Demographic Transition, Human Capital Accumulation and Economic Growth: Some Evidence from Cross-Country and Korean Micro Data

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Abstract

We offer some empirical evidence both at macro and micro levels for possible linkage between demographic transition and long-term economic performance. Based on theoretical works by Becker, Murphy, and Tamura (1990), Tamura (1995), and Lucas (2002) among others, we present two hypotheses on the linkages among human capital accumulation, change in demographic structure and economic growth. Theoretical works show that an increase in rate of return to human capital may trigger a shift from low-growth high-fertility Malthusian equilibrium to high-growth low-fertility development equilibrium by stimulating human capital investment and substitution of quantity with quality of children. One can infer that these theoretical studies predict a positive correlation between *the speed of demographic transition* and *the speed of economic growth*. Faster demographic transition is also related to faster accumulation of human capital since the main driving force is the increase in the rate of return to human capital investment. Utilizing traditional cross-county growth regression framework and newly suggested measure of speed of demographic change, we found positive answers for both of the hypotheses. We also provide supporting evidence for the quality-quantity trade-off hypothesis with micro-level household survey data from Korea where we have observed one of the fastest economic growth and demographic change.

I. Introduction and Background

It is well known that Korea has sustained remarkably fast catch-up growth since the 1960s. Another salient but less well-noted aspect of the Korean economy is its fast demographic transition. Total fertility rate, which was 5.67 in 1960, has declined very fast to hit alarmingly low level of 1.16 in 2004. Meanwhile, death rate measured by the number of death per 1,000 people also declined from 13.46 in 1960 to 5.30 in 1995, and roughly remained at that level since then. With rapid decline in both fertility and death rates, population growth rate and working age population ratio went through rapid changes as well.[1]

From an international perspective, what distinguishes Korea from other countries is her fast *speed* of demographic transition (Figure 1.A-1.D). Compared with other countries, various indicators of demographic structure such as fertility rate, working-age population ratio, and population growth rate in Korea went through most dramatic changes since the 1960s[2]. In early 1960s, the levels of these demographic indicators in Korea and other high-performing East Asian countries were similar to the average levels of Sub-Saharan African countries. By the early 1990s, however, they were roughly comparable to those of developed countries. By contrast, averaged over the whole period, levels of the demographic indicators in Korea and other East Asian countries do not stand out and are placed between those of developed and Sub-Saharan African

[1] Population growth rate registered 3.09% in 1960 but has declined since then to reach 0.49% in 2004. The number of working-age population per dependent population (working-age population ratio) was as low as 1.21 in 1960. After a brief decline, it increased continuously to reach 2.6 in 2004. See Appendix Table 1.

[2] Fast demographic transition is not confined to Korean case. The same kind of phenomenon is also observed in many high performing Asian countries.

countries.

These observations on simultaneous progress of fast economic growth and demographic transition motivate our study. Based on broad implications of important theoretical contributions by Becker, Murphy, and Tamura (1990), Tamura (1996), and Lucas (2002), we formulate an empirical framework that relates economic growth to changes in demographic structure as well as human capital accumulation, and examine whether we can find empirical evidence consistent with these broadly defined theories of growth with quality-quantity choice of children. We cast two specific questions. "Is the faster speed of demographic transition associated with faster growth of per capita income?" and "Does faster speed of demographic transition imply faster speed of human capital accumulation?" We try to tackle these questions utilizing both cross-country data and micro-level household survey data from Korea. In cross-country analysis, first of all, we suggest several measures of the *speed* of demographic transition of a country. Then we relate these measures to per capita income growth of countries relying on traditional growth regression framework, and to measures of human capital accumulation. As a complement to the cross-country analysis, we also use household survey data in Korea to examine whether families with fewer children invest more on their education. In our opinion, empirical evidence from Korea is particularly interesting in that Korea has gone through remarkably fast economic growth and, at the same time, remarkably fast changes in demographic structure.

// Insert Figure 1.A – 1.D here //

There are many micro-level empirical studies on the Beckerian trade-off between number and quality of children.[3] Also, there are many cross-country studies relating demographic indicators or demographic structure to per capita income growth.[4] However, in the case of cross-country studies, most of them do not take seriously either the theoretical implications of endogenous growth with endogenous fertility choice or the possibility that demographic transition is endogenously triggered by the conscious choice of between quality and quantity of children.

Meanwhile, some recent endogenous growth theories with endogenous fertility choice demonstrate the possible existence of multiple equilibria and try to explain the transition from high-fertility no-growth Malthusian equilibrium to low-fertility sustained-growth modern growth equilibrium (e.g., Tamura 1996). According to these theories, the transition from no growth equilibrium to sustained growth equilibrium is triggered by the rise of return to human capital investment and the resulting changes in household choice favoring the quality over the quantity of children—i.e., lower fertility and more investment on human capital per child[5]. In other words, these theories suggest that economic growth, human capital accumulation, and demographic transition are all simultaneously triggered by changes in fertility pattern stemming from increased rate of return to human capital investment. However, to the best of our knowledge, it is hard to find empirical studies which take seriously the body of growth literature with endogenous fertility choice as an empirical framework to examine actual growth

[3] Empirical studies employing micro-level data to test the significance of quality-quantity trade-off hypothesis include, among many, Rosenzweig and Wolpin(1990), Hanushek(1992), and Grawe(2005).

[4] Examples of cross-countries on the relationship between demographic indicators and economic growth are Romer (1990), Brander and Dowrick (1994), Kelly and Schmidt (1995), and Bloom and Williamson (1998). There are also many country-level studies examining demography and economic growth, such as Cutler, Poterba, Sheiner, and Summers (1990), Fougere and Merette (1999). Meanwhile, there are some cross-country studies examining the relationship between fertility rate and income level. For example, Barro and Sala-i-Martin (1995) shows that there exists an inverted-U relationship between fertility and income level.

[5] There could be many factors raising the rate of return to investment in human capital which triggers the

experiences.

Our paper contributes empirically not only to the better understanding of the process of economic growth, but also to understanding the nature of population aging. It is often suggested that a country experiencing faster increase in working-age population ratio is likely to experience faster growth of per capita GDP. This argument seems to be based on the presumption that increase in working-age population ratio contributes to growth primarily through increased supply of labor input per capita. For example, Bloom and Williamson (1998) argues that much of the miraculous per capita income growth of East Asian countries are attributable to the favorable demographic changes in those countries, such as rapid increase in working-age population relative to population. They argue that as the East Asian countries are expected to experience rapid population aging or a decrease in working-age population ratio, these countries will face significant slow down in per capita income growth in near future. In sum, Bloom and Williamson (1998) suggests that the *direction* of change in working-age population ratio matters for per capita income growth.

Not denying the possibility that directional change has significant implications on economic growth, we argue that the *speed* of demographic transition may matter for economic growth as emphasized by a large body of literature in the tradition of endogenous growth theory with endogenous fertility.[6] In this paper, we suggest several measures of the speed of demographic transition, and examine whether those measures are systematically related to per capita income growth and human capital accumulation.

Finally, by providing empirical evidence on the relationship between demographic

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transition.

[6] We will discuss more formally our empirical framework in the following section.

transition and human capital accumulation, we believe that the results from our paper also help understand the role of human capital in economic growth. Despite the important role of human capital as the engine of growth as repeatedly pointed out by endogenous growth theories, it is also true that it is quite difficult to find empirical studies documenting the importance of human capital in economic development at the comparable level suggested by theoretical studies. In so far as the changes in fertility behavior and, hence, the demographic transition are systematically related in theory to the human capital investment decision by households, the empirical relationship between demographic transition and economic growth or human capital accumulation could be presented as an indirect evidence on the role of human capital in economic growth.

The organization of this paper is as follows. In the following section, we briefly review previous theoretical studies that provide the framework for our empirical work and explain our main hypotheses. Section 3 explains the data, specification of the basic regression model, and measurement of the speed of demographic transition. Section 4 provides our cross-country regression results. We first provide per capita GDP growth regressions with the speed of demographic transition as the key explanatory variable. Then, we examine whether measures of human capital growth are related to the speed of demographic transition. Also, we discuss whether our measures of the speed of demographic transition reflect indeed the speed of demographic transition. Section 5 provides our empirical results for the household behavior on quality-quantity choice, based on micro data of Korea. Final section concludes.

II. Theoretical Background

Dating back to early pioneering works by Becker (1960), the effort to explain child-bearing and fertility pattern as results of deliberate economic decision by rational economic agents has a long tradition in economics. Especially, the negative correlation between the number (quantity) of children and "quality" of children within a family had long been well-noted statistical regularity and several authors had tried to construct theoretical model to predict trade-off between quality and quantity of children within a family. It was Becker and Lewis (1973) that first derived the quantity-quality trade-off under a general setting of utility maximization by a household without *ad hoc* assumption to induce quality and quantity trade-off[7].

Upon repeatedly observing declining fertility along with increasing per capita income, researchers had tried to explicitly introduce the Beckerain quality-quantity trade-off into the growing growth literature. Becker, Murphy, and Tamura (1990) is one of the distinguished examples that reinterpreted the implications of earlier researches on fertility decision and human capital investment in the context of economic growth. Tamura(1996) and Lucas(2002) also deserve separate mentioning as important contributions to the literature of economic growth with endogenous fertility and human capital investment. Tamura(2000) summarizes the implications of these models on economic growth and dynamic income distribution as: (1) low fertility and persistent income growth for rich countries (2) convergence in both growth rates and living standard among the economic growth countries (3) high fertility and no economic

[7] The key feature of the model that derives the trade-off relationship is the fact that the shadow price of children depends on the quality as well as the number of the children in the family. The shadow price of children with respect to the number of children is greater the higher their quality is. Similarly, the shadow price of children with respect to their quality is greater, the greater the number of children.

growth among poor countries (4) switching development regimes from high fertility-no growth to low fertility-fast growth for some countries.

