries. In the countries with a relatively low HDI (Fertility Regime 1), an increase of 0.1 point in the HDI level was accompanied by a decrease of 0.78 point in the TFR. At the same time, in the countries with a relatively high HDI (Fertility Regime 2), an increase of 0.1. point in the HDI level was matched by a decrease by only 0.36 point in the TFR.

The most important finding revealed by the threshold regression analysis conducted in this study is that in the countries with a relatively low HDI, the HDI level and fertility had a strong negative or a steeper-sloped relationship. On the other hand, in the countries with a relatively high HDI this relationship was negative but weak or flatter-sloped. In short, the empirical findings of the present study clearly indicate that a negative association between the HDI and fertility existed in the countries with a lower HDI level. In the countries with a higher HDI level, the relationship between the two variables was also negative but weak. The absence of the positive relationship between the HDI and the TFR does not support the proposition of the existence of the 'Fertility J-curve', in which case there should be a significant threshold value that marks the reversal in fertility decline.

Conclusions

This paper aims to empirically examine the existence of the 'Fertility J-curve' detected by Myrskylä *et al*. (2009) who asserted that advances in socio-economic development bring on a reversal in fertility decline. The present study employs a threshold regression analysis to assess the relationship between the Human Development Index (HDI) and the Total Fertility Rate (TFR) in 172 countries over the period 1980-2009.

As the findings indicate, in the countries with a relatively low human development index, higher levels of the HDI are tended to be associated with lower fertility rates. Likewise, in the countries with a relatively high human development index, higher levels of the HDI have been matched by lower fertility rates though the relationship was weak. In other words, in both Fertility Regime 1 and Fertility Regime 2 countries, there was detected a weak negative, not *positive*, relationship between socio-economic advancements and fertility.

In conclusion, the empirical findings of the present study do not support the proposition that socio-economic advancements are able to reverse fertility decline. Despite a fact that the findings did not detect a reversal in fertility decline some interesting trends transpired in the course of the analysis. Among them is a weaker negative relationship between socio-economic development and fertility in the more advanced countries, which indicates a slower pace of demographic transformation and a less steep fertility decline. This finding could merit further scrutiny of the relationship between socio-economic advancement and fertility from economic and demographic researchers. This study uses cross-sectional data. Future research studies may want to use different approaches, such as time-series or panel data method to examine the intriguing hypothesis of the existence of the fertility J-curve.

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AR PASTEBIMA GIMSTAMUMO MAŽĖJIMO KAITA? EKONOMINĖ J-KREIVĖS ANALIZĖ

Fumitaka Furuoka

SANTRAUKA

Šiame straipsnyje siekiama nustatyti, ar yra ryšys tarp plėtros ir gimstamumo, kuris sudarytų J-formos kreivę. Kitaip tariant, siekiama nustatyti lūžio tašką, žymintį gimstamumo mažėjimo pokyčius. Norint įvertinti žmogaus socialinės raidos indekso (ŽSRI) ir suminio gimstamumo rodiklio (SGR) ryšį 172 šalyse nuo 1980 iki 2000 metų, taikoma pereinamoji regresinė analizė. Tyrimai rodo, kad šalyse, kuriose ŽSRI yra žemas, ryšys tarp ŽSRI ir SGR lygių buvo itin neigiamas arba itin nuožulnus. Kita vertus, šalyse, kuriose ŽSRI yra palyginti aukštas, santykis tarp ŽSRI ir SGR buvo nežymiai neigiamas arba mažiau nuožulnus. Nors šie rezultatai nėra itin svarbūs J-formos kreivės esatį rodantys empiriniai įrodymai, jie rodo įdomią naują demografinės kaitos tendenciją.

REIKŠMINIAI ŽODŽIAI: gimstamumo mažėjimas, žmogaus socialinė raida, demografinis pokytis, ekonomikos plėtra, kiekybinė analizė.

Appendix I

Detailed description of the statistical method: Hansen's threshold regression method

Hansen's threshold estimation is based on two-regime structural equations 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 the threshold value, *y* is the dependent variable, *x* is the independent variable, *q* is the threshold variable, *θ* is the slope coefficient, and *e* is the error term.

Because the threshold value is unknown *a priori,* it should be estimated in addition to the 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 this paper, the OLS regression without threshold can be expressed as:

$$TFR_i = \beta_0 + \beta_1 HDI_i + \varepsilon \qquad (3)$$

where β_0 is the intercept, β_1 is the slope coefficient, *ε* is the error term; TFR_i is the total fertility rate over the period 1980-2009 in the country *i*; HDI_i is the human development index in the country *i* over the period 1980-2009.

The threshold regression can be expressed as:

$$TFR_i = (\beta_{10} + \beta_{11} HDI_i) d\{HDI_i \le \gamma\} + (\beta_{20} + \beta_{21} HDI_i) d\{HDI_i > \gamma\} + \varepsilon \qquad (4)$$

where $d\{.\}$ is the indicator function; $d\{HDI_i \le \gamma\}$ equals to 1, and $d\{HDI_i > \gamma\}$ equals to 0 if HDI_i is equal to or less than the threshold value, which indicates a regression estimate of 'Fertility Regime 1'. On the other hand, $d\{HDI_i \le \gamma\}$ equals to 0, and $d\{HDI_i > \gamma\}$ equals to 1 if HDI_i is greater than the threshold value, which indicates a regression estimate of the 'Fertility Regime 2'.

Hansen's threshold regression analysis consists of three steps. As the first step this study examines whether there is a threshold effect in equation 4. The threshold effect is defined as the difference in the slope coefficients between the first and the second regimes (Hansen, 1997). The null hypothesis is that there is no threshold or no difference in the slope coefficients between the two regimes. The heteroskedasticity-consistent Lagrange multiplier (LM) test can be used to test this hypothesis (Hansen, 1996).

The second step estimates the threshold value. According to Hansen (1997), an appropriate estimation method for this purpose is the Least Squares (LS). The LS estimation of *γ* is the value that minimizes the residual variance as

$$\hat{\sigma}_n^{\,2}(\gamma) = \frac{1}{n}\sum_{i=1}^{n} \hat{e}_i(\gamma)^2 \qquad (5)$$

where *n* is number of observations, and *e* is the residual.

As the third step, this study proceeds to form a confidence level for *γ*. According to Hansen (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 a poor finite sample behavior; 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*.