

Effects of longevity and dependency rates on saving and growth: Evidence from a panel of cross countries*

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Abstract

While earlier empirical studies found a negative saving effect of old-age dependency rates without considering longevity, recent studies have found that longevity has a positive effect on growth without considering old-age dependency rates. In this paper, we first justify the related yet independent roles of longevity and old-age dependency rates in determining saving and growth by using a growth model that encompasses both neoclassical and endogenous growth models as special cases. Using panel data from a recent World Bank data set, we then find that the longevity effect is positive and the dependency effect is negative in savings and investment regressions. The estimates indicate that the differences in the demographic variables across countries or over time can well explain the differences in aggregate savings rates. We also find that both population age structure and life expectancy are important contributing factors to growth.

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1. Introduction

The last century has seen dramatic increases in life expectancy around the world (e.g. Lee and Tuljapurkar, 1997). This has been accompanied by low fertility in industrial countries, causing serious population aging and higher old-age dependency rates. Both individuals and governments are increasingly concerned about the effects of aging, though their concerns differ. Individuals are more concerned about increased longevity because it affects their own financial and labor market plan (Hurd 1997), whereas governments are more concerned about old-age dependency as an aspect of population aging (Weil 1997). Yet it is important to realize that individual aging leads to population aging (holding other things constant). The significance of these demographic changes has attracted a great deal of attention among economists (see, e.g., Bos and von Weizsacker, 1989; Culter, Poterba, Sheiner and Summers, 1990; Lee and Skinner, 1999; Lagerlöf, 2003).

One of the issues at the heart of the related empirical investigations is the effect of demographic changes on national savings, investment, and economic growth. There are two separate sets of related studies in the literature. One set of them is concerned with the effect of population dependency rates on aggregate savings, following the seminal work of Leff (1969) that finds a significant negative effect of the old-age dependency rate on the aggregate saving rate. For example, Edwards (1996) finds evidence that supports Leff's early results. However, Adams (1971), Gupta (1971), Goldberger (1973), and Ram (1982, 1984) present cases in which the dependency effect on savings may be insignificant or even positive.¹ This debate has concentrated on one important aspect of the issue: the relationship between age and savings. However, the entire debate and related empirical work have ignored another important aspect of the issue: the relationship between savings and expected life span. What happens to savings regressions if life expectancy and old-age dependency are jointly considered?

In contrast to the studies on aggregate saving rates, the other set of the related studies has paid little attention to dependency rates and has instead focused on the effect of longevity in investment

¹See the replies from Leff (1971, 1973, 1984), and the more recent work of Mason (1988), Brander and Dowrick (1994), Weil (1994), Kelley and Schmidt (1995), Higgins and Williamson (1997), and Lee, Mason and Miller (2000).

and growth regressions. It has typically found a positive effect of longevity on investment and growth (e.g. Ehrlich and Lui, 1991; Barro and Sala-i-Martin, 1995, Ch. 12).² The strong positive effect of longevity on growth is interpreted by Barro and Sala-i-Martin as a reflection of growth enhancing factors (in addition to good health itself) such as good work habits and high levels of skill. We will offer a different interpretation by giving a more direct role for longevity in life-cycle optimization. In general, this set of studies has omitted dependency rates in growth regressions. Due to this omission, it cannot capture an important aspect of the issue: removing a group of workers from production and adding them to the dependent population will obviously change both the level and growth rate of output per capita.

At a theoretical level, the longevity versus dependency effects we have discussed here simply reflect two aspects of the life-cycle hypothesis. On the one hand, individuals save more when they expect to live longer. On the other hand, when the population becomes older, dissavers increase in number relative to savers. Intuitively, both middle-aged and old-aged individuals contribute to aggregate savings. With increasing life expectancy, at a given point in time, middle-aged individuals save more and raise aggregate savings. However, increasing life expectancy also implies more old people who dissave and reduce aggregate savings. Hence, the effect of rising longevity can only be estimated with the population age structure held constant, and vice versa.

In this paper, we first construct a simple growth model with overlapping generations that encompasses both neoclassical and endogenous growth models as special cases, to shed light on the explicit and separate roles of life expectancy, dependency rates, and fertility (or population growth). We show that rising longevity (life expectancy) raises the saving rate at both the household level and aggregate level, and that it raises the growth rate of output per capita. However, a rising old-age dependency rate lowers the aggregate saving rate, whereas a rising total dependency rate reduces the growth rate of per capita output. Although demographers have long noticed the importance of both fertility and longevity to the dependency ratio, economists have largely ignored one of the

²Ehrlich and Lui (1991) used mortality, which is similar to the use of life expectancy. Recent theoretical studies have investigated the effect of life expectancy (or mortality) on capital accumulation and growth. See, for example, Skinner (1985), Ehrlich and Lui (1991) and de la Croix, and Licandro (1999).

factors in their analysis. Thus, we contribute to the economic literature by taking into account these realistic demographic factors.