The main vehicle that brings differences among countries in theses literature is human capital accumulation. There are two types of human capital in the economy; skilled and unskilled. Each child is born with fixed amount of unskilled human capital and parents allocate time endowment into consumption, fertility, and skilled human capital investment for their children. Skilled human capital has comparative advantage in human capital production and unskilled human capital in goods production. The rate of return to human capital investment is higher for skilled parents than for unskilled ones and child rearing requires fixed amount of parental time so that the cost of a child is higher for skilled parents. As a result unskilled parents choose to have a large family and no income growth. On the contrary, skilled parents choose a perpetual income growth path characterized by low fertility, high and constantly rising human capital stock. This line of logical chain can be further extended to the aggregate level to conclude that there may exist two stable steady state equilibria in the economy. One is the "Malthusian" equilibrium with low rate of return to human capital investment, high fertility, and no economic growth. The other is the "development" equilibrium where the rate of return to human capital investment is high and households put more emphasis on quality rather than quantity of children so that smaller family size and the economy enjoys a perpetual income growth.

However, the earlier versions provided neither a mechanism through which each economy is assign to the path to which steady state equilibrium nor a bridge through which an economy on the path to the Malthusian equilibrium switch to the path leading to the development equilibrium. Once initial endowment of human capital stock falls short of the “threshold” level, the economy will constantly suffer from a trilemma of low human capital stock, high fertility, and no economic growth and it is impossible to escape without a favorable exogenous shock to human capital stock that can bring a sudden transition to the path to the development equilibrium.

Tamura (1996) tries to bridge the gap left unfilled by the earlier researches by allowing spillover of human capital in the accumulation technology. Under the presence of spillover effect in human capital investment, as long as some countries choose perpetual growth of human capital driven by incidentally high level of initial human capital and the level of global human capital stock constantly increases, the rate of return to human capital investment directly linked to the level of global human capital stock will rises in all countries including countries trapped by the Malthusian no growth equilibrium. Thus, at least some countries under no growth regime may choose to invest in skilled human capital investment that will ultimately lead to transition to the development equilibrium since the spillover effect from the increasing global stock of human capital will lower the threshold level required to achieve high growth steady state equilibrium. Therefore, it is possible that economic growth in rich countries lowers the critical human capital stock required for growth for all countries and facilitates the take-off of poor countries.

Lucas (2002) views sustained economic growth of countries since the late 19th century—i.e., industrialization—as a process of diffusion of the Western industrial revolution to other regions of the world. He further suggests that countries with open trading regime and private property right protection went through changes in household’s decision in the direction of favoring quality, rather than quantity of children and experienced *both demographic transition and sustained increase in per capita* *income*.

Under the perspectives of line of thinking discussed above, both demographic transition and sustained per capita income growth could be understood as two different manifestations of one phenomenon, in as much as both are triggered by changes in fertility decisions of households in response to the changes in the rate of return to human capital investment. Then it could be conjectured that the faster the speed of demographic transition of a country, the faster both the rate of per capita income growth and human capital accumulation. So, we have two testable hypotheses as follows.

Hypothesis 1. *A country with faster demographic transition experiences higher rate of per capita income growth, other things being equal.*

Hypothesis 2. *A country with faster demographic transition experiences faster human capital accumulation.*

III. Data and Specification of Cross-country Regressions

III. 1 Measurement of Speed of Demographic Transition

1) Construction of the Measure

Our measures of the speed of demographic transition are based on the assumption that the speed of demographic transition is fixed for a country, and are basically the magnitudes of changes in certain demographic indicators during a given time interval. We consider three alternative demographic indicators – fertility rate, working-age population ratio, and population growth rate – and, for each of these indicators, construct the measure of the speed of demographic transition. Our measure of the speed of demographic transition is devised to capture how much on average certain demographic indicator has changed for a country during one unit of time interval. SFERTIL is defined as the estimated coefficient on linear time trend when fertility rate is regressed on a constant and linear time trend from 1960 to 2004. SWRATIO and SPOPGR are similarly defined for working age population ratio and population growth rate.[8]

In fact, measuring the speed of demographic transition for a country for a given time period is not as obvious a task as it might seem, even with the assumption of fixed speed. Above all, it is more likely that the demographic indicators move in a non-linear pattern rather than change linearly over time as we assumed in deriving the second type of measures. It is well known that the time profile of a country's working-age population ratio exhibits a non-linear pattern. During one cycle of a typical demographic transition, as exemplified in Figure 2[9], both working-age population ratio and population growth rate follow roughly inversely U-shaped pattern. The working-age population ratio, for example, mildly declines for a short time and then continues to increase with the decline in fertility rate during the early stage of a demographic transition. In later stage, it begins to decline until it finally levels off. Therefore, it is possible that the linearity assumption produces two different estimates for two countries that are experiencing the same of speed of demographic transition, depending on which phase of the transition each country is located.

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[8] In earlier version of this paper, we also considered a simpler measure of the speed of demographic transition, which is the difference between the time averages of the corresponding demographic indicator for the two roughly evenly divided sub-periods. Specifically, for each country, DFERTIL was defined as the difference in mean fertility rates for the two adjacent sub-periods: 1960-1984 and 1985-2004. DWRATIO and DPOPGR were defined correspondingly for working-age population ratio and population growth rate. Since the regression results using this alternative measure were not qualitatively different from Table 4-6 below, we do not report them separately here.

[9] Figure 2 is taken from Bloom and Williamson (1998).

Even with these limitations of our measure of demographic transition, we chose to maintain the linearity assumption primarily because it is a simple and easy way to start. More importantly, as suggested by Figure 1, even in the case of working-age population ratio for which the linearity assumption could potentially be most problematic, most countries are located to the left half of the inversely U-shaped curve at least during the period of our analysis, which seems to make the linearity assumption less problematic.[10]

2) Preliminary Analysis

Table 1 shows summary statistics of our measure of speed of demographic transition. First of all, the average estimated speed of change in fertility rate in the whole sample is about -0.06, which means that it took about 17 years on average for fertility rate to decline by one, say, from 3 to 2 persons per woman. However, we can note that there is a large variation across countries in the measure as suggested by the large standard deviation (about 0.04). So, the estimated speed of change in fertility rate of a country at one standard deviation above the sample mean is about -0.02, which suggests that it takes about 50 years for this country to experience one percentage point decline in fertility rate. Next, the average estimated speed of change in working-age population ratio defined as the number of working-age population per dependent population, is about 0.01, which suggests that it takes about 100 years on average for working-age population ratio to rise, say, from 1 to 2. Again, there is a large variation of this measure across countries. Lastly, the average estimated speed of change in population growth rate is about -0.017, which means that it takes about 60 years on average for population growth rate to drop by one percentage point, say, from 2 percent to 1 percent per annum.

[10] In the case of working-age population ratio, there is also the problem of whether the measured speed of change truly reflects the speed of demographic transition or the direction of change. This issue will be discussed later in the paper.

// Insert Table 1 here //

The estimated speed of demographic transition also shows large variation across regions. Overall, East Asia and China stand out from other regions in all of the three measures. For example, the speed of changes in fertility rate in East Asia and China are -0.09 and -0.11 respectively, which are about three times as large as developed countries or Sub-Saharan African countries. The estimated speed of changes in fertility rate for most other developing regions falls in between East Asia and Sub-Saharan African countries.[11] Similar phenomenon is observed for the speed of changes in working-age population ratio. It was highest in China followed by East Asia, which are fast growers, and lowest in Sub-Saharan Africa followed by Europe and Central Asia and developed countries. The speeds of change in working-age population ratio in East Asia and China are also about three times as large as developed countries.

Although many, if not most, countries experienced decline in fertility rate, increase in working-age population ratio, and decline in population growth rate during the sample period we examine, there were some countries that do not follow this general pattern. Table 2 shows the number of countries according to the estimated sign of each measured speed of demographic transition. In the case of SFERTIL, negative coefficient values were obtained for 133 countries out of 141, among which 128 cases were significant at 1 percent level. There were 8 countries where the coefficient was negative and five of them were significant at 5 percent level. Meanwhile, in the case of SWRATIO and SPOPGR, 36 and 34 out of 141 countries, respectively, exhibited negative coefficient most of which are significant at 10 percent level.

[11] However, MENA (Middle East and North Africa) region experienced somewhat faster decline in fertility rate than East Asia and Europe and Central Asia slower decline than Sub-Saharan African region.

// Insert Table 2 here //

Particularly in the case of working-age population, the existence of negative coefficients may be problematic especially if these are for mature economies that have already passed the peak of the inverted U-shaped curve. This is so because we are trying to examine whether the speed, rather than the direction, of demographic transition matters for growth and, hence, want to get a positive estimate of the speed of changes in working-age population ratio for a country located at the declining phase of the inverted U-shaped curve. However, among the 36 countries where negative values of SWRATIO were obtained, only one country (Sweden) belongs to the developed region and 28 countries belongs to Sub-Saharan Africa. Nevertheless, we take this phenomenon into account and consider alternative measures of the speed of changes in working-age population ratio later in this paper.

