Analyses & Alternatives 2023 7(2): 035-077
DOI: 10.22931/aanda.2023.7.2.002

Compressed Demographic Transition and Economic Growth in the Latecomer

Inyong Shin* · Hyunho Kim**

Asia University, Chonnam National University

Abstract

This study aims to solve the entangled loop between demographic transition (DT) and economic growth by analyzing cross-country data. We undertake a national-level group analysis to verify the compressed transition of demographic variables over time. Assuming that the *LA (latecomer advantage) on DT over time* exists, we verify that the DT of the latecomer is compressed by providing a formal proof of *LA on DT over income*. As a DT has the double-kinked functions of income, we check them in multiple aspects: early maturation, leftward threshold, and steeper descent under a contour map and econometric methods. We find that the developing countries (the latecomer) have speedy DT (CDT, compressed DT) as well as speedy income such that DT of the latecomers starts at lower levels of income, lasts for a shorter period, and finishes at the earlier stage of economic development compared to that of developed countries (the early mover). To check the balance of DT, we classify countries into four groups of DT---balanced, slow, unilateral, and rapid transition countries. We identify that the main causes of rapid transition are due to the strong family planning programs of the government. Finally, we check the effect of latecomer's CDT on economic growth inversely: we undertake the simulation of the CDT effect on economic growth and the aging process for the latecomer. A worrying result is that the CDT of the latecomer shows a sharp upturn of the working-age population, followed by a sharp downturn in a short period. Compared to early-mover countries, the latecomer countries cannot buy more time to accommodate the workable population

* Department of Economics, Asia University, 5-24-10 Sakai Musashino. Tokyo 180-8629, Japan. Email: shin@asia-u.ac.jp (the first author)
** Department of Economics, Chonnam National University, 77 Yongbong-ro Buk-gu. Gwangju 61186, Korea. Email: hyunkim@jnu.ac.kr (Corresponding author)

www.kci.go.kr

for the period of demographic bonus and prepare their aging societies for demographic onus. Thus, we conclude that CDT is not necessarily advantageous to developing countries. These outcomes of the latecomer's CDT can be re-interpreted as follows. Developing countries need power sources to pump up economic development, such as the following production factors: labor, physical and financial capital, and economic systems. As for labor, the properties of early maturation and leftward thresholds on DTs of the latecomer mean that demographic movement occurs at an unusually early stage of economic development; this is similar to a plane that leaks fuel before or just before take-off, with the result that it no longer flies higher or farther. What is worse, the property of steeper descent represents the falling speed of a plane so that it cannot be sustained at higher levels, and then plummets to all-time lows.

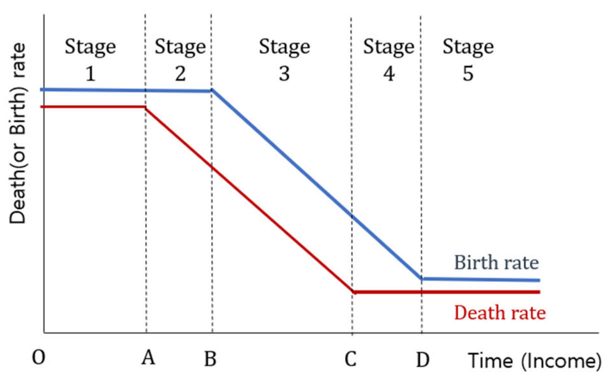
Keywords
Demographic transition, Latecomer's advantage, Economic growth, Change-point model, Hierarchical Bayesian method

www.kci.go.kr

Ⅰ. Introduction

We focus on the change of demographic variables for several reasons: First, it contains rich data to be analyzed and many parts that are still not specifically identified and verified through data analysis. Second, demographic transition (DT) is a long-term issue that is more fundamental since the collapse of balanced population distribution is a more terrifying and essential issue for future generations in terms of shaking the foundations of the population structure and imposing huge burdens, such as smaller working-age groups and higher aging populations in the long term.[1]

<Figure 1. Concept of DT>



Source: Shin & Kim(2020)

The literature presents numerous studies on the issue, and hence, we arrange them in accordance with the related sub-themes: DT, latecomer's advantage, compressed DT, and demographic bonus or onus. Let us start by considering DT itself. DT refers to the transition from high death and high birth rates to low death and low birth rates as a country develops from a pre-industrial to an industrialized economic system.[2] Such a DT is

[1] We propose considering the other issues mentioned above as a series of research themes with respect to rapid growth in a future study.

[2] This is based on the interpretation of demographic history developed by the American demographer

www.kci.go.kr

usually described by the relationship between two variables, death (or birth) rate as a demographic variable and time flow as an economic variable, that is, *DT over time*. Figure 1 suggests the conceptual graph of DT, which can be divided more specifically into five stages: stage 1 indicates the pre-industrial society period when the death and birth rates are high and roughly in balance so that population growth is typically very low. In stage 2, most developing countries experience first a rapid drop in death rates due to improvement in food supply, sanitation technology, education, etc. With no corresponding fall in birth rates, countries in this stage experience a population explosion. In stage 3, birth rates start to fall from access to contraception, urbanization, an increase in status and education of women, reduction in the value of child labor, etc. Thus, population growth begins to level off in this stage. In stage 4, death rates fall to a low level of convergence while birth rates continue to drop. Finally, in stage 5, the industrialized economic system leads to population stabilization with low death and birth rates. Therefore, most developed countries are in stage 4 or 5, the majority of developing countries are in stage 2 or 3, and the remainder are poor countries still in stage 1.

DT is the composite transition of death and birth rates over time (or income) and previous studies can be summarized according to both variables. With regard to the drop of death rates as the economy develops, they can be classified into three forces (Cutler et al., 2006; Tekce, 1985; Weil, 2013): (i) improvement in living standards, such as nutrient levels, public health equipment, housing equipment (e.g., accessibility to safe water), and sanitary practices (e.g., washing hands); (ii) improvement in medical sources, such as vaccination and medical treatments; and (iii) changes in social status, such as a mother’s academic level and the householder's occupation. On the other hand, we can categorize the literature on the fall of birth rate into the following five trends. (i) Increased availability of contraceptives through improvement of birth control technology and family planning

Warren Thompson (Thompson, 1929). This belief has been referred to as demographic transition theory, by which fertility decline and population stabilization occur as a natural consequence of socio-economic modernization (Kirk, 1996). Moreover, Weber (2010) and Galor (2011) provide details of the survey on DT.

www.kci.go.kr

programs: while developed countries showed a major decline in birth rates before the prevalence of modern contraception, the decline of birth rates in developing countries (from the early 1960s to the 1990s) coincides with family planning programs that usually practice some form of modern contraception methods.[3] (ii) Effect of mortality reduction: as the decline of the death rate precedes that of the birth rate, parents start to control their fertility in order to care for a fixed number of surviving children; that is, a drop in the mortality rate eliminates the need for higher fertility (Weil, 2013). (iii) Higher substitution effects compared to income effects: as the wages of women increase, the feasibility of having more children as a normal good increases, but the opportunity cost of childcare increases as well. Such conflicting effects indicate that substitution effects are higher than income effects and are reinforced by the education of women (Galor&Weil, 1996).[4] (iv) Decreasing reliance of parents on children as an old-age resource: while in the pre-industrialization period, parents depended for their old-age resources on the labor of children and their portfolios by spreading out their risk with many children, as the country develops, they can support their old age from the development of financial markets and government programs, such as social security. Finally, (v) trade-offs between quality and quantity of children: as the cost of raising children increases and the status and education of women improve, parents try to gain security by concentrating their resources on only a few children, etc.[5]

Now, let us consider the literature on DT combining the transitions of death and birth rates. Most researchers on DT deal with fairly long-term data of a specific country or

[3] Between the early 1960s and 1998, the rate of contraceptive prevalence, or the proportion of married couples aged 15-49 years practicing some form of contraception in the developing world rose from 9% to 55%. The program explains 10-40% of the decline in fertility in developing countries (Keyfitz, 1989; Sadik, 1991; United Nations, 2011).

[4] Some studies report that an increase in income leads to a fertility increase (Doepke, 2005; Fernandez-Villaverde, 2001; Murphy, 2015)

[5] Numerous theoretical studies have examined the decline in the birth rate using different methodologies: Becker (1960), Easterlin (1966), and Nerlove et al. (1978) are static studies, whereas dynamic studies include Barro and Becker (1989), Becker and Barro (1988), Becker et al. (1990), Benhabib and Nishimura (1989), Dahan and Tsiddon (1998), Galor and Weil (1996), Kremer (1993), Lapan and Enders (1990), and Qi and Kanaya (2010).

www.kci.go.kr

region on different time sequences: Doepke (2005) considers United Kingdom data covering about a century (1861 to 1951). Vallin (1991) presents English, French, Finnish, and Norwegian mortality-rate charts based on data up to 1720. In the monitoring document of the World Economy 1820--1992, Maddison (2001) provides some pictures and tables of mortality and fertility experiences of most regions of Western Europe. In addition, Galor (2011) describes the DTs of different regions using different time tables---European countries experienced a decline in population growth from the end of the 19th century to the beginning of the 20th century, whereas Latin American and Asian countries experienced such a decline during the last decades of the 20th century. With regard to Africa, even with a rising population growth rate, the pattern has been changing, with a decline in fertility rates since the 1980s. Despite this research, no study so far has analyzed global DT with worldwide phenomena. This could be the reason that every country has a different time sequence of DT depending on its own industrialization period under a disparate economic background; some countries have completed their DTs while others are still in progress. In order to analyze global DT using cross-country data, we present demographic variables as a function of GDP per capita instead of time sequence.[6]

For group analysis of countries in the context of economic development, the countries can be classified as follows: early-mover countries representing developed countries, and latecomer countries representing developing countries, including less developed ones. Gershenkron (1962), who is the first to mention latecomer's advantage (LA), suggests an economic model in which developing countries might enjoy the tangible and intangible advantages of being the latecomer relative to the early mover in the process of economic development. The latecomer might easily learn from experiences, borrow technologies, and duplicate legislation from the early mover. Therefore, developing countries could reduce the time required to reach the target of economic development, that is, *LA on*

[6] Sen (1998) argues that the death rate is an exogenous variable since it is not in itself an economic phenomenon, while some studies analyze the transition of death rate as an endogenous variable (Chakraborty, 2004; Chakraborty et al., 2010; Mizushima, 2009; Momota et al., 2005; Pecchenino&Pollard, 1997; Tabata, 2005).

www.kci.go.kr

income over time.[7] Many studies describe this as the ``catching-up'' process of latecomer countries and verify that the speed of their development is faster than the pace of the early-mover countries at a national level (Ozawa, 2004; Perkins&Neumayer, 2005).[8]

We next consider the concept of compressed DT (CDT) that latecomer countries have over time relative to the early movers. Just as the *LA on income over time* is applied to the speed of income changes for the latecomer, the concept of CDT (similar to *LA on DT over time*) is applied to the speed of DT for the latecomer.[9] Some textbooks describe this concept even though it is not `compressed' explicitly.[10] Weil (2013) compares the speed of mortality transitions with respect to life expectancy at birth.[11] France, for example, took more than three times the time India took for roughly the same change of life expectancy at birth. In addition, the change in fertility transition has been compared to total fertility rate (TFR).[12] Indonesia took only 15 years for the same change in TFR relative to 63 years in the United States. Todaro and Smith (2009) show the DT differences in Western Europe and developing countries; countries in Western Europe took more than 2 centuries whereas some countries in the developing world took less than 70 years to reach a stable level of population. In addition, Van den Berg (2012) shows a conceptual graph of DTs over time between developed and developing countries. The study demonstrates that the spread of population growth of developing countries in the shorter period is more intensively closed compared to that of developed countries. However, most previous studies merely provide an example or a conceptual graph to explain CDT

---

7 Note that LA is not the result or performances necessarily applied to all developing countries that might enjoy such advantages on income growth or DT. Some might succeed in using those advantages, but others may not.

