Demographic Change and Economic Growth:
It's More Important than We Thought

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I. Introduction

It has long been believed that population growth can dampen the economic growth. However, not until recently can economists prove this relationship empirically. The problem is that demographic transitions have both positive and negative effects on the economic growth. Often, these two effects cancel out and leave us observe no net relationship. Bloom and Williamson (1996) estimated cross-country growth convergence model with the growth of total population and working-age population as explanatory variables and found that these two variables work in the opposite direction. This paper is aimed to re-examine these recent studies on demographic transition and economic growth. We argue that it is as important to consider their economic significance as well as to test their statistical significance. Estimates provided by Bloom and Williamson, although significant, have values that are inconsistent with the theory. We raise the possibility that the demographic transitions affect not only the current income but the income at the steady state as well. Also, we argue that this relationship between demographic transition and economic growth may be complex and different between the long-run and short-run.

II. Economic Growth and Demographic Change

A usual starting point of studies on cross-country economic growth is the convergence of income. The neoclassical growth theory typically implies that the income per worker should converge to its steady-state equilibrium in the long run. We can linearize the path of convergence around the steady state to obtain a linear path as the following (Romer, 2000):

$$\ln(Y_t/L_t) - \ln(Y_0/L_0) = (1 - e^{-\lambda t})[\ \ln(Y^*/L^*) - \ln(Y_0/L_0)\ ] + \varepsilon_t \qquad (1)$$

where Y_t is the aggregate income, and L_t is the number of workers. Time 0 denotes the initial period. The term Y^*/L^* denotes the income per worker at the steady state. Equation (1) implies that an economy with larger difference between initial and steady-state income should experience a higher economic growth rate. The speed of convergence, which describes how fast a country closes the gap between the initial income and its steady-state level each year, is given by λ. It is traditionally believed that the speed of convergence is around 2% (Shioji, 1997).

Yet, many researchers are more interested in the convergence of income per capita rather than the income per worker. The income per capita is argued to be a more appropriate measure when dealing with the welfare distribution issue, while the income per worker is more proper for analyzing the efficiency. We can write down an identity relating income per worker and income per capita as:

$$\ln(y_t) - \ln(y_0) \equiv \ln(L_t/L_0) - \ln(N_t/N_0) + \ln(Y_t/L_t) - \ln(Y_0/L_0) \qquad (2)$$

where $y_t \equiv (Y_t/N_t)$ is the income per capita, and N_t is the total population. The term $\ln(L_t/L_0)$ and $\ln(N_t/N_0)$ are the growth rate of workers and total population from time 0 to time t, respectively. Following this identity, a 1-percentage rise in growth of working-age population[1] must increase the growth of income per capita by 1 percent, and so does a 1-percentage decline in the growth of total population.

Equation (2) gives us the first link between demographic transition and economic growth. The demographic transition usually occurs in 3 stages, and each stage affects the growth of working-age population and total population differently. Declines in mortality rate indicate the first stage of transition. The second stage starts when fertility begins to decline. The transition is completed when both mortality and fertility rates are stabilized at low levels. At the onset of the transition, low mortality and high fertility causes a rapid increase in the population growth. This results in a higher dependency ratio. Since there are more people to share the same amount of wealth, the growth of income *per capita* should slow down at this stage. After a lag, working-age population begins to grow rapidly. There are more workers available for production, which leads to a rapid increase in income.

We can substitute (1) into (2) and obtain the convergence condition in per captia term as the following equation.

$$\ln(y_t) - \ln(y_0) = \ln(L_t/L_0) - \ln(N_t/N_0) + \beta\ln(Y^*/L^*) - \beta\ln(y_0) + \beta\ln(L_0/N_0) + e_t \quad (3)$$

where $\beta \equiv (1 - e^{-\lambda t})$. If equation (2) is the only link between the demographic transition and economic growth, it will give us four restrictions on the parameters in (3); that is, (I) coefficients of $\ln(L_t/L_0)$ and $\ln(N_t/N_0)$ must be equal in magnitude but opposite in sign, (II) coefficient of $\ln(L_t/L_0)$ must be 1, (III) coefficient of $\ln(N_t/N_0)$ must be -1, and (IV) coefficient of $\ln(y_0)$ and $\ln(L_0/N_0)$ must be equal in magnitude but opposite in sign.