As the last preliminary analysis, we present simple correlations of various measures of the speed of demographic transition and per capita GDP growth of countries for the period from 1960 to 2004. As shown in Table 3, per capita GDP growth of countries are negatively correlated with SFERTIL and positively correlated with SWRATIO at conventional significance level, although it is not significantly correlated with SPOPGR. Also, there are strong correlations among the three measures of speed of demographic transition. That is, countries under fast demographic transition by one measure, SFERTIL for example, also exhibit fast demographic transition by other measures, such as SWRATIO and SPOPGR. The existence of strong correlations among these variables suggests that these variables indeed are likely to be three different ways to measure the speed of demographic transition of a country. One can also infer that it is useful to take into account all these three variables in examining the relationship between demographic transition and per capita GDP growth.

// Insert Table 3 here //

III. 2 Specification of the Empirical Models and Data

Equipped with three different measures of speed of demographic transition, we are now ready to embark on examining the hypotheses presented in previous section.

In testing the first hypothesis on the positive relationship between economic growth and speed of demographic transition, we follow the typical strategy found in empirical growth literature; that is, including the key variable of interest as an additional explanatory variable into a reduced-form "standard" growth regression specification and testing the statistical validity of the variable of interest.

$$GI_i = \gamma DT_i + \beta' X_i + \varepsilon_i$$

where GI_i is country *i*'s growth rate of per capita GDP and DT_i is the variable of key interest in our study and represent one of the measures of speed of demographic transition defined earlier. X_i is the vector of usual "suspect" variables recognized as having certain explanatory power as the determinants of economic growth.

In this paper, we consider three specifications as the "standard" regression models: two of them suggested by Levine and Renelt(1992) and one with additional explanatory variables taking subsequent development in literature into account. Then we examine whether our measure of demographic transition has additional explanatory power.[12] The first regression from Levine and Renelt(1992) includes as explanatory variables

[12] These are the regression equations (i) and (ii) in Table 5 from Levine and Renelt (1992).

initial real GDP per capita in 1960, investment share of GDP, initial secondary-school enrollment rate and the average annual rate of population growth. The second regression from Levine and Renelt(1992) has almost equivalent structure to Barro (1991), which, in addition to the first specification, includes primary-school enrolment rate, average rate government consumption expenditure to GDP, a dummy variable for socialist economic systems, indicators for revolutions and coups, and dummy variables for countries in Latin America and sub-Saharan Africa. The third regression includes, in addition to the explanatory variables in the second regression, institutional quality, openness, natural resource abundance, and terms of trade growth.

To test the second hypothesis that relates speed of demographic transition to human capital accumulation, we examine the simple correlation between various measures of speed of demographic transition and measures of changes in human capital investment by estimating simple regression model.

The data sources for this paper are as follows. We use real GDP per capita (RGDPL) from Penn World Table (PWT) 6.2 to measure growth rate of per capita GDP for each country. Fertility rate, death rate, population growth rate, and working-age population ratio are taken from the World Development Indicator (WDI) 2006. The control variables in the first and the second regression equations are from the data set provided by Levine and Renelt (1992). The data sources for other control variables are as follows. Openness, the average years a country is open between 1950 and 1990, and natural resource abundance, the share of primary product exports in GDP in 1970, are from Sachs and Warner (1995). Institutional quality is from Knack and Keefer (1995). Terms-of-trade is the average terms of trade growth rate between 1960 and 1990 from Barro and Lee (1994).

In regressions of human capital accumulation, human capital investment is measured with years of schooling. Barro and Lee (2000) provides estimates of number of years of schooling achieved by the average person at the various levels and at all levels of schooling combined. We use TYR(total years of schooling), PYR(primary years of schooling), SYR(secondary years of schooling), and HYR (years of higher schooling) for population aged 25 years or above from Barro and Lee's data set.

We tried to construct as large a sample of countries as possible for which the data on real GDP and several key demographic indicators are available. Our sample consists of 141 countries.[13]

IV. Cross-country Regression Results

IV. 1 Per Capita GDP Growth

Table 4-6 shows our cross-country regressions of per capita GDP growth with measures of speed of demographic transition as the explanatory variables of main interest. We use OLS, as well as GMM estimation technique to address the endogeneity problem that might exist in measures of speed of demographic transition. Along with all explanatory variables in the original regressions except for the speed measure, we include as the instruments measures of human capital of a country relative to the frontier country in 1960, total years of schooling (TYR) of each country divided by total years of schooling of the frontier country (the U.S.) in 1960, and the difference between average educational attainment of a country and that of the U.S. in 1960.[14] Other instruments

[13] However, the number of observations in the regressions below can be smaller than 141 due to missing values for some of the variables. For more detailed description of the construction of our sample countries, see Appendix 1.

[14] We calculated average educational attainment of a country simply as the sum of educational attainment

included are working-age population ration in 1960, fertility rate in 1960, population growth rate in 1960, and life expectancy at birth in 1960, and female labor participation rate in 1960, which are available from WDI.

Overall, the regression results strongly support our first hypothesis that faster speed of demographic transition is associated with faster growth of per capita GDP.[15] The comparison between OLS and GMM results tells us that endogeneity issue may not be a major concern at least in our specifications[16].

Most of all, <Table 4> shows that estimated coefficients on SFERTIL are mostly negative and highly significant, suggesting that countries with rapidly declining fertility rate experienced higher growth rate of per capita income. The result is robust to the inclusion of some of the conventional determinants of growth. Next, SWRATIO also enters the regressions with positive and highly significant coefficient, suggesting that countries with rapidly changing working-age population ratio exhibited faster growth (Table 5).[17] <Table 6> shows that the estimated coefficient on SPOPGR is also negative, as expected, although it lost significance with the inclusion of additional controls.

Thus, as discussed in section II, the regression results are broadly consistent with the implications of several growth theories with endogenous fertility choice. Also, the fact that we could obtain qualitatively similar results using all three alternative measures of

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of population aged 25 or above at six levels of schooling from Barro and Lee (2000)—primary school attained, primary school complete, secondary school attained, secondary school complete, higher school attained, and higher school complete.

[15] Taking logarithms of our measures of speed of demographic transition hardly affected the results qualitatively. In the case of the speed of changes in fertility rate, we considered an alternative measure—the number of years it takes for fertility rate to decline from 5 to replacement level (about 2)—and observed qualitatively similar results, which we do not report here.

[16] According to J-statistic reported in the last row of <Table 4> , we cannot reject the null hypothesis of over-identifying restrictions.

[17] In section IV.3, we discuss whether the speed of change or the direction of change in working-age

the speed of demographic transition is strongly supportive of our first hypothesis.

// Insert Table 4-6 here //

IV. 2 Human Capital Accumulation: Growth of Years in Schooling

Now, we turn to our second hypothesis: the faster the speed of demographic transition of a country, the faster the speed of its human capital accumulation. So, we ran simple regressions with the speed of accumulation of human capital as dependent variable and our measure of speed of demographic transition as independent variable. As the measure of the speed of human capital accumulation, we use each country's annualized difference in years of schooling for the period from 1960 to 2000. Table 7 shows 12 regression results. The first row of the table shows the four dependent variables – annualized differences in TYR, PYR, SYR, and HYR – and the first column shows three measures of the speed of demographic transition.

// Insert Table 7 here. //

The regression results are fairly strongly supportive of our hypothesis that a country experiencing fast demographic transition also experiences fast accumulation of human capital. That is, all three measures of the speed of demographic transition successfully explain variations of annualized differences in TYR and PYR. Specifically, the coefficients of SFERTIL are significantly negative in regressions of (annualized differences in) TYR and PYR. Although insignificant in regressions of SYR and HYR, they are still estimated to be negative. Both SWRATIO and SPOPGR, respectively, enter the four regressions significantly with positive coefficients. So, countries with faster changes in working-age population ratio or faster decline in population growth

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population ratio, in particular, matters for growth.

rate also experienced faster increase in years of schooling at all levels.

In order to see whether the regression results reflect cross-regional differences, rather than cross-country differences, we also ran the same regressions with the inclusion of dummy variables for Latin America and Sub-Saharan Africa (not reported). However, the regressions results with the two region dummy variables were not much different from the simple regression results above, except that the coefficients of SWRATIO and SPOPGR became insignificant in HYR regressions.[18]

IV. 3 Speed of Change vs. Direction of Change

Up to now, we have tried to come up with various measures of the speed of demographic transition of a country and provided empirical evidence suggesting that a country with faster speed of demographic transition experienced not only faster growth of GDP per capita but also faster accumulation of human capital. In the case of working-age population ratio, for example, it was shown above that a country with faster changes in working-age population ratio not only grew faster but also accumulated human capital more rapidly.

However, one could raise the question whether our measure of speed of demographic transition reflect indeed the speed of change, not the direction of change. For example, do the positive coefficients on SWRATIO in regressions of per capita GDP growth and human capital accumulation capture the effect of “the speed of demographic transition” or “the increase” in working-age population relative to population? As noted at introduction, there do exists a view holding that a significant

[18] Meanwhile, the dummy variables for Latin America and Sub-Saharan Africa were significant in many cases. We do not report the results of these regressions to save the space. The regression results are available upon request..

part of the miraculous growth of East Asian countries are due to rapid increase in working-age population (labor supply) relative to population (Bloom and Williamson 1998). Although assessing the validity of the above view is not a main objective of this paper, we think this issue needs further examination regarding interpretation of our empirical results.