8 Some studies examine latecomer countries' disadvantages and advantages from the micro approach, that is, firm levels in late-industrializing countries (Cho et al., 1998; Wong, 1999). At the national level, however, we accept the existence of LA over time from the macro approach.

9 This can be described by the chain rule of *LA on DT over income* and *income over time.* See equation (1) for details.

10 The term `compressed' is used to focus on the time reduction of DT by differentiating it from `advantage' used as a more general term.

11 Life expectancy at birth is the average number of years a newborn is expected to live.

12 TFR indicates the number of children a woman would have if she were to live through all her childbearing years and experience relative age-specific fertility rates at each age.

www.kci.go.kr

without a formalized treatment that thoroughly treats both fertility and mortality rates through a statistical process (Todaro&Smith, 2009; Van den Berg, 2012; Weil, 2013).

Demographic bonus is defined as the period of time in a country when large portions of its population are in the working-age group.[13] On the contrary, demographic onus is regarded as the period when the working-age group collapses from shortage of inflows and excessive outflows. The duration of these periods is closely related to the process of DT, that is, the height and width of changes of death and birth rates; in other words, how further the rates should fall and how long the rates take to reach the convergent level.[14]

The objective of this study is to solve the entangled loop between DT and economic growth by analyzing cross-country data in two ways: how rapid economic growth can affect DT, and how DT can influence future economic growth inversely. The contribution of this study can be summarized as follows. The first contribution of this study is as follows. The DT of the latecomer can be proved compressed using two methods: the conceptual and descriptive approach on the contour map, and the statistical approach through group analysis of national-level data. CDT is construed as the chain rules of *LA on DT over income* and *LA on income over time*. Assuming that the *LA on income over time* exists, we focus on verifying the *LA on DT over income*. Since a DT has the double-kinked function of income, we check them in the following aspects. (i) Latecomer

[13] The UN population department has defined demographic bonus as the period when the proportion of children and youth under 15 years of age falls below 30% and the proportion of people 65 years and older is below 15% (United Nations, 2005).

[14] In stage 2 in DT, in which death rates fall without changes in birth rates, a higher proportion of the population less than 65 years stays in the working-age group without outflows from death so that the dependency ratio (the ratio of the elderly and youth per 100 working-age members of the population) decreases. In stage 3, in which the death and birth rates decline, we still observe large inflows of the youth population born in stage 2 and the older age group remains in the working group. If the death rates converge and birth rates fall in stage 4, the age pyramid starts to shrink, with a gradually lowering proportion of the youth population and the dependency ratio passing through the lowest level. In the case of death and birth rates converging in stage 5, the lower birth rates from stages 3 to 5 (with no inflows from the youth group) cause the population to become older and the growing proportion of elderly people from stages 2 to 4 cause the dependency ratio to rise.

www.kci.go.kr

countries pass through DT at a lower level of income than do early movers in the whole process of DT (*early maturation*). (ii) The two thresholds of the latecomer countries' DT occur at a lower level of income than those of early movers (*leftward thresholds*). (iii) The latecomer countries' demographic variables have steeper negative slopes than the early-movers' demographic variables (*steeper descent*). Although a new determinant of DTs cannot be found theoretically, this study contributes to several multilateral results that can solve CDT issues using recent cross-country data.

The second contribution of this study is as follows. In order to check the balance of DT, we classify all the countries into four groups of DT based on the mode of transition: balanced transition (*BT*) slow transition (*ST*), unilateral transition (*UT*), and rapid transition (*RT*). BT includes countries that experienced the balanced path of both rates after the transition of death rate moved in tandem with that of birth rate. *ST* includes the countries whose DTs of both rates are so slow that they continued to stay in phase 1 or 2. *UT* countries' death rates have already reached a stable level but their birth rates are still in the process of phases 1 and 2. *RT* refers to the group of countries showing rapid transition of one demographic variable relative to another. Moreover, we check the cumulative results of each country based on effects of external factors or artificial policies on demographic issues. We find that the main causes of rapid transition are due to the strong family planning programs that some governments have taken.

The third contribution of this study is as follows. We undertake a simulation to measure the effect of DT on economic growth and the aging process for both the latecomer and early-mover countries. We find that the effect of demographic bonus (or onus) on income growth is determined by two aspects: the extent to which the working-age group to total population ratio changes and the length of the interval of bonus (or onus). The population surplus from the gap between death and birth rates in the initial stage of DT spawns one of the main sources of economic growth, that is, the potential of the working-age population. In the middle stage of DT, such a demographic bonus could have a large impact on economic growth, provided the redundant labor force could be absorbed into

www.kci.go.kr

the labor market by appropriate employment policies. However, as the large demographic bonus becomes older in the convergent stage of DT, the country would have to confront the problem of a larger elderly population and shrinking youth population due to a lower birth rate.

Our data are collated from the Penn World Tables 6.3 and World Development Indicators (WDI) 2010 and cover 108 countries for 51 years (1960-2010); crude death and birth rates are used for demographic variables and real GDP per capita in log transformation for personal income.

The rest of this paper is organized as follows. Section 2 describes the data used and summarizes basic statistics about the data. Section 3 analyzes whether the DT is compressed, particularly in developing countries. Section 4 mentions the effect of DT on economic growth. Section 5 reaches to the conclusion.

Ⅱ. Data

We use a dataset of real GDP per capita and crude death and birth rate data taken from the Penn World Tables 6.3 and WDI 2010 covering 108 countries and regions for 51 years (1960-2010).[15] From among the 214 countries listed in the sources, we consider 108 countries with full data of the three variables for the period. Real GDP per capita as provided by the Penn World Tables refers to GDP per capita converted to the 2005 international dollar rate using purchasing power parity (PPP) rates. Crude death (birth) rate from the WDI is defined as the total number of deaths (births) per 1,000 members of the population each year. We employ these rates rather than other measures because they remain intact and gauge population changes.[16]

[15] The data can be downloaded from the websites suggested in references.
[16] There are various other demographic measures, such as mortality rate and fertility rate, but they have

www.kci.go.kr

Table 1 reports the basic statistics, such as means with standard deviations of three variables and elasticities of both rates with respect to GDP per capita for 108 countries every 10 years. We find that (i) the average death rates dropped drastically by 48.3% for 50 years, from 16.81 to 8.69 deaths per 1,000 people; (ii) the average birth rates continuously declined 39.8% during that period, from 38.79 to 23.37; (iii) GDP per capita increased steadily by 2.18 times for the period; (iv) death rates show little convergence while birth rates were divergent, but GDP per capita is neutral in terms of the coefficient of variation[17]; and (v) GDP per capita elasticities of both rates show a convex trend, with a large decline over the period 1960-1990 and a slight increase over 2000-2010.[18](see Kim, 2020)

<Table 1. Basic statistics>

Year		1960	1970	1980	1990	2000	2010
Mean of Variables	Birth rate	38.79	35.99	33.25	29.97	26.00	23.37
		(11.84)	(12.36)	(13.18)	(12.41)	(12.06)	(11.16)
	Death rate	16.81	14.09	11.81	10.47	9.72	8.69
		(7.14)	(6.07)	(4.99)	(4.94)	(4.31)	(3.36)
	Income	4068.25	5848.54	7474.75	8784.04	10995.70	12912.61
		(4654.87)	(6774.40)	(8377.70)	(10517.33)	(13400.65)	(15116.07)
Elasticity w.r.t. GDP per capita	Birth rate	--	-0.32	-1.56	-0.48	0.29	0.99
		--	(1.56)	(5.99)	(4.41)	(3.52)	(9.59)
	Death rate	--	-2.25	-8.47	-0.33	-0.18	0.29
		--	(10.06)	(63.41)	(4.87)	(15.48)	(8.23)

Numerous studies in the literature use individual country data to explain death and birth rates with respect to time flow on the horizontal axis, *DT over time*. However, when using

different meanings for different situations. Mortality rate is the number of deaths scaled to the size of the annual population, and fertility rate is the expected number of children born per woman in her childbearing years. Although the WDI includes these data, they are not suitable to measure the changes in total population, and, moreover, they are collected every 5 years. Thus, we use the crude death and birth rates as compatible demographic variables to measure population changes.

17 The coefficient of variation of a certain variable is calculated by its own standard deviation divided by the average level.

18 The positive elasticity of death is related to the growing proportion of the aging population and the positive elasticity of birth is related to the higher income effect in developed countries.

www.kci.go.kr

cross-country data, it is difficult to find any correlation between each rate and time flow, because each country has a different time sequence of DT depending on its own industrialization period under different economic backgrounds. To make matters worse, we cannot extract common properties and take a comparative analysis of different countries on DTs. Thus, we configure per capita GDP as the base (explanatory) variable to describe DTs with the pooled cross-country data of death and birth rates, that is, *DT over income*. Such a framework allows us to (i) conclude that DT arises from internal accumulation as income increases over time, and is not an external phenomenon; (ii) compare the DT characteristics of different countries over income. Moreover, (iii) we can experiment with the disparate effects of DTs over groups of countries; in more concrete terms, and we can examine the differentiated effects of DTs on economic growth and the aging process of the group.

Ⅲ. Latecomer's CDT

We undertake a group analysis to compare the differences in DTs at the national level. In the field of economic development, the most well-known distinction method is division of countries into early-mover and latecomer groups. The early-mover group represents developed countries that have already achieved higher levels of income through earlier economic takeoff. On the other hand, the latecomer group represents developing countries, including less-developed ones, that have been late to initiate economic development and hence, have lagged behind the early movers. The proportion of latecomers is usually measured by a continuous variable, the initial level of income; the lower is the initial income of a country, the closer it is to the latecomer.[19] The main property in this categorization is the latecomer's advantage of being able to reduce the time required for economic growth by minimizing its trials and errors from the lessons and experiences of

[19] This is a more natural and general method than the artificially discrete categorization into two or three groups by a certain criterion.

www.kci.go.kr

the early mover's development process, that is, *LA on income over time*. Numerous empirical studies have confirmed that countries with lower initial income reveal higher income growth rates in a given period (Ozawa, 2004; Perkins&Neumayer, 2005).