We then carry out a panel study using the World Bank's World Development Indicators 2005 dataset, which contains more substantial information for over two hundred countries from 1960 to 2004 than previously used data sets.³ Consistent with our intuitive and theoretical predictions, our fixed effects estimations show that the longevity effect is positive and the dependency effect is negative in the saving, investment, and growth regressions. The findings are generally robust when we add other determinants of savings, investment, and growth.

The remainder of this paper is organized as follows. Section 2 justifies the roles of life expectancy, population growth, fertility, and the population age structure in the determination of aggregate savings and per capita income growth in a simple growth model with overlapping generations. Section 3 describes the data and the empirical specifications. Section 4 reports the regression results. The final section provides concluding remarks.

2. A simple theoretical model and testable implications

Following the life-cycle hypothesis, we use a simple overlapping generations model that links savings, investment, and growth to longevity, population growth, and population age structures. The simple model is constructed only to capture our main points and is not meant to be comprehensive. In this model, agents live for three periods: making no choices in childhood, working in middle age, and living in retirement in old age. The middle-age population has a mass L_t in period t . Fertility is exogenous at a rate of $N_t = L_{t+1}/L_t$. All workers have a probability of P to survive to old age and a death rate of $1 - P$ at the end of their middle age. The size of the old population at time t is $L_{t-1}P_{t-1}$, and the size of the total population is $L_t(1 + N_t) + L_{t-1}P_{t-1}$.

A middle-aged agent inelastically supplies one unit of labor endowment to work and earns a wage income of W_t . The wage income is divided between middle-age consumption c_t and savings

³Other popularly used macro data sets do not have observations for the saving rates, such as those extended from Summers and Heston (1991), which adjust for cross-country differences in the cost of living by using observed prices of goods and services. Barro and Sala-i-Martin (1995) found that growth regressions from both the World Bank data and the Summers-Heston data gave very similar results.

s_t for old-age consumption z_{t+1} . There is a perfect annuity market that channels the savings of workers to firms and distributes the savings plus interest of those who die to old-aged survivors. Hence, every worker expects to receive an annuity income of $R_{t+1}L_t s_t / (L_t P_t)$ in old age (where R is the interest factor) that is conditional on survival. Thus, the lifetime budget constraint of a worker is $c_t = W_t - s_t$ and $z_{t+1} = R_{t+1} s_t / P_t$.

The preference is assumed to be $U_t = \log c_t + P_t \beta \log z_{t+1}$ where β is the subjective discount factor. This simple version of preferences in a standard overlapping generations model will yield rich specifications of the saving rate and growth equations, and avoid unnecessary complexity. The solution to this simple problem is

$$c_t = \Gamma_{c,t} W_t, \quad \Gamma_{c,t} = \frac{1}{1 + P_t \beta}, \quad (1)$$

$$s_t = \Gamma_{s,t} W_t, \quad \Gamma_{s,t} = \frac{P_t \beta}{1 + P_t \beta}, \quad (2)$$

$$z_{t+1} = \beta R_{t+1} c_t. \quad (3)$$

As implied by the life-cycle hypothesis, a higher rate of survival raises the fraction of income for savings Γ_s but reduces the fraction of income for middle-age consumption Γ_c . In the Appendix we will discuss whether this positive correlation between the saving rate and the rate of survival remains when survival depends on current consumption as in Gersovitz (1983).

Note that $\Gamma_c + \Gamma_s = 1$. In this household problem, we focus on savers (middle-aged agents) and dissavers (old-aged agents) and thus ignore child consumption and child mortality. Including child consumption and child mortality usually gives a negative role of the number of children in the saving equation. In the later empirical analysis, a lagged-fertility-rate variable will be used to partly control for any child effects.

The production function is $Y_t = AK^\alpha (L_t \tilde{k}_t^\theta)^{1-\alpha}$, $A > 0$, $0 < \alpha < 1$, and $0 \leq \theta \leq 1$, where K is capital L labor, and \tilde{k} the average level of capital per worker in the economy. When $\theta = 0$, the model is neoclassical without sustainable growth in the long run, whereas when $\theta = 1$ (or close to 1) it is an AK model with sustainable long-run growth in the spirit of Romer (1986).