Thus, we tried to perform additional regressions which, we hope, can shed light on this issue, focusing on the speed of changes in working-age population ratio for which interpretation of our results could be most controversial. In the previous regressions, we tried to relate per capita GDP growth from 1960 to 2004 to measured speed of change in working-age population ratio for the same period. However, the existence of contemporaneous positive relationship between per capita GDP growth and speed of changes could be compatible with both views: speed of change and direction of change.

So, firstly, we ran again previous regressions with some modification of the time period in such a way that there is no overlap of time periods for which dependent variables and measures of speed of demographic transition are constructed. Specifically, in this subsection, the speed of changes in working-age population ratio is measured for the period from 1960 to 1980 and the per capita GDP growth rate and human capital accumulation are measured for the period from 1980 to 2004. The idea is to cut the channel where the changes in working-age population ratio affect per capita GDP growth by increasing per capita labor supply, and see whether our main results are preserved. Secondly, we ran regressions with SWRATIO replaced by absolute value of SWRATIO. Given the existence 36 countries with the estimated values of SWRATIO negative, this procedure will reduce the “direction” nature of the measure.

The first column of Table 8 is the reproduction of regression (3) (OLS) of Table 5, the second column is the regression result with the overlap of time periods minimized, and the third column is the regression results which is the same as the first column except that SWRATIO is replaced with absolute value of SWRATIO. The table shows that our main results are still preserved in these additional regressions. That is, column (2) shows that the speed of changes in working-age population ratio is still strongly correlated with growth of per capita GDP in subsequent non-overlapping period, and the size of the coefficient became even larger. Also, the absolute value of SWRATIO performed equally well. Thus, our main regression results seem to capture the relationship between the *speed* of demographic transition and growth.[19]

// Insert Table 8 here //

V. Quality-quantity Choice in Korea: Evidence form Household Survey

In the previous section, we have shown that change in demographic structure is closely related to both human capital accumulation and economic growth. As already discussed in Section II in detail, the main factor that derives the linkage between demographic structure and economic performance is the decision made by households facing trade-off between quality and quantity of children in response to changing rate of return to human capital. Therefore, it is quite an interesting exercise to examine whether the quality-quantity trade-off channel in household's fertility and human capital investment decisions is actually working at household level.

In this section, we present some evidence that explicit choice between quality and

[19] As mentioned already, the fact that all three measures of speed of demographic transition are

quantity of children is deliberately made by Korean households. There are already many studies that confirm the validity of quality-quantity trade-off hypothesis both in developed and developing countries.[20] However, we believe that it would be very interesting to re-examine the hypothesis in Korean context considering the fact that Korea has experienced one of the fastest both economic growth and demographic transition.[21]

The National Statistical Office of Korea has been conducting a household survey on income and expenditure, National Household Survey, since 1963. The Survey started with the sample of wage earners residing in urban areas and later extended the coverage to include both the self-employed and non-urban residents. The survey conveys detailed information on both sides of cash flow, income and expenditure as well as demographic information such as number of children. The Survey consists of five segments of rotating panels that each segment stays at the sample for five years. Samples from the surveys conducted in 1998 and 2007 are used. Since we are interested on human capital investment on children, we include households with dependents of age below than 30.[22]

We suggest the following regression specification;

$$lave\_ex_i = \alpha N_i + \beta' X_i + \varepsilon_i$$

---

significantly related with growth is also conducive to our proposition.

[20] See Hanushek(1992) or Grawe(2005), among others.

[21] There are some, if not many, studies that examine the hypothesis in Korean context such as Lee (2007). We do not claim that our study presents new evidence on the topic but that a new regression specification and an innovative approach to instrumental variables in our study may provide more solid empirical evidence supporting quantity-quality trade-off hypothesis.

[22] It is generally observed in Korea that children do not leave their parents' house until they graduate college – almost 80% of high school graduates go to college in Korea- and get the job or get married. For male children, they are typically 27~30 years old when they leave parents' house. Therefore, expenditures on education appear in the cash flow of households with dependents aged younger than, say, 30.

where $lave\_ex_i$ is the log of per child expenditure on education[23] by household *i*, N_i is the number of children in household *i*, and X_i is the vector of covariates. We include as explanatory variables average age of children and its square, educational achievement of household head and, if any, his or her partner measured by the number of schooling years, sex of household heads, log of total debt repayment, log of disposable income. Average age of children and its square term are included to account for possible differences in educational expenditure by level of schooling. We expect per capital educational expenditure to be inverted-U shaped reflecting the fact that educational expenditure increases as children advance to higher level of schooling at a decreasing rate. Parental educational levels are expected to exert positive impacts on average educational expenditure of their children. The reason we included the sex of household head as an explanatory variables is that women are known to put more emphasis on children's education than men in Korea. So the households headed by women are more likely to allocate more resources to children's education than the ones headed by men. Log of total debt repayment defined as the total debt service including the principal and interest payments is thought to have negative impact on educational expenditure and log of disposable income positive impact.

Negative estimated coefficient on the number of children N_i implies that as more children are born, the family responds by reducing the size of resources devoted to each child's education. As long as the price for one unit of education quality does not vary across household,[24] one can interpret a statistically significant and negative estimate of

[23] As properly pointed out by one commentator, educational expenditure reported in National Household Survey includes expenditure on education of household member other than children, which implies that our dependent variable may be plagued with measurement error. However, if the measurement error in dependent variable is not correlated with other variables and across observational units, we still obtain a consistent estimator without taking further remedial measures.

[24] The assumption will hold if households are "price takers" in the market for education.

the coefficient on N_i as a supporting evidence for quality-quantity trade-off hypothesis. Note that a household's total expenditure on education tot_ex_i can be decomposed into three different components; quality of education q_i, price for one unit of education quality p_q, and the number of children N_i.

$$tot\_ex_i = p_q \times q_i \times N_i$$

Therefore,

$$lave\_ex_i = \ln\left(\frac{tot\_ex_i}{N_i}\right) = \ln\left(p_q \times q\right).$$

Then,

$$\alpha = \frac{\partial\left(lavg\_ex\right)}{\partial N_i} = \frac{\partial\left(\ln\left(p_q q\right)\right)}{\partial N_i} = \frac{1}{q}\frac{\partial q}{\partial N_i}$$

A fundamental difficulty with the specification suggested above is that the key explanatory variable N_i suffers from an econometric problem, endogeniety bias. The key presumption in the theoretical literature that we pay close attention to in the paper is that fertility is the result of deliberate choice of a family and decisions on fertility cannot be separated from the ones on human capital investment. In other words, the number of children, the explanatory variable of our primary concern, is determined jointly with the dependent variable, quality of education and hence orthogonality condition crucial for the consistency of ordinary least squares estimator cannot be maintained. In order to cope with the problem, we need to find proper instruments required for GMM estimation. Along with all explanatory variables in the regression except for N_i, we use two instrumental variables; dummy for the sex of the first child and age difference between the first child and mother. Some researchers argue that the sex of the first child is strongly correlated with the number of children in the family, especially in East Asian countries such as Korea and China where preference for male child is still strong due to Confucius tradition (Lee (2007)). Family whose first child happens to be male is less likely to have another child than the family with female child as the first child. The other instrument we propose, age difference between the first child and the mother, could be also strongly correlated with the number of children in a family. That is, larger age difference implies that the mother got married and then bore the first child at relatively old age and the number of children she eventually delivers is more likely to be small. On the other hand, there is no particular reason to believe that the age gap between the first child and the mother is correlated with the average educational expenditure. It is highly unlikely that a woman postpones marriage for the concern on fertility decision.

For comparison's sake, we report the results of both OLS and GMM in <Table 5>. OLS estimate for the coefficient on the number of children shows a downward bias compared to GMM estimate. Households with higher educational achievement by parents, especially household head and lower debt burden show the tendency to spend more on education of each child. Interestingly and as expected, female headed households spend more on education. The inverted U relationship between average educational expenditure and children's average age is also confirmed by the result. According to the estimates, it seems that average expenditure on education increases with increasing rate after kid's age reached 5. One result that cannot be intuitively understood is the relationship between household's income and educational expenditure per child. Households with less income show the tendency to spend more on education for each child. Statistically significant negative estimate of the key explanatory variable confirms the hypothesis that quality-quantity trade-off channel is working in fertility and human capital investment decisions among Korean households.

VI. Conclusion

We have presented some empirical evidence both at macro and micro levels for possible linkage between demographic transition and long-term economic performance. A group of literature represented by Becker, Murphy, and Tamura (1990), Tamura (1995), and Lucas (2002) paid particular attention to the role played by human capital and endogenous fertility decision in the process of economic growth. They show that an increase in rate of return to human capital may trigger a shift from low-growth high-fertility Malthusian equilibrium to high-growth low-fertility development equilibrium by stimulating human capital investment and substitution of quantity with quality of children. One of the neglected implications from these theoretical studies is that possibility that *the speed of demographic transition* is positively correlated with *the speed of economic growth*. Noting that human capital investment shows increasing rate of returns over a certain range (Becker, Murphy, and Tamura (1990)) or positive externality at the global level (Tamura (1990)), one can infer that an increase in return to human capital investment large enough to push the human capital stock over the threshold level brings accelerated human capital investment and demographic transition, which ultimately results in faster economic growth. Despite very sophisticated and convincing arguments forwarded by the theoretical works, it is not easy to find empirical studies to tackle the issue directly as we did in this paper.