Here, we are interested in the existence of *CDT* with the same meaning of *LA on DT over time*. However, the analysis of DT over time on cross-country data faces the same problem observed in the previous section---that every country has a different time sequence of DT. This can be overcome by the chain rule formula: the *DT over time* ($\Delta \mathrm{DT}/\Delta \mathrm{t}$) is represented by the product of *DT over income* ($\Delta \mathrm{DT}/\Delta \mathrm{Y}$) and *Income over time* ($\Delta \mathrm{Y}/\Delta \mathrm{t}$).

$$\Delta DT\ /\Delta t = \Delta DT/\Delta Y \times \Delta Y/\Delta t \quad (1)$$

In case *LA on income over time* exists ($\Delta \mathrm{Y}/\Delta \mathrm{t} \uparrow$), the DT of the latecomer becomes *CDT* if the *LA on DT over income* can be proved to exist ($\Delta \mathrm{DT}/\Delta \mathrm{Y} \uparrow$). We consider that the latecomer can have *CDT* only if the *LA on DT over income* is present even when there are no advantages on the income growth of the latecomer over time. To identify the latecomer's CDT, we focus on verifying the *LA on DT over income* in this section.

As a DT shows the form of a double-kinked function of income,[20] the *LA on DT over income* should be demonstrated in multiple aspects as follows.

- *Early maturation*: latecomer countries pass through the level of DT at a lower income than the early movers in the whole process of DT.[21] This shows that latecomer countries show an early matured trend of demographic variables at a lower level of income than do early movers in the process of economic growth.

[20] If a demographic variable has the monotonic function of income, it is sufficient to measure the *LA on DT over income* only with the absolute value of the slope over income.

[21] In other words, latecomers have a lower level of demographic variables than early movers at the same level of income in the process of DT.

www.kci.go.kr

- *Leftward thresholds*: two thresholds of the latecomer's DT occur at a lower level of income than do those of early movers. This means that the latecomers' transition of demographic variables starts and ends at lower levels of income than the early movers' transition.

- *Steeper descent*: in the second phase of DT, the latecomers' demographic variables have steeper negative slopes than the early movers' demographic variables. This indicates that the demographic changes of the latecomers are faster than those of the early movers.

1. Methods

We employ two methods to examine three aspects of the *LA on DT over income*: the contour map and econometric method of the hierarchical Bayesian model based on its applicability and persuasiveness.

1.1 Contour map

By accommodating three aspects of *LA on DT over income*, we suggest the conceptual graph of a demographic variable (death or birth rate) over current income $\ln(GDP\ per\ capita)$ with three countries that have different levels of initial income $\ln(initial\ GDP\ per\ capita)$, $A < B < C$ on the left-hand panel of Figure 2.[22] Based on the left panel, we illustrate a contour map with contour lines as a function of two variables---initial income and current income---by connecting the points at which a function has equal elevation of a demographic variable (death or birth rate) in the right-hand panel of Figure 2.[23] Under a death rate of *r4*, for instance, country A has a current

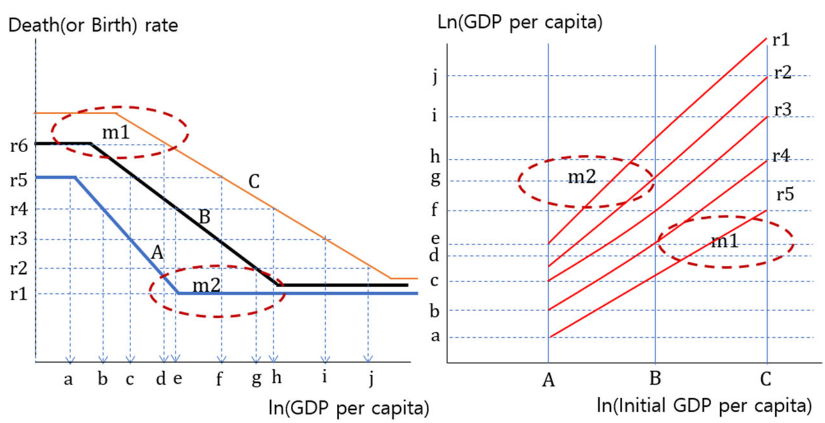
[22] Country *A* is much closer to the latecomer with lowest initial income relative to countries *B* to *C*. Country *A* (*C*) with a lower (higher) initial income presents a lower (higher) level of demographic variables over current income (*early maturation*). Thresholds of country *A* occur at lower levels of income to the left relative to countries *B* to *C* (*leftward threshold*). Furthermore, country *A* has a steeper negative slope than do other countries in the second phase (*steeper descent*).

[23] There are other ways to draw the level set; a contour line indicates equal level of current income as a function of initial income and a demographic variable. However, we report the contour map only as a function of initial and current incomes because other methods could bring the same results.

www.kci.go.kr

income of *b*, country B has a current income of *e*, and country C has a current income of *h*. Then, a contour line can be drawn to connect the points of the current income and initial income of each country, indicating equal elevation of *r4*. Similarly, a contour map can be presented for the different levels of a demographic variable in the right-hand panel of Figure 2.

<Figure 2. Contour map on concept>



We can now deduce two conceptual properties of the contour map as follows. First, the contour map has a positive slope of current income as a function of initial income without crossing each other; this represents that the country with lower initial income always passes through a demographic variable at a lower current income level than the country with higher initial income. Moreover, there is no reversal of negative relationship between current income and birth (or death) rate in a country and among countries. This property comes from *early maturation* and *leftward thresholds*. Second, the slopes of the contour map become steeper as the demographic variable declines toward *r1* from *r5*; in a higher range of demographic variables (*r5*), the current income gap between countries is narrow, but widens further as the demographic variable becomes lower (*r1*). The reason for this is that countries have different DT slope values such that the country with lower initial income has a steeper slope. This is due to the property of *steeper descent*.

www.kci.go.kr

1.2 Econometric method

We use an econometric model to validate *LA on DT over income*, which takes into account the heterogeneity of individual countries. However, we cannot consider the estimates of 108 countries because of the heavy burden of more than 1,000 parameters. As the next best approach, we instead choose a model of moderation by adding two assumptions as follows.

(A1) All countries are classified into a number of groups based on the DT process of each variable.

(A2) The estimates of thresholds of each country's DT are determined by a function of its own initial income only.

For each demographic variable, all countries can be categorized into four groups in (A1), depending on how it is dispersed by optimal categorization using the MLE method; some countries have a demographic variable (death or birth rate) enumerated from phases 1 to 3. Other countries go by phases 1 and 2, phases 2 and 3, or simply stay in phase 2.[24] Thus, four groups of countries take as many types of change-point regression models to display the transition process of a demographic variable, as follows:

$$y_{it} \sim N(\mu_{it}, \sigma^2) \tag{2}$$

[24] The transition of a single rate can be scattered to three phases from the definition of DT in Section 1. There are six ways to pass by phases, such as phase (1,2,3), (1,2), (2,3), (1), (2), and (3). We find that no country remains in only phase (1) or (3) of DT for both demographic variables.

www.kci.go.kr

subject to

(G1) $\mu_{it} = \beta_{10} + \beta_{11}(x_{it} - \tau_i^l)_+, \quad \text{if } x_{i1} \le \tau_i^l < x_{iT} \le \tau_i^h,$

(G2) $\mu_{it} = \beta_{20} + \beta_{21}(x_{it} - \tau_i^l)_+ - \beta_{21}(x_{it} - \tau_i^h)_+, \quad \text{if } x_{i,1} \le \tau_i^l < \tau_i^h \le x_{i,T},$

(G3) $\mu_{it} = \beta_{30} + \beta_{31}x_{it}, \quad \text{if } \tau_i^l \le x_{it} \le \tau_i^h,$

(G4) $\mu_{it} = \beta_{40} + \beta_{41}(x_{it} - \tau_i^l)_+ - \beta_{41}(x_{it} - \tau_i^h)_+, \quad \text{if } \tau_i^l \le x_{i1} < \tau_i^h \le x_{iT},$

where y_{it} is the death rate (or birth rate); x_{it} is the income (log GDP per capita) at country i and time t, $i \in \{1, \dots, 108\}$, $t \in \{1, \dots, 51\}$; and $(\cdot)_+$ is an indicator function that returns a positive element, or zero otherwise. Specifically, the four groups can be explained by different types of the mean μ_{it} of a demographic variable: (G1) includes countries with initial income of less than the estimated first threshold ($x_{i1} \le \tau_i^l$) and final income of less than the second threshold ($x_{iT} \le \tau_i^h$). Thus, they have experienced DT of a demographic variable over phases 1 and 2.[25] In the same way, (G2) encompasses countries whose demographic variables are spread over phases 1, 2, and 3. (G3) is the group of countries staying only in phase 2 for the period. Finally, (G4) includes countries whose data pass through phases 2 and 3. The estimates of intercepts and slopes (β_{10}, β_{11}, β_{20}, β_{21}, β_{30}, β_{31}, β_{40}, β_{41}) are identical for countries in a group but different between groups, and all thresholds (τ_i^l, τ_i^h) differ from country to country.

Following the second assumption (A2), the thresholds of each country are represented on average as a linear function of its own initial income x_{i1},

$$\tau_i^l \sim N(\phi_i^l, \sigma_l^2) I(\tau_a^l, \tau_b^l), \quad \text{where } \phi_i^l = l_0 + l_1 x_{i1}, \tag{3}$$

$$\tau_i^h \sim N(\phi_i^h, \sigma_h^2) I(\tau_a^h, \tau_b^h), \quad \text{where } \phi_i^h = h_0 + h_1 x_{i1}, \tag{4}$$

where I is an indicator function by which τ_i^l and τ_i^h are assumed to be truncated normal distributions with mean and variance (ϕ_j^l, σ_j^2), $j \in \{l.h\}$ in the ranges (τ_a^l, τ_b^l)

25 Retrogression of income over time is a drop in the bucket. We assign all countries to the four groups based on their level of initial and final income relative to the estimated thresholds.

www.kci.go.kr

and (τ_a^h, τ_b^h), respectively. Thus, we can set a moderate model for group analysis by reducing the number of parameters to less than 500.