[1] We do not attempt to differentiate working-age population, workers or labor force in this paper. In other words, we assume that the labor force participation rate and the unemployment rate are constant over time.

Nevertheless, equation (2) is not the only possible link between demographic transition and economic growth. In the famous Solow (1956) growth model, an increase in the amount of workers reduces the available physical capital per worker, increases the needs for replacement investment, and lessens the economic growth. Mankiw, Romer and Weil (1992; MRW hereafter) also showed the evidence supporting the negative relationship between the growth of working-age population and the growth of income per worker (Y/L).

If we allow the growth of working-age population to affect the steady-state level of income as suggested by Solow; that is, $\ln(Y^*/L^*) = a_0 + \alpha_1\ln(L_t/L_0) + \mathbf{X}_t\varphi + u_t$, we can rewrite equation (3) as the following.

$$\ln(y_t) - \ln(y_0) = a_0 + a_1\ln(L_t/L_0) - \ln(N_t/N_0) + \mathbf{X}_t\gamma - \beta\ln(y_0) + \beta\ln(L_0/N_0) + e_t \quad (4)$$

where $\mathbf{X}_t$ is a vector of other variables affecting the steady-state income per worker. Under (4), we relax restriction I and II but maintain restriction III and IV. The coefficient of working-age population growth, a_1, should be greater than 1, but the coefficient of population growth is still equal to -1.

To complete our discussion here, we need to consider a possibility that the population growth can affect the steady-state income as well. Although this argument is not pervasive in the literature, it is not unlikely. The saving rate is assumed to be exogenous in the Solow model, and it defines the level of steady-state income. Mason (1988), however, pointed out that the demographic transitions can affect the saving rate through changes of savers-dissavers composition. In other words, we assume that the steady-state income is described by $\ln(Y^*/L^*) = a_0 + \alpha_1\ln(L_t/L_0) + \alpha_2\ln(N_t/N_0) + \mathbf{X}_t\varphi + u_t$. Therefore, equation (3) becomes

$$\ln(y_t) - \ln(y_0) = a_0 + a_1\ln(L_t/L_0) + a_2 \ln(N_t/N_0) + \mathbf{X}_t\gamma - \beta\ln(y_0) + \beta\ln(L_0/N_0) + e_t \quad (5)$$

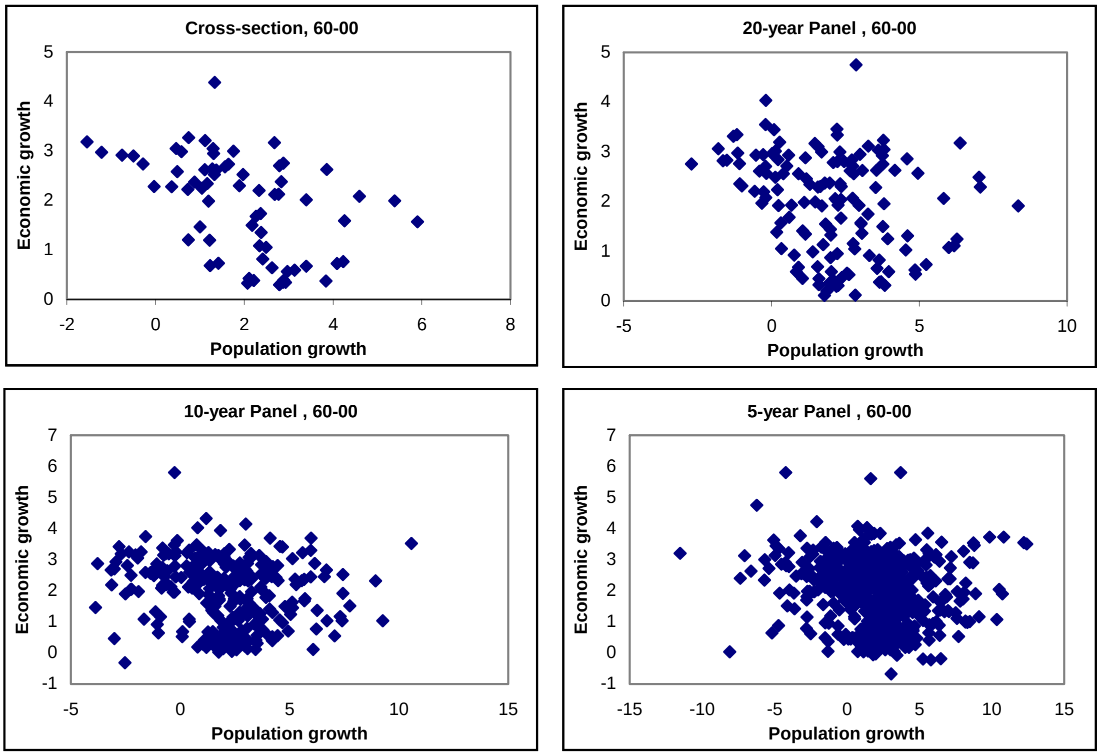
Under this specification, we relax restriction I-III above but still maintain the last restriction.