Utilizing cross-county growth regression framework well accepted by most researchers, we present a pretty robust evidence to support our hypothesis that faster demographic transition is positively correlated with faster growth in per capita income. It is needless to say that the validity of our findings seriously depends on the appropriateness of the measure we suggested for speed of demographic transition. We took the slope of linear time trend in various demographic measures such as fertility rate and working age population ratio. Checking the plausibility of the measure in several aspects we believe that the measure we utilized in the paper indeed represents the speed of change in demographic indicators we chose reasonably well. We also provided some evidence for the hypothesis that relates the speed of human capital accumulation with the speed of demographic transition. Finally, we examined the existence of quality-quantity trade-off in human capital investment with Korean household data. Korea has gone through one of the fastest change in both economic growth and demographic structure and provides a good platform in which we can investigate the existence of linkage between the fertility choice and decision on human capital accumulation. We found a favorable evidence for quality-quantity trade-off hypothesis.

References

Barro, Robert J. 1991. "Economic Growth in a Cross Section of Countries," Quarterly Journal of Economics, Vol. 106, 407-444.

Barro, Robert J., and Xaview Sala-i-Martin. 1995. *Economic Growth*. New York: McGraw-Hill.

Barro, Robert J. and J. W. Lee. 2001. "International Data on Educational Attainment: Updates and Implications", *Oxford Economic Papers* Vol.53, No.3, Special Issue on Skills Measurement and Economic Analysis, pp.541-563

Barro, R. J., and J. W. Lee, 1994, "Sources of Economic Growth," Carnegie-Rochester Conference Series on Public Policy 40(June): pp.1-46.

Becker, Gary S. 1960, "An Economic Analysis of Fertility." In Demographic and Economic Change in Developed Countries. Universities-National Bureau Conference Series, no. 11. Princeton, N.J.: Princeton Univ. Press (for NBER),

Becker, G. S., K. M. Murphy, and R. Tamura, 1990, "Human Capital, Fertility, and Economic Growth," Journal of Political Economy, Vol.98, No.5, pp.S12-S37.

Bloom, David E. and J. G. Williamson, 1998, "Demographic Transitions and Economic Miracles in Emerging Asia," The World Bank Economic Review, Vol.12, No.3, pp.419-455.

Brander, J.A., and Steve Dowrick. 1994. "The Role of Fertility and Population in Economic Growth: Empirical Results from Aggregate Cross-National Data," *Journal of Population Economics* 7(1), pp. 1-25.

Cutler, D. M., J. M. Poterba, L. M. Sheiner, and L. H. Summers, 1990, "An ageing society: Opportunity or Challenge?"' Brookings Papers on Economic Activity, No.1.

Duraisamy, P., James, Estelle., Lane. J., and J. P. Tan, 1998, "Is there a quantity–quality trade-off as pupil–teacher ratios increase? Evidence from Tamil Nadu, India?" International Journal of Educational Development Vol. 18, pp. 367-383

Fougere, M. and M. Merette, 1999, "Population Ageing and Economic Growth in Seven OECD Countries," Economic Modelling Vol.16, pp.411-427.

Kelly, Allen C., and Robert M. Schmitt. 1995. “Aggregate Population and Economic Growth Correlations: The Role of Components of Demographic Change,” Demography 32(4). Pp. 543-55

Knack, Stephen and Phillip Keefer. 1995. "Institutions and Economic Performance: Cross-Country Tests Using Alternative Institutional Measures," Economics and Poitics, 1995, pp. 207-228.

Lee, Jungmin., 2007. “Sibling size and investment in children’s education: an Asian instrument,” Journal of Population Economics, Online version.

Levine, Ross and David Renelt. 1992. “A Sensitivity Analysis of Cross-Country Growth Regressions,” American Economic Review, Vol. 82. No. 4. 942-963.

Lucas, Robert E., 2002. Lectures on Economic Growth, Massachusetts: Harvard University Press.

Romer, Paul M. 1990. "Capital, Labor, and Productivity," Brookings Papers on Economic Activity: Microeconomics 1990, pp. 337-67.

Rosenzweig, M. and K.I. Wolpin 1980. “Testing the Quantity-Quality Fertility Model: The Use of

Twins as a Natural Experiment,” Econometrica, 48, 227-240.

Sachs, J. D., and A. Warner, 1995, "Economic Reform and the Process of Global Integration," Brookings Papers on Economic Activity 1: pp.1-118.

Tamura, R. 1996, “From Decay to Growth: A Demographic Transition to Economic Growth,” Journal of Economic Dynamics and Control 20: pp.1237–1262

Tamura, R., 2000, “Growth, Fertility, and Human Capital: A Survey,” Spanish Economic Review 2: pp.183-229

World Bank. *World Development Indicator*, various years.

Appendix 1. Country Sample and Country Names

Among 185 countries which are included in both PWT 6.2 and WDI, we discarded 44 countries for which we think there are not enough observations to measure the speed of demographic transition and growth of GDP per capita for the period from 1960 to 2004. To be more specific, there were many missing observations for fertility rate for some of the years during the sample period. Since measuring the speed of demographic transition is important in our paper, we tried to minimize the possibility that only a few observations dictate our measure. Also, mostly for transition economies, real GDP variable were not available before the 1990s. Thus, we first divided our sample period into two sub-periods – 1960-1984 and 1985-2004 – and threw away 44 countries that had less than five non-missing entries for real GDP or fertility rate. The table below shows the country names of our sample by region.