We use a Bayesian statistical method[26] to estimate the parameters of death and birth rates. By substituting equations (3) and (4) into equation (2), we obtain the composite error structures involving identification and heteroscedasticity problems.[27] To solve the problems, we use a two-stage hierarchical Bayesian model to estimate parameters; the prior of the posterior distribution can be broken down into the product of conditional prior distribution and hyperprior distribution with hyperparameters. Then, we can represent the posterior distribution in this model as follows:

$$\underbrace{\pi(\theta|\mathbf{x},\mathbf{y})}_{Posterior} \propto \underbrace{L(\mathbf{x},\mathbf{y}|\beta,\tau)}_{Likelihood}\ \underbrace{p(\tau|\alpha)}_{Con.prior}\ \underbrace{p(\alpha,\beta)}_{Hyperprior}, \tag{5}$$

where $\beta = (\beta_{10}, \beta_{11}, \beta_{20}, \beta_{21}, \beta_{30}, \beta_{31}, \beta_{40}, \beta_{41}, \sigma^2)$ and $\tau = (\tau_i^l, \tau_i^h)$ as parameter vectors, $\alpha = (l_0, l_1, h_0, h_1, \sigma_l^2, \sigma_h^2)$. In addition, we need to assume the distribution of priors and hyperpriors for each parameter: $\beta_{ij} \sim N(0, \sigma_\beta), ij \in \{10, 11, 20, 21, 30, 31, 40, 41\}$, $\sigma^2 \sim IG(a, b)$, $l_i \sim N(0, \sigma_{\phi l}^2)$, $h_i \sim N(0, \sigma_{\phi h}^2), i = \{0,1\}, \sigma_i^2 \sim IG(a, b)$, and $\sigma_h^2 \sim IG(a, b)$. We use the Gibbs sampling algorithm to calculate the statistics of the posterior.[28] The values of parameters in the prior and hyperprior are assigned as follows: $\sigma_\beta^2 = \sigma_{\phi l}^2 = \sigma_{\phi h}^2 = 1000, a = 0.001, b = 0.001, \tau_a^l = 5.0(5.0), \tau_b^l = 8.0(8.2), \tau_a^h = 8.0(8.2), \tau_b^h = 9.0(11.0)$ for death rate (birth rate).

26 We use Bayesian statistical method in this study because the model has the composite error structures.

27 For example, by merging equations (3) and (4) into the (G4) equation in (2), we obtain a composite error structure from the change-point regression model of $y_{it} = \beta_{40} + \beta_{41}(x_{it} - \tau_i^l)_+ - \beta_{41}(x_{it} - \tau_i^h)_+ + \epsilon_{it} = \beta_{40} + \beta_{41}(x_{it} - l_0 - l_1 x_{i1} - \epsilon_i^l)_+ - \beta_{41}(x_{it} - h_0 - h_1 x_{i1} - \epsilon_i^h)_+ + \epsilon_{it}$.

28 Another method, called the maximization a posterior, maximizes the posterior to estimate parameters. This is difficult to use in this case because this model contains more than 200 dimensions to be maximized.

www.kci.go.kr

1.3 Estimation results

Table 2 presents the estimation results of death and birth rates.[29] We show that the sampling converged from Geweke's CD and all estimates are significant for both variables, except for the slope of the second threshold in death rate h_1, from the HPD interval of θ-values. The change-point regression functions of each demographic variable for the four groups can be described by the average values of estimated parameters as follows:

[Death rate]

(G1) $\mu_{it} = 20.372 - 18.105(x_{it} - \tau_i^l)_+ \quad \textit{in phase 1,2,}$

(G2) $\mu_{it} = 11.796 - 9.106(x_{it} - \tau_i^l)_+ + 9.106(x_{it} - \tau_i^h)_+ \quad \textit{in phase 1,2,3,}$

(G3) $\mu_{it} = 53.737 - 5.716x_{it} \quad \textit{in phase 2,}$

(G4) $\mu_{it} = 80.860 - 8.412(x_{it} - \tau_i^l)_+ + 8.412(x_{it} - \tau_i^h)_+ \quad \textit{in phase 2,3,}$

s.t. $\phi_i^l = 5.003 + 0.243x_{i1} \quad \text{and} \quad \phi_i^h = 8.344 + 0.026x_{i1}.$

[Birth rate]

(G1) $\mu_{it} = 44.816 - 25.216(x_{it} - \tau_i^l)_+ \quad \textit{in phase 1,2,}$

(G2) $\mu_{it} = 32.665 - 13.784(x_{it} - \tau_i^l)_+ + 13.784(x_{it} - \tau_i^h)_+ \quad \textit{in phase 1,2,3,}$

(G3) $\mu_{it} = 94.368 - 7.150x_{it} \quad \textit{in phase 2,}$

(G4) $\mu_{it} = 114.085 - 10.243(x_{it} - \tau_i^l)_+ + 10.243(x_{it} - \tau_i^h)_+ \quad \textit{in phase 2,3,}$

s.t. $\phi_i^l = 5.017 + 0.289x_{i1} \quad \text{and} \quad \phi_i^h = 7.151 + 0.282x_{i1}.$

[29] We use WinBUGS Version 1.4 to calculate the estimation results in Table 3. BUGS is a generic tool that can be used in a wide variety of situations because it makes complex calculations easy and simple to code. The sampling has been taken by 2,000,000 iterations with a burn-in of 1,000,000.

www.kci.go.kr

<Table 2. Estimation results of death and birth rates>

Parameters	Death rate				Birth rate			
	Mean	SD	95% HPDI	CD	Mean	SD	95% HPDI	CD
β_{10}	20.372	(0.126)	[20.110 , 20.460]	0.662	44.816	(0.147)	[44.530 , 45.110]	0.003
β_{11}	-18.105	(0.793)	[-19.890 , -17.570]	-0.138	-25.216	0.526	[-26.260 , -24.200]	0.345
β_{20}	11.796	(0.296)	[11.220 , 12.000]	-0.340	32.665	(0.466)	[31.750 , 33.580]	0.877
β_{21}	-9.106	(0.776)	[-10.680 , -8.576]	0.004	-13.784	(0.626)	[-15.010 , -12.550]	-0.066
β_{30}	53.737	(1.008)	[51.760 , 54.420]	-0.144	94.368	(1.201)	[92.040 , 96.750]	0.090
β_{31}	-5.716	(0.137)	[-5.984 , -5.624]	0.088	-7.150	(0.150)	[-7.448 , -6.856]	-0.243
β_{40}	80.860	(1.927)	[77.100 , 82.160]	-0.730	114.085	(1.891)	[110.400 , 117.800]	-1.115
β_{41}	-8.412	(0.230)	[-8.868 , -8.256]	0.735	-10.243	(0.212)	[-10.670 , -9.834]	1.208
σ^2	3.097	(0.030)	[3.040 , 3.117]	-0.302	4.841	(0.047)	[4.751 , 4.934]	-0.530
l_0	5.003	(0.597)	[3.934 , 5.378]	0.015	5.017	(0.516)	[4.098 , 6.131]	1.032
l_1	0.243	(0.085)	[0.061 , 0.302]	-0.032	0.289	(0.071)	[0.133 , 0.414]	-1.070
h_0	8.344	(0.236)	[7.883 , 8.503]	0.747	7.151	(0.506)	[6.228 , 8.213]	-0.490
h_1	0.026	(0.029)	[-0.031 , 0.045]	-0.674	0.282	(0.060)	[0.156 , 0.392]	0.725
σ_l^2	0.575	(0.073)	[0.445 , 0.622]	-0.297	0.511	(0.065)	[0.400 , 0.655]	0.362
σ_h^2	0.245	(0.020)	[0.210 , 0.258]	0.854	0.470	(0.050)	[0.383 , 0.577]	-0.293

SD: Standard Deviation, HPDI: Highest Posterior Density Interval, CD: Geweke's Convergence Diagnostic.

With regard to death rates, the first and second thresholds of the country i, $= (\tau_i^l, \tau_i^h)$, are determined by truncated normal distributions of $N(\phi_i^l, 0.575)$ and $N(\phi_i^h, 0.245)$, where $= (\phi_i^l, \phi_i^h)$follow the linear function of initial income for each country, such as $\phi_i^l = 5.003 + 0.243x_{i1}$ and $\phi_i^h = 8.344 + 0.026x_{i1}$. Thus, a country is assigned to a group depending on the levels of initial and final incomes relative to the two thresholds: for instance, if the initial income of the country is less than the first threshold and the final income is greater than the first and less than the second threshold, the country is classified into (G1) of death rates. Since the DT of the country has a kinked linear function of income, the average of death rate μ_{it} in (G1) is 20.372 if $x_{it} \leq \tau_i^l$ or μ_{it}=20.372-18.105$(x_{it} - \tau_i^l)$ is satisfied if $x_{it} > \tau_i^l$. The birth rate can be explained in the same way. The thresholds of birth rates of each country follow truncated normal distributions $N(\phi_i^l, 0.511)$ and $N(\phi_i^h, 0.470)$ subject to $\phi_i^l = 5.017 + 0.289x_{il}$ and $\phi_i^h = 7.151 + 0.282x_{il}$. For example, if the incomes of a country are always

www.kci.go.kr

greater than the first threshold and less than the second threshold, the country is assigned to (G3) of the birth rate. Then, the birth rate of the group has a linear regression function of the income, $\mu_{it} = 94.368 - 7.150x_{it}$ in phase 2. The DTs of other groups can be explained similarly.

2. Results on Latecomer CDT

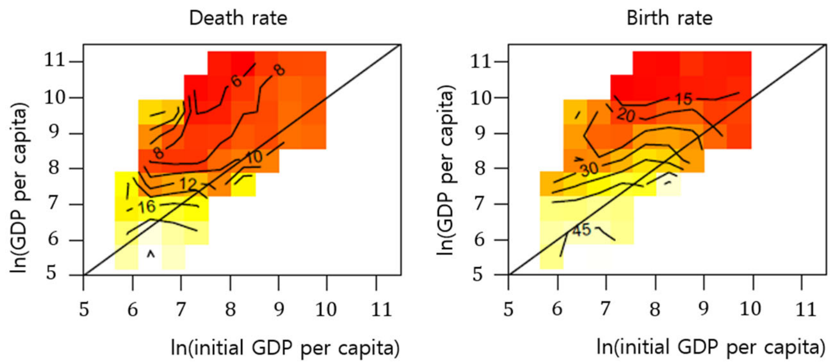
We examine the existence of latecomer CDT by evaluating the outcomes of three aspects of *LA on DT over income* in terms of the properties of contour map and econometric estimation results.

2.1 Early maturation

We compare the conceptual properties with the results of data analysis on the contour map. We represent the contour map of demographic variables (death and birth rates) in Figure 3. We easily show that the contour lines of both rates have positive slopes of less than one; this means that countries with lower initial income (latecomers) reach the same level of demographic variable at lower current incomes than countries with higher initial incomes (early movers). As contour lines never intersect, we can assert that early maturation has been sustained over the period of DTs. However, there are limitations to data collection for the period; early-mover countries lack data on higher rates of demographic variables at lower income (the region of *m1* in Figure 2) because they started DT earlier. By contrast, the latecomer has no data on a lower rate at higher income (the region of *m2* in Figure 2) since their DTs have not ended yet. Thus, the upward slope in Figure 2 is explained partially by data analysis on the corresponding regions in Figure 3.