In equilibrium $k_t = \tilde{k}_t = [Y_t/(AL_t)]^{1/[\alpha+\theta(1-\alpha)]}$. For simplicity, we assume a 100% depreciation of capital within one period in production. Factors are paid by their marginal products: $W_t = (1-\alpha)Ak_t^{\alpha+\theta(1-\alpha)}$ and $R_t = \alpha Ak_t^{(1-\alpha)(\theta-1)}$. Output is equal to the sum of labor income and capital income: $Y_t = L_tW_t + K_tR_t$. As capital income goes to old-age survivors, we can express aggregate old-age consumption as $L_{t-1}P_{t-1}z_t = K_tR_t$.

The aggregate net saving that is denoted by S_t , is defined as aggregate output less aggregate consumption, that is, $S_t = Y_t - L_t c_t - L_{t-1}P_{t-1}z_t$. Substituting young-age consumption $c_t = W_t - s_t$ and aggregate old-age consumption $L_{t-1}P_{t-1}z_t = K_tR_t$ into the aggregate saving equation, we have $S_t = Y_t - L_t(W_t - s_t) - K_tR_t = L_t s_t$ as $Y_t = L_tW_t + K_tR_t$. Thus, we obtain the result that the aggregate net saving is equal to the sum of savings by workers.⁴

However, output is equal to aggregate spending: $Y_t = L_t c_t + L_{t-1}P_{t-1}z_t + K_{t+1}$ or $K_{t+1} = Y_t - L_t c_t - L_{t-1}P_{t-1}z_t$. Combining this accounting identity on the spending side with the aggregate saving equation in a closed economy, we have $S_t = K_{t+1} = L_t s_t$, or $k_{t+1} = K_{t+1}/L_{t+1} = s_t/N_t$ where capital per worker in the next period depends positively on savings but negatively on fertility today as in a standard neoclassical growth model.

In equilibrium, capital per worker evolves according to

$$k_{t+1} = A(1-\alpha)\Gamma_{s,t} \left(\frac{1}{N_t}\right) k_t^{\alpha+\theta(1-\alpha)}. \quad (4)$$

Clearly, when $\theta = 1$ (close to 1), the level of capital per worker will never (take many periods to) converge, and thus there will be long-run growth as in Romer (1986). However, regardless of the value of θ , the rate of capital accumulation (and hence growth) on the transitional equilibrium path is determined by both the saving rate and the exogenous fertility rate. As a higher rate of survival

⁴One might mistakenly define the aggregate net saving as $S_t = L_t s_t - L_{t-1}P_{t-1}z_t$ when z_t is regarded as dissavings by the elderly. This alternative definition would change S_t from ‘total output less total consumption’ to ‘total wage income less total consumption’, because from $L_t s_t = L_t W_t - L_t c_t$, we would have $S_t = L_t W_t - L_t c_t - L_{t-1}P_{t-1}z_t$. It is important to realize that dissaving in old age (z) is already financed by capital income according to $L_{t-1}P_{t-1}z_t = K_t R_t$ or $z_t = R_t s_{t-1}/P_{t-1}$, and hence the net savings in old age (i.e., capital income less old-age consumption) is zero for every old survivor. As a result, the aggregate saving S comes only from workers’ savings in such an overlapping generations framework. However, the aggregate savings that is determined by workers only is an *end* result. During the process of reaching this end, the aggregate saving is also affected by the ratio of old to worker population, through the mechanism that the amount of capital stock that is accumulated by the elderly in the past determines output and savings together with the number of workers today.

raises the fraction of income for savings $\Gamma_{s,t}$ in (2), it will promote capital accumulation per worker according to (4). By accelerating capital accumulation, the increase in the rate of survival will also reduce the interest rate in the neoclassical model of growth with $\theta \in (0, 1)$, according to the interest-rate equation $R_{t+1} = \alpha A k_{t+1}^{-(1-\alpha)(1-\theta)}$.