// Insert appendix Table 2 here //

Figure 1.A. Trends of the Fertility Rates in Major Regions

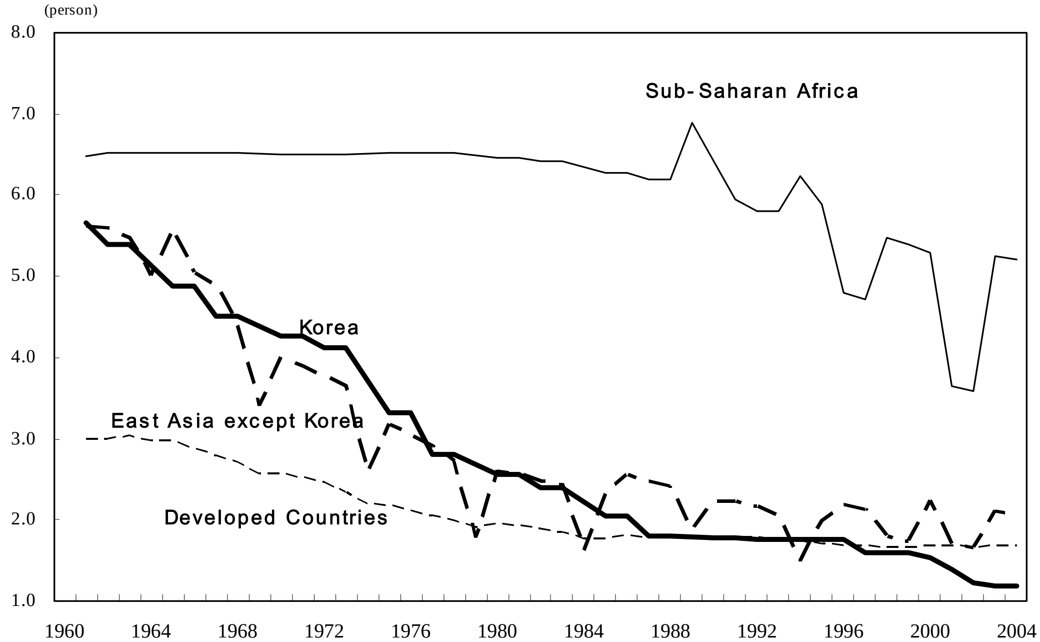


Figure 1.B. Trends of the Death Rates in Major Regions

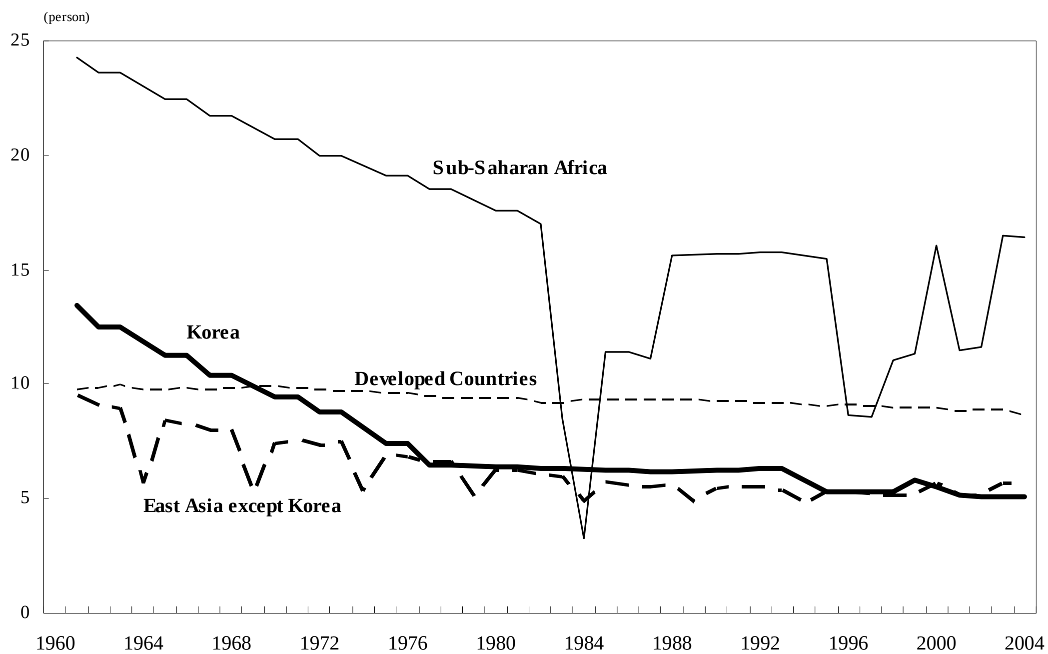


Figure 1.C. Trends of Working-age Population Ratios in Major Regions

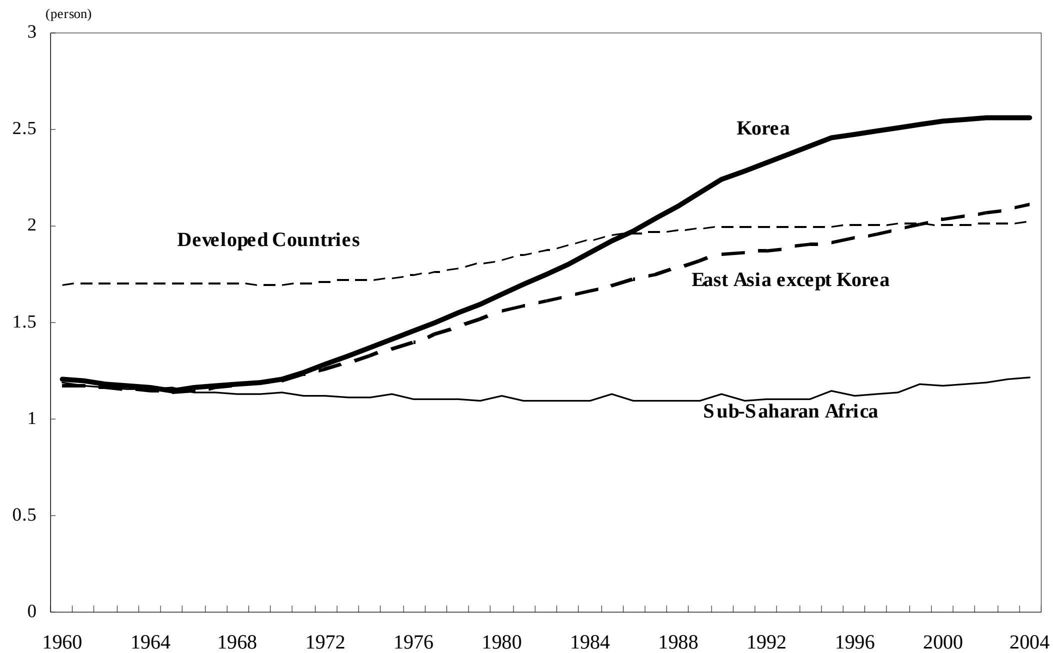


Figure 1.D. Trends of Population Growth Rates in Major Regions

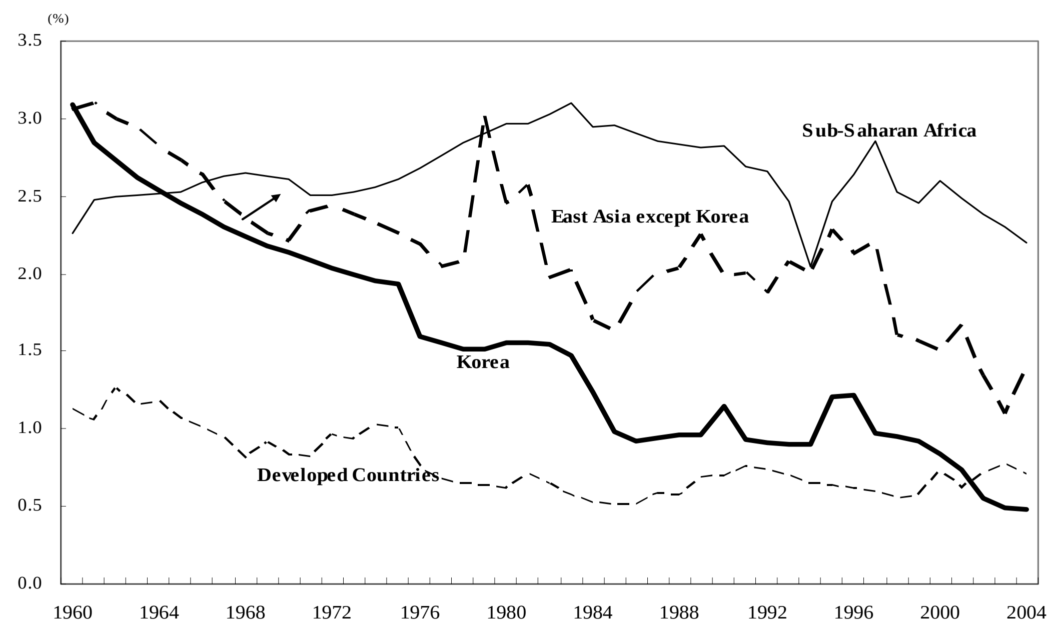
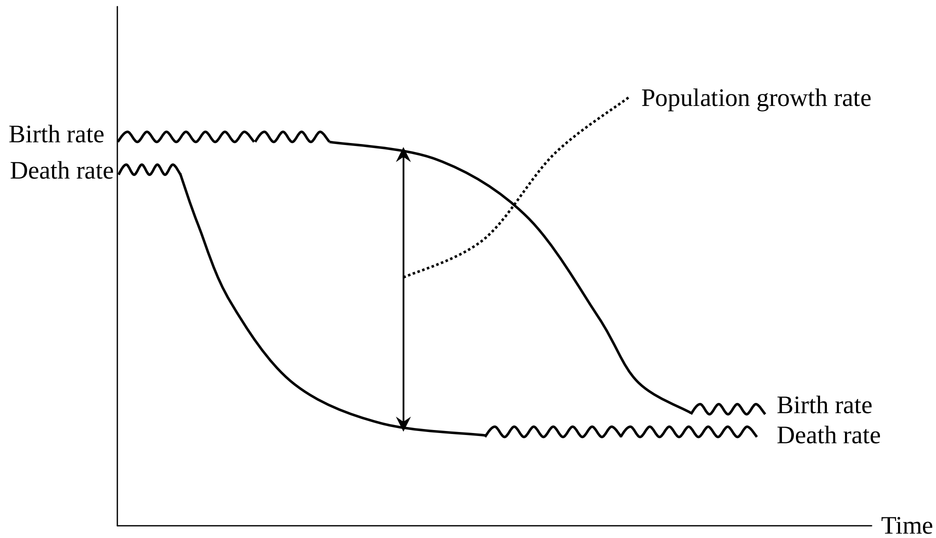
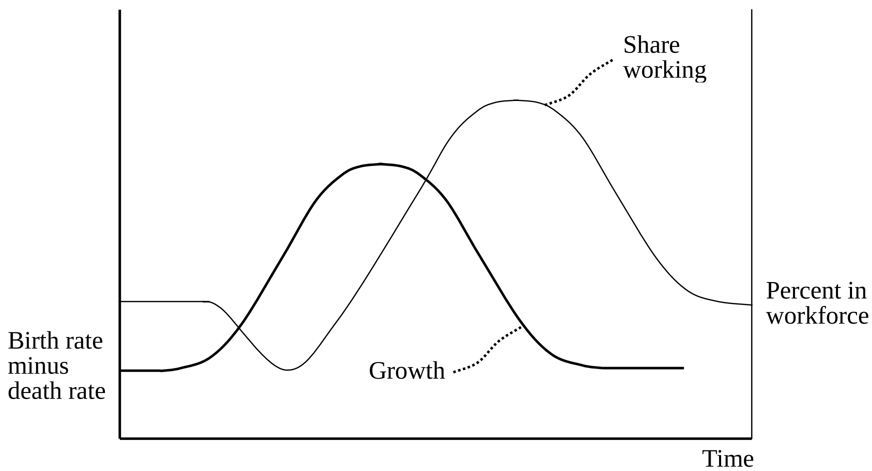


Figure 2. Patterns of Demographic Indicators in a Demographic Transition

fertility rate and death rate



Population growth and working-age population ratio



Source: Bloom and Williamson (1998)

Table 1. Measures of Speed of Demographic Transition: Summary Statistics

A. SFERTIL

Region	mean	std.	min	max	N
EASIA	-0.09	0.01	-0.12	-0.08	7
SASIA	-0.07	0.03	-0.11	-0.01	8
SUBSAHA	-0.03	0.04	-0.11	0.04	43
MENA	-0.10	0.04	-0.15	-0.03	16
LAMERICA	-0.08	0.03	-0.12	-0.02	30
INDUSTRY	-0.04	0.02	-0.10	-0.01	23
PACIFIC	-0.07	0.03	-0.11	-0.03	10
EURCASIA	-0.03	0.01	-0.03	-0.02	3
CHINA	-0.11		-0.11	-0.11	1
Total	-0.06	0.04	-0.15	0.04	141