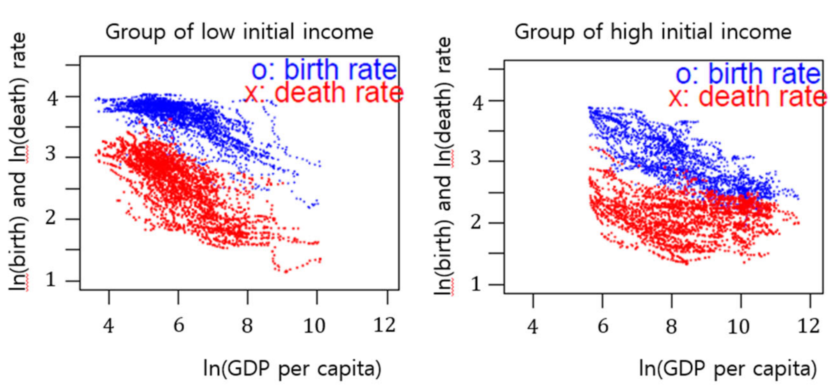
www.kci.go.kr

<Figure 3. Contour map on demographic variables>



In addition, early maturation can be verified by regression functions using average values of estimates. For convenience, we reset the four groups of countries, (G1) to (G4), into two groups (early mover and latecomer) for each variable according to the following criteria: (a) whether the country has experienced phase 1, (b) whether the country has lower initial income, and (c) whether the country has the first threshold at a lower income. Thus, (G1) and (G2) are categorized in the latecomer group and (G3) and (G4) are in the early-mover group for both demographic variables. Figure 4 presents the scatter diagrams of DTs for the two groups.

<Figure 4. Two groups of demographic transitions by initial incomes>



www.kci.go.kr

From this categorization, the phenomenon of early maturation for the latecomer group can be deduced from the following results of the econometric method in Table 2. First, the constant terms of (G1) and (G2) in phase 1 of DT are lower than those of (G3) and (G4): $\beta_{10} = 20.372(44.816)$ in (G1), $\beta_{20} = 11.796(32.665)$ in (G2), $\beta_{30} = 53.737(94.368)$ in (G3), and $\beta_{40} = 80.860(114.085)$ in (G4) for the death rate (birth rate). It indicates that the latecomer group has the lower level of both demographic variables from the starting point of DT. Second, the threshold functions for both rates have positive slopes with the initial income (0.243, 0.026) in the death rate and (0.289, 0.282) in the birth rate. It means that the positive slope makes the threshold levels of the latecomers earlier and lower than the early movers. Third, the slopes of (G1) and (G2) are higher in absolute value than those of (G3) and (G4): $\beta_{11} = -18.105(-25.216)$ in (G1) of the death rate (birth rate), $\beta_{21} = -9.106(-13.784)$ in (G2), $\beta_{31} = -5.716(-7.150)$ in (G3), and $\beta_{41} = -8.412(-10.243)$ in (G4). This rapid transition of the latecomer group reconfirms maintaining the lower level of demographic variables in the process of DT.[30] In summary, compared to the early-mover group, latecomer countries with lower levels of demographic variables in phase 1 have transition thresholds at lower levels of income with a rapid negative rate of demographic variables over income.

2.2 Leftward threshold

We have already observed in Figure 3 that early maturation of the latecomer may present consistent results without a reversal of current incomes over demographic variables. In other words, if a threshold level of the early mover exists prior to that of the latecomer, the contour lines might cross each other and violate early maturation. Thus, no reversal of contour line indicates that leftward thresholds are satisfied under early maturation.

[30] The second deduction is the result of *leftward thresholds* and the third is the result of *steeper descent.*

www.kci.go.kr

On the other hand, we can directly infer the parameters of leftward thresholds from the estimation results in Table 2. These results present the average slopes of estimated thresholds as a function of the initial income in equations (6) and (7), (l_1, h_1); (0.243, 0.026) are the average slopes of the first and second thresholds in the death rate; and (0.289, 0.282) are those in the birth rate. All slopes are positive and significant, except for the second threshold in the death rate. We then argue that the DT of birth rates for the latecomer started from a lower income and finished at a lower income compared to the early mover. While the DT of the death rate for the latecomer started from a lower income, we cannot confirm that the death rates in the latecomer group have converged at a lower income than those in the early-mover group owing to lack of data on the latecomer.

2.3 Steeper descent

Following the conceptual contour map, the slopes of contour lines should be steeper as the rates descend. We can confirm this from Figure 3, where the contour lines of death rates show steeper slopes on the contour line as the death rate decreases but those of birth rates are unclear.

In addition, we examine the steeper descent on the econometric method in terms of slopes of the second phase in the DT. The average slopes of the second phase in death rates are $\beta_{11} = -18.105$ in (G1), $\beta_{21} = -9.106$ in (G2), $\beta_{31} = -5.716$ in (G3), and $\beta_{41} = -8.412$ in (G4). For birth rates, the slopes are $\beta_{11} = -25.216$ in (G1), $\beta_{21} = -13.784$ in (G2), $\beta_{31} = -7.150$ in (G3), and $\beta_{41} = -10.243$ in (G4). The absolute values of the slopes follow the same order of (G1)>(G2)>(G4)>(G3) for both death and birth rates with significance in terms of the 95% HPD interval. This proves that the second phase of the DT process in the latecomer group, including (G1) and (G2), has declined more sharply than that in the early-mover group of (G3) and (G4).

2.4 Summary

The results of the three aspects of early maturation, leftward thresholds, and steeper descent are summarized to prove the existence of *LA on DT over income* in Table 3.

www.kci.go.kr

Although some results are unclear and not sufficient for verification, *LA on DT over income* can be confirmed by combining two different methods.

<Table 3. Summary of three aspects of LA on DT over income>

Three aspects		Contour map method		Econometric method	
		Death rate	Birth rate	Death rate	Birth rate
Early maturation		Yes	Yes	--	--
Leftward thresholds	First threshold	Yes	Yes	Yes	Yes
	Second threshold			Unclear	Yes
Steeper descent		Yes	Unclear	Yes	Yes

In conclusion, we find two types of LAs: the first is the *LA of income over time* (speedy income) proved in the literature, and the second is the *LA of DT over income*, verified in this section. By combining these two approaches, we reach the CDT (speedy DT) such as that in equation (4) in the development process of developing countries.

3. Group analysis of countries

We undertake additional analysis of the group of countries already categorized by DT in the econometric method. For each rate, 108 countries are classified into four groups; the distributions of the groups are (G1, G2, G3, G4) = (23, 10, 27, 48) for the death rate and (G1, G2, G3, G4) = (41, 7, 24, 36) for the birth rate. We observe the expected result that (G4) passing phases 2 and 3 is the majority group for the death rate and (G1) passing phases 1 and 2 is the majority group for the birth rate, since the death rate precedes the fall in the birth rate in the process of DT.

www.kci.go.kr

<Table 4. Balance of DTs for groups of countries>

Joint groups		List of countries (number of countries)
Balanced Transition	(G1,G1)	Bangladesh, Brundi, Ethiopia, Indonesia, Lesotho, Mozambique, Nepal, Tanzania, Togo, Uganda, Zimbabwe (11)
	(G3,G3)	Algeria, Benin, Bolivia, Cameron, Cote d'Ivoire, Guinea, Haiti, Mali, Niger, Rwanda (10)
	(G4,G4)	Argentina, Australia, Austria, Barbados, Belgium, Canada, Chile, Cyprus, Denmark, Finland, France, Greece, Hong Kong, Iceland, Iran, Ireland, Italy, Japan, Luxembourg, Mexico, Netherland, New Zealand, Norway, Panama, Paraguay, Portugal, Puerto Rico, Singapore, Spain, Sweden, Switzerland, Trinidad and Tobago, UK, US, Uruguay (35)
Slow Transition	(G3,G1)	Burkina Faso, Central Africa, Chad, Congo(D), ElSalvador, Gambia, Guatemala, Guinea Bissau, Madagascar, Malawi, Namibia, Nigeria, Senegal, Zambia (14)
	(G1,G3)	Comoros, Congo(R), Kenya, Pakistan, Papua New Guinea (5)
Unilateral Transition	(G4,G1)	Brazil, Cape Verde, Colombia, Dominican(R), Ecuador, Egypt, Fiji, Honduras, India, Jordan, Phillippines, Syria, Turkey (13)
	(G4,G3)	Botswana, Costa Rica, Gabon, Ghana, Israel, Jamaica, Nicaragua, Peru, South Africa, Venezuela (10)
Rapid Transition	(G2,G1)	Morocco, Mauritania (2)
	(G2,G4)	Equatorial Guinea (1)
	(G1,G2)	Sri Lanka (1)
	(G4,G2)	Romania, Malaysia, Thailand, Mauritius, China, South Korea (6)

In order to check the balance of DT, depending on which group a country has been allocated to, we undertake a joint group analysis of countries for both rates. We make 16 joint groups of countries, 4×4 for both rates, but 11 joint groups of countries can be collected in total from Table 4;[31] A joint group of (G1,G2), for instance, includes countries whose DT of the death rate is classified in (G1) and DT birth rate is classified in (G2). Such joint groups can be re-organized according to *BT*, *ST*, *UT*, and *RT*.

BT countries are those that experienced the balanced path of both rates since the transition of the death rate proceeded in tandem with that of the birth rate. More than half of the countries are included in this category (56/108); this can be divided further into three sub-groups: first, (G1,G1) includes most of the less developed countries whose

[31] No country has been assigned to groups (G2,G2), (G1,G4), (G2,G3), (G3,G2), and (G3,G4).

www.kci.go.kr

transitions are initially late and still lag. Second, (G3,G3) includes countries whose DTs are so sluggish that they simply remain in phase 2 for the period. Finally, (G4,G4) forms the largest group with most developed countries (35/108), which have reached a stable state of DT for both rates. Thus, *BT* shows the population growth leveling off since the transitions of both rates keep pace with each other.

ST includes countries in the joint groups of (G3,G1) and (G1,G3) whose DTs of both rates are so slow that they stay in phase 1 or 2. Population growth in these countries is expected to be too small to enjoy demographic bonus, with a narrow gap between the birth and death rates. Most countries in this category (16/19) are African nations, except for El Salvador, Pakistan, and Papua New Guinea. The main reasons for the slow DT of the death rate in these countries are related to chronicle problems, such as (civil) war, famine, or natural disasters.

UT countries are characterized by the transition of the death rate being much faster than that of the birth rate, such that death rates have already reached a stable level but birth rates are still in phases 1 and 2. The majority of these countries are in Latin America (10/23) and some are in Africa (7/23). These countries can expect to have the big fortune of demographic bonus since they have a higher gap between birth and death rates. To realize demographic bonus as much as possible, they need to pursue cautious labor policies such that large proportions of their workforces are employed.