III. Literature Review

The effect of demographic transitions on the economic growth has long been discussed in the literature. However, because of the opposite effects of population growth and labor force growth, it is sometimes difficult to observe such relationship. Simple scatter plots between population growth and economic growth as shown in Figure 1 are normally not sufficient to draw any conclusion. Although it might be possible to point out a negative relationship between economic growth and population growth in the long run (i.e. when growth is calculated over 40 years), such conclusion become ambiguous in the short run (i.e. when growth is computed over a period less than 40 years). It is true that the population growth has a negative effect on economic growth. However, a faster growth of labor force, which usually follows higher population growth, has a positive effect on the GDP growth. No relationship between population and economic growth observed in Figure 1 may be a result of the two effects canceling out.

Bloom and Williamson (1998; BW hereafter) may be the first who emphasize the different roles played by an increase in population and an increase in worker. They proposed a model similar to (5) to capture the positive and negative effect of demographic transitions. Based on cross-country growth between 1965 and 1990, they concluded that the growth of labor force is positively related to the economic growth, and the population is negatively related to the economic growth.

Figure 1 Population growth and economic growth, 1960-2000



Source: Heston, Summers and Aten (2002)

Although the results from BW seem convincing, many studies that follow have shown 2 major caveats in BW results. The first problem pointed by Kelley an Schmidt (2001) is that the BW seem to focus more on the statistical significance and less on the economic significance. Although the coefficients are significant, the magnitudes are greatly different from what suggested by the theory. BW's estimates of a_1 and a_2 in (5) are mainly 2 and -2 and significantly different from 1 and -1. The second problem pointed by Bloom, Canning and Malaney (1998) that BW have incorrectly transformed equation (2) into (3). The term $\ln(L_0/N_0)$ is omitted from the BW study. The problem with omitted variables is that the estimates will be biased, and this bias will not disappear as the sample size gets larger (Pindyck and Rubinfeld, 1998). However, when Bloom and Canning (2001) added this initial ratio of working-age population to total population, the magnitudes of coefficients depart even further from 1 and -1. The estimated coefficients of working-age population and total population are approximately 3 and -3 instead.

IV. Econometric Specifications and Data Considerations

In this exercise, we estimate equation (5) and many of its variants. There are four issues needed to be addressed here—the length of a time period, the set of control variables, the functional form, and the unobserved heterogeneity problem. The first issue is the length of time over which we consider the growth rates. It is believed that the convergence condition in equation (1) holds only in the long run. BW calculate the growth over a 25-year period from 1965 to 1990. In contrast, Kelley and Schmidt (2001) employ a panel of 10-year growth over 1960-95. In this paper, we collect annual data from 1960 to 2000, which allows us to calculate growth over different lengths of period. We therefore investigate the issue using cross-sectional growth from 1960-2000 (i.e. 40-year period) as well as panel of 20-year, 10-year and 5-year periods. In the panel dataset, we include the time trend to capture the other effects on growth that may vary with time.