B. SWRATIO

Region	mean	std.	min	max	N
EASIA	0.03	0.01	0.01	0.04	7
SASIA	0.01	0.01	0.00	0.02	8
SUBSAHA	0.000	0.01	-0.01	0.03	43
MENA	0.01	0.01	0.00	0.03	16
LAMERICA	0.01	0.01	0.00	0.04	30
INDUSTRY	0.01	0.01	0.00	0.02	23
PACIFIC	0.02	0.02	0.00	0.06	10
EURCASIA	0.01	0.004	0.00	0.01	3
CHINA	0.03		0.03	0.03	1
Total	0.01	0.01	-0.01	0.06	141

C. SPOPGR

Region	mean	std.	min	max	N
EASIA	-0.03	0.02	-0.07	0.00	7
SASIA	-0.01	0.03	-0.04	0.05	8
SUBSAHA	-0.001	0.03	-0.14	0.08	43
MENA	-0.04	0.06	-0.22	0.02	16
LAMERICA	-0.02	0.02	-0.07	0.01	30
INDUSTRY	-0.01	0.01	-0.03	0.01	23
PACIFIC	-0.02	0.03	-0.07	0.02	10
EURCASIA	-0.03	0.01	-0.04	-0.02	3
CHINA	-0.03		-0.03	-0.03	1
Total	-0.02	0.03	-0.22	0.08	141

Table 2. Sign Distributions of Measures of Speed of Demographic Transition

	No. of Countries with Positive Coefficient	No. of Countries with Negative Coefficient	Total number of countries
SFERTIL	8 (3,2,0)	133 (128,0,1)	141
SWRATIO	105 (98,0,0)	36 (29,1,2)	141
SPOPGR	34 (19,3,3)	107 (81,4,4)	141

Note: a. The speed of demographic transition using, for example, fertility rate (SFERTIL), is the slope of the simple regressions of fertility rate on year variable.

b. Numbers in parentheses are number of countries which have estimated coefficient significant at 1%, 5% and 10% level, respectively.

Table 3. Correlations between Speed of Demographic Transition and per capita GDP Growth

	GRGDPL	SFERTIL	SWRATIO	SPOPGR
GRGDPL	1.00 (0.0000)	-0.22 (0.0078)	0.45 (0.0001)	-0.01 (0.9247)
SFERTIL	-0.22 (0.0078)	1.00 (0.0000)	-0.64 (0.0001)	0.61 (0.0001)
SWRATIO	0.45 (0.0001)	-0.64 (0.0001)	1.00 (0.0000)	-0.54 (0.0001)
SPOPGR	-0.01 (0.9247)	0.61 (0.0001)	-0.54 (0.0001)	1.00 (0.0000)

Note: a. Numbers in parentheses are p-values.

b. Measures of speed of demographic transition are for the period from 1960 to 2004. GRGDPL is annual average real per capita GDP growth rate for the same period.

Table 4. Per Capita GDP Growth: Changes in Fertility Rate

	(1)	(2)		(3)		(4)	
	OLS	OLS	GMM	OLS	GMM	OLS	GMM
SFERTIL		-19.128***	-11.016	-15.675***	-10.212*	-14.365***	-14.155***
		(-5.10)	(-1.59)	(-3.22)	(-1.87)	(-2.84)	(-2.47)
Initial GDP per capita	-0.245*	-0.208*	-0.312***	-0.248**	-0.442***	-0.518***	-0.593***
	(-1.85)	(-1.75)	(-3.01)	(-2.00)	(-5.18)	(-3.29)	(-5.37)
Investment share	10.120***	6.640***	18.343***	3.876	7.250*	1.048	-1.409
	(3.83)	(2.70)	(5.14)	(1.40)	(1.92)	(0.34)	(-0.42)
Population growth	-0.514**	-0.932***	-0.612***	-0.656***	-0.298	-0.247	0.324
	(-2.37)	(-4.42)	(-2.92)	(-2.75)	(-1.48)	(-0.88)	(1.62)
Secondary school enrollment	2.455*	1.549	1.799*	0.127	1.117	-0.084	1.904**
	(1.81)	(1.26)	(1.79)	(0.10)	(1.42)	(-0.06)	(2.22)
Primary school enrollment				1.161*	1.563**	0.909	1.348*
				(1.67)	(2.08)	(1.17)	(1.64)
Government share				-1.475	3.882*	-0.993	-0.244
				(-0.47)	(1.83)	(-0.28)	(-0.09)
Socialist economy				-0.114	-0.501	-0.396	0.666
				(-0.25)	(-0.82)	(-0.77)	(1.42)
Revolution / Coups				-0.610	-0.768*	-0.295	-0.720
				(-0.97)	(-1.67)	(-0.39)	(-1.19)
Africa dummy				-0.868*	-1.374***	-1.139**	-0.959
				(-1.85)	(-3.62)	(-2.02)	(-1.61)
Latin America dummy				-1.209***	-1.036***	-0.708*	-0.599*
				(-3.13)	(-3.41)	(-1.70)	(-1.85)
Quality of Institutions						0.397***	0.365***
						(2.84)	(3.11)
Openness						0.246	1.237**
						(0.37)	(2.61)
Natural resource abundance						-3.178*	-5.484***
						(-1.90)	(-3.20)
Terms of trade						0.112	0.011
						(1.48)	(0.15)
No. Obs.	107	107	86	103	83	86	75
Adj. R^2	0.292	0.431	0.368	0.479	0.485	0.590	0.582
J-statistic			0.105		0.096		0.083

Note: a. SFERTIL is the estimated speed measure for fertility rate.

b. Numbers in parentheses are t-statistics.

c. ***, **, and * indicate that the estimated coefficient are statistically significant at 1%, 5% and 10% level, respectively.

d. J-statistic is the test statistic for over-identifying restrictions for GMM estimates. The test statistic is distributed as χ^2 with the degrees of freedom 7.

Table 5. Per Capita GDP Growth: Changes in Working-Age Population Ratio

	(1)	(2)		(3)		(4)	
	OLS	OLS	GMM	OLS	GMM	OLS	GMM
SWRATIO		82.416***	56.436***	72.406***	57.736***	66.979***	102.29***
		(6.33)	(3.03)	(4.49)	(3.38)	(3.76)	(4.85)
Initial GDP per capita	-0.245*	-0.212*	-0.371***	-0.270**	-0.377***	-0.536***	-0.482***
	(-1.85)	-(1.88)	(-5.41)	(-2.32)	(-5.65)	(-3.56)	(-5.15)
Investment share	10.120***	5.467**	9.098**	2.774	4.642	0.473	-2.874
	(3.83)	(2.32)	(2.14)	(1.04)	(1.15)	(0.16)	(-0.67)
Population growth	-0.514**	-0.543***	-0.622***	-0.389**	-0.308**	-0.126	-0.265
	(-2.37)	(-2.95)	(-4.33)	(-2.00)	(-2.09)	(-0.51)	(-1.45)
Secondary school enrollment	2.455*	1.302	2.058***	-0.126	0.208	-0.106	0.652
	(1.81)	(1.12)	(2.86)	(-0.10)	(0.29)	(-0.08)	(0.69)
Primary school enrollment				1.075	1.155*	0.802	1.044
				(1.63)	(1.86)	(1.07)	(1.36)
Government share				2.558	5.631**	3.169	3.673
				(0.81)	(2.47)	(0.90)	(1.20)
Socialist economy				-0.059	-0.231	-0.425	0.517
				(-0.14)	(-0.42)	(-0.86)	(1.18)
Revolution / Coups				-0.207	-0.466	0.110	-0.175
				(-0.34)	(-1.26)	(0.15)	(-0.34)
Africa dummy				-0.849**	-1.418***	-1.078**	-0.800
				(-2.00)	(-3.89)	(-2.04)	(-1.46)
Latin America dummy				-1.011***	-0.955***	-0.552	-0.554*
				(-2.73)	(-3.44)	(-1.37)	(-1.75)
Quality of Institutions						0.357**	0.174
						(2.64)	(1.52)
Openness						-0.107	0.350
						(-0.16)	(0.81)
Natural resource abundance						-3.197**	-3.935*
						(-2.01)	(-1.88)
Terms of trade						0.123*	0.036
						(1.69)	(0.57)
obs	107	107	86	103	93	86	75
adj_R-sq	0.292	0.488	0.458	0.526	0.517	0.620	0.616
J-statistic			0.079		0.019		0.029

Note: a. SWRATIO is the estimated speed measure for working age population rate.

b. Numbers in parentheses are t-statistics.

c. ***, **, and * indicate that the estimated coefficient are statistically significant at 1%, 5% and 10% level, respectively.

d. J-statistic is the test statistic for over-identifying restrictions for GMM estimates. The test statistic is distributed as χ^2 with the degrees of freedom 7.