RT refers to the group of countries whose transition of a demographic variable (death or birth rate) is classified in G2, rapidly passing through phases 1 to 3 for the period.[32] This can be divided into two cases: the rapid transition of the death rate, with three countries (Morocco, Mauritania&Equatorial Guinea) classified in (G2,G1) and (G2,G4), and the rapid transition of the birth rate, with seven countries (Sri Lanka, Romania, Malaysia, Thailand, Mauritius, China&South Korea) included in (G1,G2) and (G4,G2). However, following the general features of DT, it is not reasonable that the transition of

32 No country has experienced a rapid transition of both rates at the same time (G2,G2).

www.kci.go.kr

the birth rate rapidly precedes that of the death rate. We guess that there might be an intervention of visible hands such as the government's or society's intervention or cultural issues and then, such a DT could be the cumulative results of external factors or artificial policies on demographic issues. Thus, to understand *RT*, we turn to the policy differences of individual countries in four joint groups with respect to the following two issues: why does one variable show an unusually rapid transition and why does the transition of the birth rate precede that of the death rate.

- (G2,G1): The reasons for the rapid decline in the death rate, retaining a higher level of the birth rate.
- (G2,G4): The reasons for the rapid decline in the death rate, with the transition of the birth rate preceding that of the death rate.
- (G1,G2): The reasons for the rapid decline in the birth rate, retaining the higher level of the death rate.
- (G4,G2): The reasons for the rapid decline in the birth rate, with the transition of the death rate preceding that of the death rate.

The first policy difference we consider is in (G2,G1) of Morocco and Mauritania. These countries have the following in common: they are conservative Islamic countries with continued economic growth over the last 50 years.[33] On the issue of rapid decline in the death rate, these countries received and absorbed preferential treatment from external sources for the transition of the death rate.[34] The reason for retaining the higher birth rate level is related to a more conservative society. The early stages of family planning programs in both countries were slow and cautious from lack of public statements, support, and education.[35] Therefore, the large gap between death and birth rates, the

---

33 Morocco has a compound annual average growth rate (CAAGR) of 3.2% for the last 50 years (1960--2010), including 4.9% in 2003--2007. Mauritania has a steady growth rate of 2.3% for the period.

34 The radical improvement can be attributed to a series of large-scale programs launched in the 1980s and 1990s to reduce child mortality supported by external funds. The programs focused mainly on childhood diseases: comprehensive vaccination, treatment of acute watery diarrhea with oral rehydration therapy, and a nutritional program to supplement vitamin A (Brown, 2007).

35 In addition, family planning programs have encountered strong religious and political opposition

www.kci.go.kr

demographic surplus, has caused these countries to face an excessive population explosion for the period. These countries will have to confront a youth group with political discontent in the near future if their labor surplus cannot be absorbed into the labor market through appropriate economic policies.[36]

The second sub-group (G2,G4) of *RT* includes only Equatorial Guinea, with a small population of 0.74 million. The economic growth of Equatorial Guinea cannot be explained without mentioning its discovery of large oil reserves in 1996. The oil reserves and their subsequent exploitation have contributed to a dramatic increase in GDP per capita.[37] The rapid drop of the death rate is attributed mainly to enormous economic growth. In addition, Equatorial Guinea's innovative malaria control programs in the early 21st century have succeeded in reducing malaria infection, disease, and mortality in the population. The characteristic of a decline in the birth rate preceding that of the death rate is related to the deterioration of the rural economy under successive brutal regimes and migration to other countries following long dictatorships (UNHRC, 2008).

The third sub-group is Sri Lanka in (G1,G2). It shows a rapid decline in the birth rate without changes in the death rate. The only explanation for this phenomenon is a powerful external shock, *war*: Sri Lanka suffered 26 years of civil war.[38] After the war, the most important aspect of Sri Lanka's population policy was to straighten the unbalanced sex ratio and restore the reverse DT to a normal trend.

The fourth sub-group of (G4,G2) shows the property of rapid decline in the birth rate. This category includes six countries: Romania, Malaysia, Thailand, Mauritius, China, and South Korea. These countries have something in common with the birth control policy,

(Roudi-Fahimi, 2004).

36 From UN data, the median ages in Morocco and Mauritania were (26.7, 19.7) in 2012.

37 Equatorial Guinea's CAAGR was 0.7% in 1960--1995. A growth rate of more than 30% was recorded in 1996--2005.

38 Beginning on July 23, 1983, an intermittent insurgency arose against the government by the Liberation Tigers of Tamil Eelam (the LTTE, also known as the Tamil Tigers). After a 26-year military campaign, the Sri Lankan military defeated the Tamil Tigers in May 2009, bringing the civil war to an end.

www.kci.go.kr

the family planning program (FPP). We investigate the type of policies related to birth rate that each country adopted. Romania launched an FPP in the 1990s and expanded it to the national level in the 2000s, mainly focusing on increasing access to contraceptives (USAID, 2006). Malaysia started an FPP in 1966. The effect of the program was to increase the contraceptive prevalence rate from 8.8% to 52% in 20 years. The main factors for the decline in the birth rate in Malaysia are the rising age at marriage and the increased use of contraceptives (Ahmad et al., 2010). Thailand launched an FPP in 1971. The use of contraceptives increased from 15% to 70% in 15 years. Sterilization has now become the most widely used form of contraception in Thailand. The government even offers loans linked to people's use of contraception (Frazer, 1992). An FPP in Mauritius was founded in 1957 to provide birth control services. The government carried out aggressive campaigns for family planning in the 1960s using mass media. In only 10 years (1963-1973), the country reduced its birth rate by nearly half (World Bank, 2011). The radical drop of the birth rate in China is strongly linked to population control policies and forced and coerced sterilization programs.[39] In 2015, China ended its one-child policy after 35 years. Although a two-child policy has been adopted since, the Chinese economy is expected to suffer from a shortage of working-age population in the next generation with induced problems of an aging society. This will place an undue burden on the Chinese economy, especially since China's welfare system is not adequately prepared to address issues of severe unemployment of youth groups and an aging population. In addition, South Korea was one of the few developing countries to have initiated a population policy to lower birth rates in the 1960s and 1970s following population explosion. Korea began its national family planning campaign to reduce its fertility rate of six children per woman in 1962. The fertility rate fell to 4.5 in 1970 and 1.74 in 1984 under the strong government support.[40] Despite the below-replacement fertility rate, the FPP in Korea continued apace.

---

39 China started its *one-child policy* in 1979 and has constructed a penalty-and-reward system for those who violate or follow the policy. One method of enforcing the policy was to sterilize women after the first child (New York Times, Oct. 25, 2015).

40 The program was regarded as essential to achieve the goal of economic growth and modernization, with the slogan of a `small and prosperous family.' The fertility rate fell to 4.5 by 1970 against a background of rapid industrialization. A 1974 slogan was `Sons or daughters, let's have two children and raise them

www.kci.go.kr

Once the government realized that the number of women of childbearing age was declining and that the trend would accelerate, it was too late. The fertility rate continued to fall to a world record low of 1.08 in 2005 (Joo et.al., 2020, Han, 2022. Lee, 2023).

Ⅳ. Effect of CDG on economic growth

This section focuses on how the CDT influences the economic growth of developing countries. There is no guarantee that such a CDT as a composite factor will ensure the improvement of income per capita in developing countries, as speedy income is not the only concern. We might expect the shuffling of population distribution by age group to bring about fluctuation of economic growth. The relationship between demographic changes and economic growth has been simply examined from the difference between GDP per capita and GDP per worker (see Weil, 2013).

$$\text{GDP per capita} = \frac{\text{GDP}}{\text{number of workers}} \times \frac{\text{number of workers}}{\text{total population}}, \qquad (6)$$

which indicates how the well-being of a country (GDP per capita) is determined by the product of two issues (ratios): how a country is productive (GDP per worker) and how many workers are occupied in the total population (working proportion of population).[41] As a version of the growth rate, the growth rate of GDP per capita can be described approximately by the summation of the growth rate of GDP per worker and the working-age proportion of population as follows:[42]

well.' In the 1980s, there was mention of a one-child family: `Even two children per family are too many for our crowded country.' Thus, the fertility rate fell to 1.74 by 1984 (Haub, 2010).

41 Working-age is defined as the age range of 20-64 years in this section.

42 We assume that worker proportion of population is in proportion to the working-age proportion of population.

www.kci.go.kr

$$\text{growth rate of GDP per capita} = \text{growth rate of GDP per worker} + \text{growth rate of working-age proportion of the population},$$

which explains that a higher growth rate of income is attainable only with a higher growth rate of the working-age proportion of the population without the growth of GDP per worker. Thus, we concentrate on the changes in working-age groups out of the total population with regard to CDT.

Bloom and Williamson (1998) show the estimation results that DT has contributed substantially to East Asia's economic miracle. They state that ``the miracle occurred in part because East Asia's demographic transition resulted in its working-age population growing $\left(\frac{W_{t+1}-W_t}{W_t}\right)$ at a much faster rate than its dependent population $\left(\frac{P_{t+1}-P_t}{P_t}\right)$ during 1965-90, thereby expanding the per capita productive capacity of East Asian economies."[43] They define *demographic gift* as such economic benefits as a high ratio of working age to dependent population during DT.[44]

For a closer analysis of the effect of demographic gift (bonus),[45] we suggest the two figures (the figure 1 and figure 3) used in Bloom and Williamson (1998). In the first figure, they conceptually describe two facts: that population growth and share of the workforce have inverted-U shapes over time, and that population growth is a prelude to changes in the working-age structure. These facts indicate that, following population changes from DT, the age distribution fluctuates by first lowering the ratio of workers in the population (W_t/P_t), then raising it, and then again it, and thus, enables deduction of the transitional impact on the growth of GDP per capita. The second figure empirically shows how DT determines the ratio of working-age population to nonworking-age population

43 W_t is number of working-age population and P_t is total population (see pp.419, Bloom&Williamson, 1998).

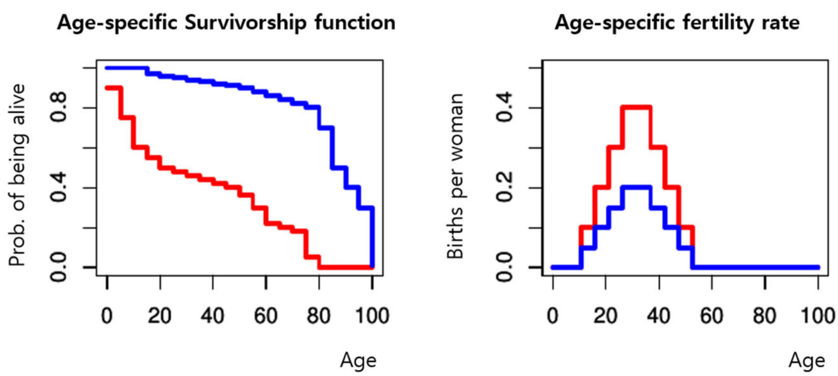
44 Moreover, Bloom et al. (2003) introduce the term *demographic dividend* to emphasize the notion that a demographic gift is not gained automatically but must be earned by the presence of suitable economic policies that allow a relatively large workforce to be employed productively.