The ratio of aggregate savings to output (the aggregate saving rate hereafter) is $\tilde{\Gamma}_{s,t} \equiv S_t/Y_t = (L_t y_t - L_t c_t - L_{t-1} P_{t-1} z_t)/(L_t y_t) = 1 - (1 - \alpha)\Gamma_{c,t} - (L_{t-1} P_{t-1}/L_t)(z_t/y_t)$ where $y_t = Y_t/L_t$ is output per worker. The first part $1 - (1 - \alpha)\Gamma_{c,t} = \alpha + (1 - \alpha)\Gamma_{s,t}$ is a positive function of the rate of survival that reflects the life-cycle hypothesis. That is, life expectancy contributes to the aggregate saving rate through influencing each individual's saving rate. The last term has two factors that reduce the aggregate saving rate through raising aggregate old-age consumption to output: $(L_{t-1} P_{t-1}/L_t)(z_t/y_t)$, that is, the ratio of old to middle-age population and the ratio of consumption per old-aged agent to output per worker. Intuitively, holding consumption per old-aged agent constant, an increase in the old-age dependency rate increases the fraction of output for old-age consumption and hence reduces the aggregate saving rate, as an implication of the life-cycle hypothesis that was focused on in previous saving regressions. However, holding the dependency rate constant, an increase in the ratio of consumption per old-aged agent to output per worker has a similar effect on the aggregate saving rate. Furthermore, the ratio (z_t/y_t) can be expressed as $\alpha N_{t-1}/P_{t-1}$;⁵ namely, the ratio of consumption per old-aged agent to output per worker is higher if previous fertility is higher (i.e., lower labor productivity today) or if the previous rate of survival is lower (i.e., a higher rate of return on savings today).

Based on the above discussion, the ratio of aggregate savings to output becomes

$$\tilde{\Gamma}_{s,t} = \alpha + \frac{(1 - \alpha)P_t\beta}{1 + P_t\beta} - \left(\frac{\alpha N_{t-1}}{P_{t-1}}\right) \left(\frac{L_{t-1}P_{t-1}}{L_t}\right). \quad (5)$$

Thus, the aggregate saving rate is an increasing function of the rate of adult survival (P_t), but is a decreasing function of both previous fertility (N_{t-1}) and the old-age dependency rate ($L_{t-1}P_{t-1}/L_t$).

⁵From (1) and (3), $z_t/y_t = \beta R_t \Gamma_{c,t-1} W_{t-1}/y_t$. Expressing R , W , and y as functions of capital per worker k and using (4), we have $z_t/y_t = A\beta\alpha(1 - \alpha)\Gamma_{c,t-1}k_{t-1}^{\alpha+\theta(1-\alpha)}/k_t = \alpha(\beta\Gamma_{c,t-1}/\Gamma_{s,t-1})(L_t/L_{t-1})$ where $L_t/L_{t-1} = N_{t-1}$. The ratio $\beta\Gamma_{c,t-1}/\Gamma_{s,t-1}$ is simply equal to $1/P_{t-1}$ by (1) and (2).

How do these demographic factors affect per capita income growth? In this model, the growth rate of per capita income is equal to $g_t \equiv \{Y_t/[L_t(1 + N_t) + L_{t-1}P_{t-1}]\}/\{Y_{t-1}/[L_{t-1}(1 + N_{t-1}) + L_{t-2}P_{t-2}]\} - 1$ and the growth rate of the total population is equal to $n_t \equiv [L_t(1 + N_t) + L_{t-1}P_{t-1}]/[L_{t-1}(1 + N_{t-1}) + L_{t-2}P_{t-2}] - 1$. It is easy to see that $g_t = (k_t/k_{t-1})^{\alpha+\theta(1-\alpha)}(L_t/L_{t-1})[1/(1 + n_t)] - 1$ where $k_t/k_{t-1} = A(1 - \alpha)\Gamma_{s,t-1}(L_{t-1}/L_t)k_{t-1}^{-(1-\alpha)(1-\theta)}$ by (4). Note that $k_{t-1} = [Y_{t-1}/(AL_{t-1})]^{\alpha+\theta(1-\alpha)}$. Moreover, define the ratio of the middle-age to total population by $\phi_t = L_t/[L_t(1 + N_t) + L_{t-1}P_{t-1}]$, which is the inverse of the total dependency rate $1 - \phi_t$ (i.e., the sum of children and old-aged agents relative to the total population). Using these definitions, the log version of the growth equation is given by:

$$\begin{aligned} \log(1 + g_t) = & \Lambda + [\alpha + \theta(1 - \alpha)][\log \Gamma_{s,t-1} - \log(1 + n_t)] + (1 - \alpha)(1 - \theta) \log \phi_t \\ & - (1 - \alpha)(1 - \theta) \log \left[\frac{Y_{t-1}}{L_{t-1}(1 + N_{t-1}) + L_{t-2}P_{t-2}} \right], \end{aligned} \quad (6)$$

where $\Lambda \equiv \log A + [\alpha + \theta(1 - \alpha)] \log(1 - \alpha)$ is a constant.