Table 6. Per Capita GDP Growth: Changes in Population Growth Rate

	(1)	(2)		(3)		(4)	
	OLS	OLS	GMM	OLS	GMM	OLS	GMM
SPOPGR		-25.730*** (-3.74)	-34.356*** (-2.80)	-13.530* (-1.68)	-20.131 (-1.23)	-13.717 (-1.45)	-9.373 -(0.65)
Initial GDP per capita	-0.245* (-1.85)	-0.283** (-2.26)	-0.420*** (-4.00)	-0.333*** (-2.65)	-0.430*** (-4.71)	-0.615*** (-3.71)	-0.559*** (-4.44)
Investment share	10.120*** (3.83)	8.303*** (3.28)	14.333*** (4.08)	4.516 (1.57)	11.165*** (2.89)	1.007 (0.31)	0.443 (0.11)
Population growth	-0.514** (-2.37)	-0.893*** (-3.92)	-0.903*** (-3.45)	-0.490* (-1.92)	-0.485 (-1.46)	-0.133 (-0.42)	0.389 (1.09)
Secondary school enrollment	2.455* (1.81)	1.142 (0.86)	1.267 (1.19)	-0.374 (-0.28)	0.294 (0.36)	-0.656 (-0.46)	1.055 (1.09)
Primary school enrollment				1.401* (1.92)	0.628 (0.76)	1.131 (1.41)	0.906 (0.99)
Government share				-1.199 (-0.36)	3.055 (1.34)	-0.062 (-0.02)	-1.049 (-0.40)
Socialist economy				0.012 (0.03)	-0.284 (-0.43)	-0.321 (-0.60)	0.771 (1.43)
Revolution / Coups				-0.694 (-1.07)	-0.647 (-1.55)	-0.455 (-0.57)	-0.614 (-1.12)
Africa dummy				-1.380*** (-3.09)	-1.399*** (-3.43)	-1.551*** (-2.77)	-1.988*** (-3.23)
Latin America dummy				-1.188*** (-2.96)	-0.909*** (-3.10)	-0.680 (-1.57)	-0.738** (-2.36)
Quality of Institutions						0.384** (2.64)	0.345** (2.53)
Openness						0.320 (0.46)	1.011** (2.26)
Natural resource abundance						-3.657** (-2.09)	-3.206 (-1.52)
Terms of trade						0.156* (1.90)	-0.021 (-0.25)
obs	107	107	86	103	83	86	75
adj_R-sq	0.292	0.372	0.369	0.438	0.416	0.557	0.490
J-statistic			0.073		0.088		0.106

Note: a. SPOPGR is the estimated speed measure for population growth rate.

b. Numbers in parentheses are t-statistics.

c. ***, **, and * indicate that the estimated coefficient are statistically significant at 1%, 5% and 10% level, respectively.

d. J-statistic is the test statistic for over-identifying restrictions for GMM estimates. The test statistic is distributed as χ^2 with the degrees of freedom 7.

Table 7. Regressions of Human Capital Accumulation

	TYR	PYR	SYR	HYR
	-0.373***	-0.291***	-0.080	-0.014
SFERTIL	(-4.78)	(-6.15)	(-1.50)	(-0.91)
	[0.18]	[0.27]	[0.01]	[-0.001]
	-0.421***	-0.158**	-0.228***	-0.049***
SPOPGR	(-3.89)	(-2.18)	(-3.37)	(-2.38)
	[0.13]	[0.04]	[0.09]	[0.04]
	1.563***	0.487**	0.919***	0.201***
SWRATIO	(5.57)	(2.44)	(5.25)	(3.70)
	[0.23]	[0.02]	[0.21]	[0.11]

Note: a. Numbers in parentheses are t-statistics and numbers in bracket are Adj.R-square.

b. The number of observation is 100.

c. Coefficients with asterisks are significant at 1%(***), 5%(**), and 10%(*) level, respectively.

Table 8. Per Capita GDP Growth: Changes in Working-Age Population Ratio

	1	2	3
SWRATIO	72.406*** (4.49)	91.720*** (4.85)	56.996*** (3.06)
Initial GDP per capita	-0.270** (-2.32)	-0.278** (-2.03)	-0.296** (-2.43)
Investment share	2.774 (1.04)	-1.754 -(0.56)	1.953 (0.67)
Population growth	-0.389** (-2.00)	-0.631*** (-2.75)	-0.257 (-1.27)
Secondary school enrollment	-0.126 (-0.10)	0.153 (0.11)	0.072 (0.06)
Primary school enrollment	1.075 (1.63)	0.796 (1.02)	1.440** (2.11)
Government share	2.558 (0.81)	3.378 (0.90)	1.112 (0.34)
Socialist economy	-0.059 (-0.14)	-0.032 (-0.06)	0.084 (0.18)
Revolution / Coups	-0.207 (-0.34)	0.058 (0.08)	-0.611 (-0.97)
Africa dummy	-0.849** (-2.00)	-0.440 (-0.88)	-1.280*** (-3.02)
Latin America dummy	-1.011*** (-2.73)	-1.157*** (-2.66)	-1.125*** (-2.89)
obs	103	102	103
adj_R-sq	0.526	0.446	0.474

Note: a. Numbers in parentheses are t-statistics.

b. ***, **, and * indicate that the estimated coefficient are statistically significant at 1%, 5% and 10% level, respectively.

Table 9. Quality-Quantity Trade-off: Korean Case

	OLS	GMM
Number of children	-0.0237*	-0.0113*
	(-1.77)	(-1.69)
Average age of children	0.3081***	0.2873**
	(5.22)	(3.21)
Average age of children squared	-0.0233***	-0.0258**
	(-2.33)	(-3.01)
Household head's years of schooling	0.1063***	0.0953***
	(4.49)	(4.03)
Sex of household head	-0.1083**	-0.0992*
	(-2.02)	(-1.81)
Partner's years of schooling	0.0523***	0.0456**
	(3.53)	(2.02)
Debt repayment	-0.2001***	-0.1692***
	(-3.00)	(-2.99)
Disposable income	-0.0263**	-0.1210*
	(-2.19)	(-1.77)
Constant	10.0854***	11.8321***
	(3.68)	(3.91)
# of obs.	3184	3184
R^2	0.1026	-
J-Statistic	-	2.56E-4

Note: a. Dependent variable is log of per child expenditure on education.

b. Dummy for the sex of the first and age difference between the first two children are used as instruments in GMM estimation.

c. J-statistic is under the null of non over-identifying restrictions is distributed as chi-square with the degrees of freedom 2.

d. Coefficients with asterisks are 1%(***), 5%(**), and 10%(*) level, respectively. Numbers in parentheses are t-statistics

Appendix Table 1. Trends in Demographic Indicators of Korea: 1960-2004

Year	Fertility rate (person)	Death rate (person/1,000)	Life expectancy (Age)	Population growth rate (%)	Working-age population ratio (person)
1960	5.67	13.46	54.15	3.09	1.21
1965	4.87	11.24	56.68	2.46	1.15
1970	4.27	9.44	59.93	2.13	1.20
1975	3.32	7.42	63.89	1.93	1.42
1980	2.56	6.38	66.84	1.56	1.64
1985	2.04	6.24	68.65	0.99	1.92
1990	1.77	6.26	70.28	1.15	2.24
1995	1.75	5.30	71.77	1.21	2.46
2000	1.47	5.20	75.86	0.84	2.55
2004	1.16	5.10	77.14	0.49	2.56

Note: a. The fertility rate is the number of babies that one woman gives birth to throughout her life.

b. The death rate is the number of the deceased per 1,000 people.

c. The working age population ratio is the reciprocal of dependency ratio, which is the number of working age people aged 15-64 per one dependent person aged under 15 or over 65.

Sources: World Bank, World Development Indicator, various issues

Appendix table 2. Country Sample

141 Countries

East Asia

(7 countries)

Hong Kong, China
Indonesia
Korea
Malaysia
Philippines
Singapore
Thailand

South Asia

(8 countries)

Afghanistan
Bangladesh
India
Maldives
Nepal
Oman
Pakistan
Sri Lanka

Pacific

(10 countries)

Brunei
Cambodia
Fiji
Kiribati
Korea, Dem. Rep.
Lao PDR
Macao, China
Mongolia
Papua New Guinea
Solomon Islands

Sub-Saharan Africa

(43 countries)

Benin
Botswana
Burkina Faso
Burundi
Cameroon
Cape Verde
Central Africa Rep.
Chad
Cote d'Ivoire
Equatorial Guinea
Ethiopia
Gabon
Gambia
Ghana
Guinea
Guinea-Bissau
Kenya
Lebanon
Lesotho
Madagascar
Malawi
Mali
Mauritania
Mauritius
Mozambique
Namibia
Niger
Nigeria
Qatar
Rwanda
Senegal
Sierra Leone
Somalia
South Africa
Swaziland
Sudan
Tanzania
Togo
Uganda
Zambia
Zimbabwe

East Europe and Middle Asia

(3 countries)

Hungary
Poland
Romania

Middle East and North Africa

(16 countries)

Algeria
Bahrain
Cyprus
Djibouti
Egypt
Iran
Iraq
Israel
Jordan
Kuwait
Malta
Moroco
Saudi Arabia
Syrian Arab Rep.
Tunisia
United Arab Emirates

Latin America

(30 countries)

Antigua and Barbuda
Argentina
Bahamas
Barbados
Belize
Bolivia
Brazil
Channel Islands
Colombia
Costa Rica
Cuba Dominican Rep.
Ecuador
El Salvador
Guatemala
Haiti
Honduras
Jamaica
Mexico
Netherlands Antilles
Nicaragua
Panama
Paraguay
Peru
Puerto Rico
St. Lucia
Suriname
Trinidad Tobago
Uruguay
Venezuela

Industrial Countries

(23 countries)

Australia
Austria
Belgium
Canada
Denmark
Finland
France
Greece
Iceland
Ireland
Italy
Japan
Luxembourg
Netherlands
New Zealand
Norway
Portugal
Spain
Sweden
Switzerland
Turkey
United Kingdom
United States

China