45 We describe demographic gift as a demographic bonus in order to meet the phonology with demographic onus.

www.kci.go.kr

$(W_t/(P_t - W_t))$ for the three sub-regions in Asia.[46] They share the common characteristic that demographic bonus started in the 1970s, will reach its peak sometime between 2010 and 2020, and will lead to demographic onus based on a decreasing trend of the ratio.

<Figure 5. Age-specific survivorship function and fertility rates for simulation>



Let us explain demographic bonus and onus over different stages of DT in detail. At the first stage of DT, the youth-dependency ratio rises sharply due to more children surviving, with falling death rates and sustained higher birth rates; thus, the falling shares of the working-age would diminish the growth rate of GDP per capita.[47] In the second and third stages of DT, demographic bonus exists with a relatively rising share of the working-age group from a large influx born in the last stage, so that we can expect an

[46] In this section, we use several different ratios for demographic bonus. It is measured by (a) a high ratio of working-age population to dependent population over time, $\frac{W_{t+1}}{P_{t+1}} > \frac{W_t}{P_t}$. In East Asia's DT, it is measured by (b) the fact that the working-age population is growing at a much faster rate than its dependent population, $\frac{W_{t+1}-W_t}{W_t} = r_w > r_p = \frac{P_{t+1}-P_t}{P_t}$. In figure 5, the bonus is measured by (c) the rise in the ratio of workers to population over time $\frac{W_{t+1}/P_{t+1}-W_t/P_t}{W_t/P_t} > 0$. In figure 6, demographic bonus can be described by (d) the ratio of working-age population to nonworking-age population, which is increasing, $\frac{W_{t+1}}{P_{t+1}-W_{t+1}} > \frac{W_t}{P_t-W_t}$. We easily show that all of these are equivalent, from (a) to (d).

[47] The youth-dependency ratio measures the ratio of children to working-age population. Meanwhile, the elderly-dependency ratio implies the ratio of the aged population to the working-age population.

www.kci.go.kr

increase in the growth rate of GDP per capita.[48] As the transition converges in stage 5, the large share of the working-age groups becomes older and starts to decline. Such countries would have to confront the problems of shrinking the growth rate of GDP per capita and moving toward an aging society.

This appears like the tornado phenomenon; a tornado is generated when the inside temperature of air becomes erratic from sudden changes in temperature. The strength of the generated tornado is in proportion to the gap in temperatures. Thus, the damage of the tornado depends on how strong and how long it continues to strike. Once the perfect tornado passed, severe damage remains. Similarly, the population surplus from the difference between death and birth rates in the initial stage of DT triggers one of the main sources of economic growth, that is, it raises the potential of the working-age population. Such a demographic bonus can have a large impact on economic growth provided the redundant labor force can be absorbed into the labor market by appropriate employment policies. Therefore, we can say that the effect of demographic bonus (onus) on income growth is determined by two aspects: the proportion of the working-age population to the total population and the duration of the bonus (onus) interval. However, we are worried that the larger demographic bonus brings about as much damage of demographic onus.

1. Simulation

We undertake a simulation to highlight the effect of CDT for the latecomer on economic growth (demographic bonus) and the aging process with the lower birth rate (demographic onus) compared to that for the early mover. Consider the fluctuation of population distribution generated by DT over time through the age-specific survivorship function and the fertility rate suggested in Figure 5.[49] In order to consider the ratio of the

[48] Note that demographic bonus in the middle phase of a transition may or may not be realized. This represents growth potential whose realization depends on other features of the social, economic, and political environment (Bloom&Williamson, 1998).

[49] The age-specific survivorship function is defined as the different age probabilities that a representative person already born will live in a country, whose summation gives the life expectancy at birth. The age-specific fertility rate is the average number of newborn children a representative woman of a given age

www.kci.go.kr

working-age group to the total population, the age ranges are divided into 21 intervals of 5-year periods from birth to 100 years old. Thus, the range of 15 to 65 years is regarded as the economically active (working-age) population. Under the assumption that DT has been complete for arbitrary *t* years, the red lines in Figure 5 indicate the initial age-specific survivorship function and fertility rate before the DT, and the blue lines represent the final survivorship function and fertility rate after the DT has been complete. These values on the function and rate are determined arbitrarily based on actual data. For example, the survival rate of those aged 40 years after DT are double the rate of the same age group before DT, and the fertility rate after DT is defined as half the level of the rate before DT. Therefore, the simulation model has been planned such that countries require only a different time *t* to finish DT from the same initial values to the same terminal values of the age-specific survival functions and fertility rates.

<Figure 6. Simulation outcome>

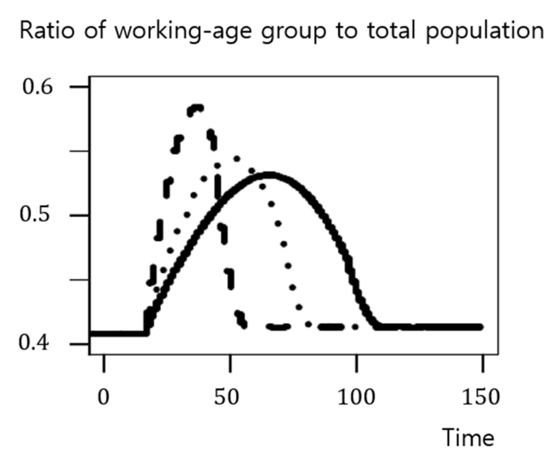


Figure 6 presents the outcomes of simulation with time on the horizontal axis and the ratio of working-age group to total population on the vertical axis. We suggest three types

will bear for a given year in a country, whose summation indicates the fertility rate of the country (Weil, 2013). External migration has still been ignored.

www.kci.go.kr

of groups with different durations for the DT process; group 1 takes *t=20* periods, group 2 takes *t=40* periods, and group 3 takes *t=60* periods, assuming that the initial distribution of population of every country has been at a steady state for the first 20 periods.[50] The dashed line represents the ratio of working-age group over time for group 1; the dotted line gives the ratio for group 2; and the solid line gives the ratio for group 3. Figure 6 clarifies that the more compressed the DT process of a country is, the more rapid is the rise and descent of the ratio of working-age group to total population, resembling a fall from a cliff after a sharp climb. On the contrary, we can say that the more time the DT takes, the higher is the ratio of the working-age group that can increase slowly and last longer. Such variety of DTs can be referred to as the functional diversity of a stove, because the choice of the stove is determined by which is more important between speedy heat conductivity and longer heat preservation.

The slope of the graph in Figure 6 can explain the effect of demographic change on economic growth. In case the dashed line is for a shorter period of DT, the higher slope of the ratio of working-age group to total population brings as much demographic bonus to economic growth, but it is too intense and short to reach the peak. However, even a shorter period of the plummeting slope can lead to primary concerns, such as the rapid depletion of the labor force in the future, which could erode the demographic bonus and, even worse, bring about a faster demographic onus, leading to an aging population and deficiency in the working population along with a low birth rate. Conversely, in the case of the solid line with a longer period of DT, there is a gradual ascent and descent, indicating that it may take longer to reach the peak and return to the floor. In other words, the demographic bonus is not so strong, but the period of enjoying the bonus is much longer than that of the dashed line.

[50] For convenience of calculation, some assumptions are added in the model such that (i) the DTs (increase in age-specific survivorship function and decrease in fertility rates) of the three groups start to change at the same time, and (ii) the annual derivatives of the age-specific survivorship function (fertility rate) are the same every year for the duration of the DT; that is, the amount of changes in the survivorship probability (fertility rate) every year is x/y under the total amount of changes of x for y years.

www.kci.go.kr

The more worrying aspect is the CDT of the latecomer; this results in a sharp upturn of the working-age population, followed by a sharp downturn for a short period. Compared to early-mover countries, developing countries cannot buy more time to accommodate the working-age population for the period of the demographic bonus and to prepare the aging society for the period of the demographic onus. Then, CDT is not necessarily advantageous to developing countries.

Ⅴ. Conclusion

We examine the relationship between economic growth and DT of birth and death rates. It is well known that DT decreases demographic variables along with economic growth, demographic variables show double kinked lines with respect to time sequence, and the drop of the birth rate follows that of the death rate. We undertake a national-level group analysis to verify the compressed transition of demographic variables over time. Assuming that the *LA on DT over time* exists, we verify that the DT of the latecomer is compressed by providing a formal proof of *LA on DT over income*. As a DT has the double-kinked functions of income, we check them in multiple aspects: early maturation, leftward threshold, and steeper descent under a contour map and econometric methods. We find that the developing countries (the latecomer) have speedy DT (CDT) as well as speedy income such that DT of the latecomers starts at lower levels of income, lasts for a shorter period, and finishes at the earlier stage of economic development compared to that of developed countries (the early mover). To check the balance of DT, we classify countries into four groups of DT---balanced, slow, unilateral, and rapid transition countries. The most of the less developed and most developed countries are classified in *BT* group simultaneously. The majority of *ST* is in African nations and that of *UT* is in Latin American countries. For the rapid transition, we compare the policy differences of the countries, focusing on how the government’s or society’s intervention or cultural issues have influences on such a rapid transition. We identify that the main causes of rapid

www.kci.go.kr

transition are due to the strong family planning programs of the government. Finally, we check the effect of latecomer's CDT on economic growth inversely: we undertake the simulation of the CDT effect on economic growth and the aging process for the latecomer. A worrying result is that the CDT of the latecomer shows a sharp upturn of the working-age population, followed by a sharp downturn in a short period. Compared to early-mover countries, the latecomer countries cannot buy more time to accommodate the workable population for the period of demographic bonus and prepare their aging societies for demographic onus. Thus, we conclude that CDT is not necessarily advantageous to developing countries. These outcomes of the latecomer's CDT can be re-interpreted as follows. Developing countries need power sources to pump up economic development, such as the following production factors: labor, physical and financial capital, and economic systems. As for labor, the properties of early maturation and leftward thresholds on DTs of the latecomer mean that demographic movement occurs at an unusually early stage of economic development; this is similar to a plane that leaks fuel before or just before take-off, with the result that it no longer flies higher or farther. What is worse, the property of steeper descent represents the falling speed of a plane so that it cannot be sustained at higher levels, and then plummets to all-time lows. A period of difficulty must be used to prepare for a period of happiness. However, a country can fall into deep trouble if the period of happiness is too short to prepare for the next period of suffering or problems. Important issues for the period of demographic bonus are how to accommodate the wealth of human resources in industrial employment, and how to prepare to minimize the turbulence of DT on the workforce for the period of demographic onus.

www.kci.go.kr

Reference

Ahmad, N., Peng, T. N., Zaman, K. F., Sapri, N. A., Manaf, M., & Kim, Y. Y. (2010). Status of Family Planning in Malaysia. In *UNFPA-ICOMP Regional Consultation*, Draft version.