The second issue relates to the control variables that may affect the steady-state income. The Solow growth theory obviously provides two important candidate: saving rate and growth of working-age population. Even though saving is an obvious choice, many previous studies, including BW, have ignored this important variable from the study. This paper includes private saving rates as one of the control variables. Further, although the theory also suggests that the depreciation rate and the rate of technology advances are important, it may be very difficult to collect data. Many studies such as MRW avoid this problem by imposing a simplifying assumption that these rates are constant in each country over time. Also, MRW suggest that the difference in educational attainment can explain the differences in growth across countries. We follow MRW by using the average years of secondary schooling in population aged 25 and over to capture the effect of this human capital investment. Data on schooling are collected from Barro and Lee (1996) dataset with the updates from Barro and Lee (2001).

Other control variables include institution quality, life expectancy, share of government spending in GDP, and trade openness. Quality of institution is collected from Knack and Keefer (1995) and life expectancy is from Gallup, Sachs and Mellinger (1999). Trade openness is measured by the sum of import and export divided by GDP. BW also include other geographic variables such as access to port, area of coastline and natural resource abundance. We argue that these variables are constant over time. Since our time 0 is not the very beginning of the economic development of the mankind, any effects from these geographic variables should be reflected in the initial income already. In addition, from the econometric ground, since these variables are not significant in BW estimation, they can be dropped from the consideration. Lastly, inflation rate measured by the change of consumer price index is included to capture any short-term effect. Otherwise explicitly mentioned, all data are from Heston, Summers and Aten (2002).

The next issue concerns the exact form of equation to be estimated and other restrictions. In general, we want to estimate equation (5). We rewrite the equation here for simplicity.

$$\ln(y_t) - \ln(y_0) = b_0 + b_1\ln(L_t/L_0) + b_2\ln(N_t/N_0) + b_3\ln(y_0) + b_4\ln(L_0/N_0) + \mathbf{X}_t\gamma + e_t \quad (6)$$

If the demographic factors do not influence steady state income, it must be true that $b_1 = 1$ and $b_2 = -1$. Deviations from (1, -1) may imply that the demographic factors affect not only the current income but the income level at the steady state as well. We also explicitly assume that b_1 and b_2 are equal in magnitude but opposite in sign and estimate the following model.

$$\ln(y_t) - \ln(y_0) = b_0 + b_1'[\ln(L_t/L_0) - \ln(N_t/N_0)] + b_3\ln(y_0) + b_4\ln(L_0/N_0) + \mathbf{X}_t\gamma + e_t \quad (7)$$

The value of b_1' in this case should be approximately equal to one if demographic factors do no affect income at the steady state.

Next, we impose a few more restrictions; that is, $b_1 = 1$, $b_2 = -1$ and $b_3=b_4$. By imposing these restrictions, we can rewrite (6) into a form with growth of income per working-age population on the left-hand side and initial income per working-age population on the right-hand side. Then, we test whether the growth of working-age population and total population still have any influence on the growth of GDP per worker. The results should show that demographic factors have no impact on the growth in income per worker given that the demographic factors do not affect the steady state income. In other words, the coefficient c_1, c_1', c_1" and c_2 in equation (8) to (10) should be insignificant.

$$\ln(Y_t/L_t) - \ln(Y_0/L_0) = c_0 + c_1\ln(L_t/L_0) + c_3\ln(Y_0/L_0) + \mathbf{X}_t\gamma + e_t \quad (8)$$

$$\ln(Y_t/L_t) - \ln(Y_0/L_0) = c_0 + c_1'\ln(N_t/N_0) + c_3\ln(Y_0/L_0) + \mathbf{X}_t\gamma + e_t \quad (9)$$

$$\ln(Y_t/L_t) - \ln(Y_0/L_0) = c_0 + c_1''\ln(L_t/L_0) + c_2\ln(N_t/N_0) + c_3\ln(Y_0/L_0) + \mathbf{X}_t\gamma + e_t \quad (10)$$

The last issue that we want to address is the unobserved heterogeneity. There may be other factors that influence the steady state income but are not included in this model. These factors can also be specific to each country or a group of countries. To control for the unobserved heterogeneity, we use the fixed-effects regression to estimate our models. Continents are used to measure the fixed effects. In other words, we assume that countries in the same continent will converge to the same steady state. The results of fixed effect however are not shown here.

Table 1 Statistical Descriptions

Variables	40-yr	20-yr	10-yr	5-yr	Descriptions
dly	2.08	2.08	2.08	2.08	Growth of GDP per capita
	(1.40)	(1.73)	(2.09)	(2.53)	
dlyl	1.81	1.81	1.81	1.81	Growth of GDP per worker
	(1.25)	(1.67)	(2.10)	(2.56)	
dladult	2.07	2.07	2.07	2.07	Growth of population aged 15+
	(0.93)	(0.99)	(1.06)	(1.14)	
dlpop	1.80	1.80	1.80	1.80	Growth of population
	(0.95)	(0.99)	(1.02)	(1.04)	
lyini	8.07	8.35	8.45	8.50	Log initial GDP per capita
	(0.87)	(0.95)	(0.98)	(0.99)	
lylini	8.56	8.81	8.91	8.95	Log initial GDP per worker
	(0.77)	(0.84)	(0.86)	(0.86)	
lsh_adultini	-0.48	-0.46	-0.45	-0.45	Log ratio of working-age pop.
	(0.13)	(0.14)	(0.15)	(0.15)	to total population
lacsave	2.57	2.69	2.64	2.63	Log saving rate
	(0.92)	(0.72)	(0.85)	(0.88)	
lakg	2.74	2.74	2.72	2.72	Log of share of government spending
	(0.42)	(0.45)	(0.48)	(0.48)	in GDP
lsyr25ini	-0.86	-0.43	-0.28	-0.39	Log average years of secondary
	(1.21)	(1.16)	(1.11)	(1.11)	schooling in 25+ population
inst	6.26	6.26	6.26	6.26	Institution quality
	(2.37)	(2.36)	(2.36)	(2.35)	
llifex	4.08	4.08	4.08	4.08	Log life expectency
	(0.19)	(0.19)	(0.19)	(0.19)	
laopenk	3.84	3.81	3.79	3.79	Log average openness
	(0.59)	(0.63)	(0.66)	(0.66)	
dlcpi	-0.07	-0.07	-0.07	-0.07	Inflation rate
	(1.27)	(2.81)	(3.83)	(6.19)	
N	60	120	240	480	Number of Observations

Note: Standard errors are in parentheses.

Our analysis is based on 60 countries (see the country list in Appendix). The statistical descriptions in Table 1 shows that the average of growth rate is approximately

2% no matter what length of period we are studying. Since many countries have gone through stages of demographic transitions, population growth tends to be slightly lower than the growth of working-age population.

V. Estimation Results

Table 2 and Table 3 illustrate the results from estimating equation (6) to (10). In the overall, the initial income level is important in determining the growth of GDP per capita or per worker. The speed of convergence ranges from 2% a year to 20% a year, depending on the length of the time period. In contrast, the initial ratio of worker to population is not significant in all specifications and all time lengths. The significance of this variable, however, may depend on control variables included in the model. Kelley and Schmidt (2001) estimated the similar model with a different set of control variables and found that the initial ratio of worker to population is significant.

Further, the evidence shows that an increase in private saving rate can boost the economic growth as suggested by the Neoclassical growth theory. On the contrary, large public sector can instead retard growth probably through the crowding-out effect. However, the effect of government spending is clear only in the short-run. In the long run, this variable has no effect on the GDP growth. Quality of institution and life expectancy also have a positive influence on the economic growth. Effects of schooling can determine the economic growth as well but only in the long run. Inflation is significant only in the short-run and never significant when we consider growth over period longer than 5 years. Adjusted R^2 of our models ranges from 26% to 71%. The value of R^2 declines when the length of time period is lessened.

Now let us focus on the growth of working-age population and total population. The results confirm that the growth of the working-age population has a significant positive effect on the growth of GDP per capita, and the growth of the total population has a negative impact. However, this relationship is significant only when we consider the growth over a period more than 20 years. In the short run, the relationship between the working-age population and the total population and the economic growth seems to vanish. One explanation is that the convergence equation like equation (1) can be used to explain cross-country growth only in the long-run. In the short run, factors that influence business cycles may have stronger influence on the pattern of growth across countries. In the case where growth of working-age population and total population are significant, the F-statistics verify that their coefficients are statistically equal in magnitude but opposite in sign.