Barro, R. J., & Becker, G. S. (1989). Fertility Choice in a Model of Economic Growth. *Econometrica* 57 (2): 481-501.

Becker, G. S. (1960). An Economic Analysis of Fertility. *Demographic and Economic Change in Developed Countries*. New York: Columbia University Press, 209-240.

Becker, G. S., & Barro, R. J. (1988). A Reformulation of the Economic Theory of Fertility. *Quarterly Journal of Economics* 103 (1): 1-25.

Becker, G. S., Murphy, K. M., & Tamura, R. (1990). Human Capital, Fertility, and Economic Growth. *Journal of Political Economy* 98 (5-2): S12-S37.

Benhabib, J., & Nishimura, K. (1989). Endogenous Fluctuations in the Barro-Becker Theory of Fertility. In *Demographic Change and Economic Development*, edited by Alois Wening and Klaus Zimmermann, 29-41. New York: Springer-Verlag.

Bloom, D., & Williamson, J. G. (1998). Demographic Transitions and Economic Miracles in Emerging Asia. World Bank Economic Review 12 (3): 419-455.

Bloom, D., Canning, D., & Sevilla, J. (2003). *The Demographic Dividend: A New Perspective on the Economic Consequences of Population Change*, Population Matters, Santa Monica CA: Rand.

Brown, G. F. (2007). Morocco: First Steps in Family Planning. In *The Global Family Planning Revolution: Three Decades of Population Policies and Programs*, edited by Warren C. Robinson, and John A. Ross, Washington, D.C., The World Bank.

Chakraborty, S. (2004). Endogenous Lifetime and Economic Growth. *Journal of Economic Theory* 116 (1): 119-137.

Chakraborty, S., Papageorgiou, C. & Perez-Sebastian, F. (2010). Diseases, Infection Dynamics, and Development. *Journal of Monetary Economics* 57 (7): 859-872.

Cho, D., Kim, D., & Rhee, D. (1998). Latecomer Strategies: Evidence from the Semiconductor Industry in Japan and Korea. *Organization Science* 9 (4): 489-505.

www.kci.go.kr

Cutler, D. M., Deaton, A. S., & Lleras-Muney, A. (2006). The Determinants of Mortality. *Journal of Economic Perspectives* 20 (3): 97-120.

Dahan, M., & Tsiddon, D. (1998). Demographic Transition, Income Distribution, and Economic Growth. *Journal of Economic Growth* 3 (1): 29-52.

Doepke, M. (2005). Child Mortality and Fertility Decline: Does the Barro-Becker Model Fit the Facts? *Journal of Population Economics* 18 (2): 337-366.

Easterlin, R. A. (1966). On the Relation of Economic Factors to Recent and Projected Fertility Changes. *Demography* 3 (1): 131-153.

Fernandez-Villaverde, J. (2001). Was Malthus Right? Economic Growth and Population Dynamics. Unpublished.

Frazer, E. (1992). Thailand: A Family Planning Success Story. *In Context* 31: 44.

Galor, O. (2011). *Unified Growth Theory*. Princeton NJ: Princeton University Press.

Galor, O., & Weil, D. N. (1996). The Gender Gap, Fertility, and Growth. *American Economic Review* 86 (3): 374-387.

Gerschenkron, A. (1962). *Economic Backwardness in Historical Perspective: A Book of Essays.* Cambridge, MA: Belknap Press of Harvard University Press.

Han, Hongyul. (2022). Structural Change as a Source of Growth: An Empirical Evidence from OECD Countries. *Analyses & Alternatives* 6(1): 195-222.

Haub, C. (2010). Did South Korea's Population Policy Work Too Well. *Population Reference Bureau*, March.
http://www.prb.org/Publications/Articles/2010/koreafertility.aspx.

Joo, Sangyong & Hyun, Jun Seog. (2020). The Effect of Demographic Changes on the Growth Potential of Korea. *Analyses & Alternatives* 4(2): 71-102.

Keyfitz, N. (1989). The Growing Human Population. *Scientific American* 261 (3): 118-126.

Shin, Inyong & Kim, Hyunho. (2020). The Relation between the Demographic Transition and GDP per capita at the National-level Data, *Korea Journal of Regional Economics* 45: 5-20.

Kirk, D. (1996). Demographic Transition Theory. *Population Studies* 50 (3): 361-387.

Kremer, M. (1993). Population Growth and Technological Change: One Million B.C. to 1990. *Quarterly Journal of Economics* 108 (3): 681-716.

www.kci.go.kr

Lapan, H. E., & Enders, W. (1990). Endogenous Fertility, Ricardian Equivalence, and Debt Management Policy. *Journal of Public Economics* 41 (2): 227-248.

Lee, Dong Jin. (2023). Asymmetric Changes in Korean Industry and Labor After Economic Crises. *Analyses & Alternatives* 7(1): 45-81.

Maddison, A. (2001). *The World Economy: A Millennial Perspective*. Organization for Economic Cooperation and Development, Paris.

Mizushima, A. (2009). Intergenerational Transfers of Time and Public Long-term Care with an Aging Population. *Journal of Macroeconomics* 31 (4): 572-581

Momota, A., Ken, T., & Futagami, K. (2005). Infectious Disease and Preventive Behavior in an Overlapping Generations Model. *Journal of Economic Dynamics and Control* 29 (10): 1673-1700.

Murphy, T. E. (2015). Old Habits Die Hard (Sometimes): Can Department Heterogeneity Tell Us Something about the French Fertility Decline? *Journal of Economic Growth* 20: 177-222.

Nerlove, M., Razin, A., & Sadka, E. (1978). *Household and Economy: Welfare Economics of Endogenous Fertility*. New York: Academic Press.

New York Times. (2015). China Ends One-Child Policy, Allowing Families Two Children. Oct. 29. *http://www.nytimes.com/2015/10/30/world/asia/china-end-one-child-policy.html*.

Omran, Abdel R. 1971, "The Epidemiologic Transition." In *International Encyclopedia of Population*, edited by John A. Ross, Vol. 1, Free Press.

Ozawa, T. (2004). Veblen's Theories of "Latecomer Advantage" and "The Machine Process": Relevancy for Flexible Production. *Journal of Economic Issues* 38 (2): 379-388.

Pecchenino, R. A., & Pollard, P. S. (1997). The Effects of Annuities, Bequests, and Aging in an Overlapping Generations Model of Endogenous Growth. *Economic Journal* 107 (440): 26-46.

Perkins, R., & Neumayer, E. (2005). The International Diffusion of New Technologies: A Multi-technology Analysis of Latecomer Advantage and Global Economic Integration. *Annals of the Association of American Geographers* 95 (4): 789-808.

Qi, L., & Kanaya, S. (2010). The Concavity of the Value Function of the Extended Barro-Becker Model. *Journal of Economic Dynamics and Control* 34 (3): 314-329.

www.kci.go.kr

Roudi-Fahimi, F. (2004). Islam and Family Planning. *MENA Policy Brief*, Population Reference Bureau.

Sadik, N. (1991). *Population Policies and Programs: Lessons Learned from Two Decades of Experience*, United Nations Population Fund, New York: NYU Press.

Sen, A. (1998). Mortality as an Indicator of Economic Success and Failure. *Economic Journal* 108 (446): 1-25.

Tabata, K. (2005). Population Aging, the Costs of Health Care for the Elderly and Growth, *Journal of Macroeconomics* 27 (3): 472-493.

Tekce, B. (1985), Determinants of Child Survival: Comments on a New perspective. In *Population Factors in Development Planning in the Middle East*, edited by Fredric C. Shorter and Huda Zurayk, New York, Population Council: 137-147.

Thomson, W. S. (1929). Population. *American Journal of Sociology* 34 (6): 959-975.

Todato, Michael P. & Stephen C. Smith. (2009). *Economic Development*, Boston MA: Addison Wesley.

United Nations (2006). *World Population Policies 2005*, United Nations publication, Sales No. E.06.XIII.5, New York.

United Nations (2011). World Contraceptive Use 2011, Chart, Department of Social and Economic Affairs, UN Population Divisions.

United Nations Human Rights Council. (2008), *World Directory of Minorities and Indigenous Peoples – Equatorial Guinea: Overview*, Minority Rights Group International.

University of Pennsylvania. 1960-2010. Penn World Tables 6.3, Gross Domestic Product per capita. *http://pwt.sas.upenn.edu/php_site/pwt63/pwt63_form.php* (accessed February 10, 2014).

USAID. 2006. *Romania: Scaling Up Integrated Family Planning Services: A Case Study*, Delivery Project. Washington D.C.

Vallin, J. (1991). Mortality in Europe from 1720 to 1914: Long-term Trends and Changes in the Patterns by Age and Sex. In *The Decline of Mortality in Europe*, edited by Roger Schofield, David Reher, and Alain Bideau, Oxford, Oxford University Press: 38-67.

Van den Berg, H. (2012). *Economic Growth and Development*, 2nd edition, Singapore: World Scientific.

www.kci.go.kr

Weber, L. (2010). *Demographic Change and Economic Growth: Simulations on Growth Models*, London, UK: Physica-Verlag.

Weil, D. N. (2013). *Economic Growth*, Pearson, Boston MA: Addison Wesley.

Wikipedians. (2011). *Economics*, Mainz Germany: Pedia Press.

Wong, Poh-Kam. (1999). National Innovation Systems for Rapid Technological Catch-up: An Analytical Framework and a Comparative Analysis of Korea, Taiwan and Singapore. Paper presented at the DRUID Summer Conference on National Innovation Systems, *Industrial Dynamics and Innovation Policy*, Rebild: Denmark.

World Bank. (2011). Mauritania - Reproductive Health at a Glance. *MENA Policy Brief*, Population Reference Bureau. *http://documents.worldbank.org/curated/en/2011/05/14659199 /mauri tania-reproductive-health-glance.*

World Bank. 1960-2010. ``World Development Indicators 2010, Birth Rate, Crude.” *http://data.worldbank.org/indicator/SP.DYN.CBRT.IN* (accessed February 10, 2014).

World Bank. 1960-2010. ``World Development Indicators 2010, Death Rate, Crude.” *http://data.worldbank.org/indicator/SP.DYN.CDRT.IN* (accessed February 10, 2014).

Manuscript: May 21, 2023; Review completed: Jun 1, 2023; Accepted: Jun 2, 2023

www.kci.go.kr