However, in most cases, we can reject the hypothesis that the coefficient of working-age population growth is equal to 1 and the coefficient of total population growth is equal to -1. This may suggest that the demographic transitions also affect the steady-state income level. In fact, the only sample that we cannot reject this hypothesis is when the GDP growth is calculated over a 20-year period, which is similar BW sample. They used data from 1965 to 1990 and could not reject this hypothesis. Our results seriously raise doubt over BW conclusion. The magnitudes of these coefficients seem to depend on the length of time period being considered, and the theory of course does not imply that we should calculate growth over what length.

Table 2 Estimation Results, Convergence in GDP per Capita, 1960-2000

Depedent variable: Growth of GDP per capita	**Equation 6**				**Equation 7**			
	40-yr	**20-yr**	**10-yr**	**5-yr**	**40-yr**	**20-yr**	**10-yr**	**5-yr**
dladult	2.84	1.37	0.56	0.46				
	(0.60)	(0.42)	(0.26)	(0.27)				
dlpop	-2.74	-1.03	-0.23	-0.07				
	(0.60)	(0.42)	(0.31)	(0.35)				
dladult-dlpop					2.79	1.20	0.46	0.41
					(0.58)	(0.39)	(0.25)	(0.27)
lyini	-1.73	-2.23	-2.28	-2.33	-1.69	-2.06	-2.15	-2.20
	(0.28)	(0.36)	(0.35)	(0.36)	(0.25)	(0.32)	(0.33)	(0.35)
lsh_adultini	3.35	6.25	5.33	3.91	2.72	3.88	3.36	1.29
	(2.50)	(3.00)	(2.58)	(2.72)	(1.72)	(2.08)	(1.98)	(2.11)
lacsave	-0.19	0.79	0.49	0.90	-0.18	0.80	0.50	0.93
	(0.17)	(0.23)	(0.19)	(0.21)	(0.17)	(0.23)	(0.19)	(0.21)
lakg	-0.21	-0.34	-0.59	-0.52	-0.20	-0.30	-0.56	-0.48
	(0.24)	(0.25)	(0.25)	(0.27)	(0.23)	(0.25)	(0.25)	(0.27)
lsyr25ini	0.22	0.27	0.19	0.20	0.21	0.23	0.15	0.16
	(0.13)	(0.19)	(0.20)	(0.21)	(0.13)	(0.18)	(0.20)	(0.21)
inst	0.20	0.10	0.22	0.21	0.19	0.11	0.22	0.22
	(0.08)	(0.10)	(0.10)	(0.11)	(0.08)	(0.10)	(0.10)	(0.11)
llifex	3.70	3.98	4.82	5.31	3.59	3.66	4.52	5.03
	(1.21)	(1.44)	(1.52)	(1.62)	(1.15)	(1.41)	(1.50)	(1.62)
laopenk	-0.26	-0.04	0.03	-0.06	-0.26	-0.02	0.05	-0.07
	(0.19)	(0.19)	(0.19)	(0.21)	(0.19)	(0.19)	(0.19)	(0.21)
dlcpi	0.09	0.05	0.05	0.06	0.09	0.05	0.05	0.06
	(0.09)	(0.06)	(0.03)	(0.02)	(0.09)	(0.06)	(0.03)	(0.02)
time trend	0.00	-0.35	-0.17	-0.13	0.00	-0.45	-0.19	-0.14
	(0.00)	(0.39)	(0.15)	(0.09)	(0.00)	(0.38)	(0.15)	(0.09)
Constant	2.62	5.38	2.70	-0.48	2.56	4.70	2.34	-1.08
	(4.56)	(5.67)	(5.80)	(6.33)	(4.51)	(5.65)	(5.80)	(6.33)
R-squared	0.71	0.54	0.31	0.27	0.71	0.53	0.31	0.26
Prob. of F-test on dladult=-dlpop	0.73	0.28	0.23	0.13				
Prob. of F-test on lyini = - lsh_adultini	0.50	0.16	0.21	0.54	0.53	0.36	0.52	0.65

Note: Standard errors are in parentheses.

Table 3 Convergence in GDP per Working-Age Population, 1960-2000

Depedent variable: Growth of GDP per working-age population	Equation 8				Equation 9				Equation 10			
	40-yr	20-yr	10-yr	5-yr	40-yr	20-yr	10-yr	5-yr	40-yr	20-yr	10-yr	5-yr
dladult	0.19	0.02	-0.23	-0.03					1.69	0.02	-0.61	-0.58
	(0.20)	(0.18)	(0.15)	(0.16)					(0.55)	(0.34)	(0.22)	(0.26)
dlpop					0.00	0.02	0.10	0.28	-1.73	0.00	0.72	0.87
					(0.22)	(0.22)	(0.21)	(0.20)	(0.60)	(0.42)	(0.31)	(0.34)
lylini	-1.86	-1.98	-2.08	-2.17	-1.84	-1.98	-2.15	-2.19	-1.65	-1.98	-2.11	-2.26
	(0.26)	(0.31)	(0.33)	(0.35)	(0.27)	(0.31)	(0.33)	(0.35)	(0.25)	(0.31)	(0.33)	(0.35)
lacsave	0.05	0.82	0.45	0.86	0.09	0.83	0.44	0.85	-0.18	0.82	0.53	0.91
	(0.16)	(0.22)	(0.19)	(0.21)	(0.16)	(0.22)	(0.19)	(0.21)	(0.17)	(0.23)	(0.19)	(0.21)
lakg	-0.27	-0.29	-0.57	-0.49	-0.27	-0.29	-0.62	-0.51	-0.17	-0.29	-0.56	-0.50
	(0.24)	(0.25)	(0.26)	(0.27)	(0.25)	(0.25)	(0.26)	(0.27)	(0.23)	(0.25)	(0.25)	(0.27)
lsyr25ini	0.27	0.25	0.10	0.11	0.24	0.25	0.16	0.16	0.21	0.25	0.19	0.20
	(0.14)	(0.18)	(0.20)	(0.21)	(0.14)	(0.19)	(0.20)	(0.21)	(0.13)	(0.19)	(0.20)	(0.21)
inst	0.26	0.14	0.23	0.18	0.24	0.14	0.26	0.21	0.20	0.14	0.25	0.23
	(0.08)	(0.09)	(0.10)	(0.10)	(0.08)	(0.10)	(0.10)	(0.10)	(0.08)	(0.10)	(0.10)	(0.10)
llifex	3.77	3.73	4.46	5.01	3.47	3.72	4.87	5.36	3.59	3.73	4.64	5.29
	(1.28)	(1.43)	(1.53)	(1.63)	(1.29)	(1.43)	(1.54)	(1.63)	(1.19)	(1.44)	(1.52)	(1.62)
laopenk	-0.21	-0.07	0.08	-0.05	-0.14	-0.07	0.02	-0.10	-0.29	-0.07	0.01	-0.08
	(0.20)	(0.19)	(0.19)	(0.20)	(0.19)	(0.19)	(0.20)	(0.20)	(0.18)	(0.19)	(0.19)	(0.20)
dlcpi	0.10	0.06	0.04	0.06	0.08	0.06	0.05	0.06	0.10	0.06	0.05	0.06
	(0.10)	(0.06)	(0.03)	(0.02)	(0.10)	(0.06)	(0.03)	(0.02)	(0.09)	(0.06)	(0.03)	(0.02)
time trend	0.00	-0.31	-0.24	-0.19	0.00	-0.31	-0.20	-0.17	0.00	-0.32	-0.13	-0.12
	(0.00)	(0.37)	(0.14)	(0.09)	(0.00)	(0.39)	(0.15)	(0.09)	(0.00)	(0.40)	(0.15)	(0.09)
Constant	2.00	2.54	1.97	-0.34	3.10	2.55	0.29	-2.13	1.78	2.54	0.61	-1.70
	(4.70)	(5.30)	(5.59)	(6.03)	(4.73)	(5.32)	(5.65)	(6.04)	(4.37)	(5.35)	(5.57)	(6.00)
R-squared	0.57	0.52	0.33	0.26	0.56	0.52	0.32	0.27	0.64	0.52	0.34	0.28
Prob. of F-test on dladult=-dlpop									0.85	0.92	0.61	0.14

Note: Standard errors are in parentheses.

In equation (7), we explicitly restrict that the coefficients of working-age population growth and total population growth must be equal in magnitude but opposite in sign. The estimation results are similar to what mentioned above. Differences between the two demographic growth rates are significant only when we calculate growth over a period of 20 years or longer. Also, the coefficients are not statistically different from 1 only when we calculated growth over a 20-year period.

When we make even more restrictions to our model and estimate equation (8), the results are very surprising. The growth of working-age population cannot explain the variation in the growth in the GDP per worker across countries. This conclusion is surprising because it contradicts to the Solow growth theory and the empirical evidence provided by MRW. Nevertheless, it should be emphasized that MRW used a very small set of control variables on in fact only 3 explanatory variables. An experiment was conducted, although not shown here, by carrying out the same regression as MRW. We obtain results similar to MRW; that is, all 3 variables are significant. However, when we include other control variables as in equation (8), the growth of working-age population is no longer significant. We argue that MRW may face a serious problem of omitting important variables. In equation (9), the growth of total population cannot explain the variation of GDP per worker as well.

It is however possible that the statistical insignificance of demographic factors found in equation (8) and (9) is a result of the two variables working in the opposite direction. Thus, in equation (10), we add both the growth of working-age population and the growth of total population. The results confirm that these two variables have significant but opposite effects on the growth of GDP per worker. The analysis becomes more complex when the signs of these coefficient change with the length of the growth period. When we consider growth over a 40-year period, the growth of working-age population has a positive relationship with the growth of GDP per worker, while the growth of population has a negative relationship. However, when we focus on the short-run growth (growth over a period less than 20 years), the relationships go in the opposite direction. The growth of working-age population now significantly reduces the economic growth, and the growth of population significantly pushes up the growth of GDP per worker.

Variety of explanation is possible. The Solow model itself already suggests the negative relationship between the growth of working-age population and the economic growth as found in our short-run regression. However, if the growth of working-age population has positive externalities to the economy such that it shifts the production function for any given amount of worker, this will result in a positive relationship between the working-age population and economic growth in the long run. Further, an increase in population may boost the aggregate demand in the short run. However, in the long run, the dependency ratio will rise, and saving rates and the economic growth will fall. Clearly, more work is needed to address these issues.

VI. Conclusions and Suggestions

In conclusion, this paper emphasizes that looking at the statistical significance of demographic factors may not be enough, we need to look at the economic significance of the coefficients as well. Previous studies may have ignored this matter and find themselves making inaccurate conclusions. We show the evidence that the demographic transitions are more important than affecting only the current income. The transitions can possibly affect the income level at the steady state as well.

This paper is only the first look at the issue. Certainly, more work needs to be done. We suggest that future research should take the endogeneity problem of the demographic factors into account. Many researchers, for example Kelley and Schmidt (2001), employ the 2 stage least square technique in the estimation. The generalized method of moments (GMM) can be another choice of estimation technique. The GMM estimators are believed to be consistent in the presence of endogenity and measurement error problems. A work on theoretical explanation of how demographic transitions can influence the income level at the steady state is much needed as well.

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Appendix

Country list

1. Cameroon
2. Ghana
3. Kenya
4. Malawi
5. Niger
6. Senegal
7. South Africa
8. Zambia
9. Zimbabwe
10. Canada
11. Costa Rica
12. Dominican Republic
13. El Salvador
14. Guatemala
15. Honduras
16. Jamaica
17. Mexico
18. Trinidad & Tobago
19. United States
20. Argentina
21. Bolivia
22. Brazil
23. Chile
24. Colombia
25. Ecuador
26. Paraguay
27. Peru
28. Uruguay
29. Venezuela
30. Bangladesh
31. Hong Kong
32. Indonesia
33. India
34. Israel
35. Japan
36. South Korea
37. Malaysia
38. Pakistan
39. Philippines
40. Sri Lanka
41. Syria
42. Thailand
43. Austria
44. Belgium
45. Denmark
46. Finland
47. France
48. Greece
49. Ireland
50. Italy
51. Netherlands
52. Norway
53. Portugal
54. Spain
55. Sweden
56. Switzerland
57. Turkey
58. United Kingdom
59. Australia
60. New Zealand