From (6), the growth rate of per capita income is positively related to the previous saving rate $\Gamma_{s,t-1} = P_{t-1}\beta/(1 + P_{t-1}\beta)$ (or previous life expectancy in a reduced form), and to the ratio of middle-age to the total population. However, it is negatively related to population growth and previous per capita income. Among the three demographic factors, high previous life expectancy means high previous savings and investment. Hence, there is a high capital stock per worker and high output per worker today, when holding other factors constant. Rapid population growth means a large current population relative to the past population, which leads to lower current output per capita if the population age structure remains the same for a given level of aggregate capital stock at the beginning of the current period. Given the size of the total population, if children and old agents account for a large portion of the total population (or high total dependency) today relative to the past, then output per capita should be low today relative to the past.

The relationships in equations (5) and (6) capture the entire dynamic path of the model, and are valid for all times. Moreover, these relationships are derived from the decisions of both households and firms, as in recent studies on savings and growth. Although our simple theoretical model is

very much in line with the recent new growth literature on savings and growth,⁶ our explicit joint consideration of longevity, the age structure, and fertility in affecting savings and growth seems to be novel and is itself an important contribution to the literature.

3. Empirical specifications and data

The empirical specifications for saving or investment and growth equations are based on (5) and (6) which illuminate the explicit roles of life expectancy, population growth, fertility, the population age structure, and previous income per capita. As life expectancy at time t reflects the up to date information on the rate of survival, it will replace P_t in (5) and (6). Consequently, the saving rate equation is specified as

$$\begin{aligned} (\text{aggregate saving/output})_{it} = & a_0 + a_1(\text{life expectancy})_{it} + \\ & a_2(\text{old to work age population ratio})_{it} + a_3(\text{fertility})_{i,t-1} + u_{it}, \end{aligned} \quad (7)$$

where a linear functional form is assumed; subscript i refers to a country and subscript t refers to a period. According to the theoretical discussion, we expect that $a_1 > 0$, $a_2 < 0$, and $a_3 < 0$, i.e. a positive longevity effect, a negative old-age dependency effect, and a negative fertility effect. The investment equation shares the same specification with the saving equation in a closed-economy model; in open economies, this saving rate equation specification may apply well in the investment equation if savings and investment are closely related.

The growth equation is based on (6):

$$\begin{aligned} \log(1 + \text{growth rate})_{it} = & b_0 + b_1 \log(\text{GDP per capita})_{i,t-1} + b_2 \log(1 + \text{population growth})_{it} \\ & + b_3 \log(\text{work age to total population ratio})_{it} + b_4 \log(\text{life expectancy})_{i,t-1} + u_{it}. \end{aligned} \quad (8)$$

⁶An alternative approach in the literature seems to emphasize how exogenous growth and age structures affect the saving rate (see, e.g., Mason, 1988, Higgins and Williamson, 1997, and Lee et al., 2000). They clearly showed that exogenous technological progress would affect saving rates. In this paper, we follow the more recent new growth literature of Romer, Lucas, Ehrlich, and Barro in which exogenous factors determine growth determinants, such as saving rates, fertility, and human capital that in turn affect growth. The former approach has put emphasis on savings, whereas the latter approach has focused on sustainable growth as the ultimate variable to be determined in the model. Our major focus is on the separate effects of several demographic factors on saving and growth rates when they are controlled for jointly.

We expect that $b_1 < 0$, as in the literature on growth regressions, and according to our theoretical predictions, $b_2 < 0$, $b_3 > 0$, and $b_4 > 0$, i.e. a negative population growth effect, a negative total dependency effect, and a positive longevity effect. In this growth equation, the log of previous life expectancy has replaced the log of the previous saving rate that is chosen by households (not the aggregate saving rate) that is present in the theoretical growth equation (6).

In comparison to the previous studies, a distinctive feature of our specifications of the saving, investment, and growth equations is that we consider the population age structure, population growth (or fertility), and life expectancy jointly. To facilitate the comparison of our results with those in the previous work, we will also consider specifications where one of the life expectancy and population age structure variables is excluded from the saving, investment, or growth equation. To control for unobservable country and cyclical effects, we employ the country and time fixed-effects model for both (7) and (8).⁷

The data used here are based on the World Bank's World Development Indicators 2005 for the period from 1960 to 2004, which cover over 200 countries. The dataset contains a wide range of variables, such as the ratio of investment to GDP, the growth rate, school enrollment, and demographic statistics. Regarding the population age structure, data are available for the proportions of the population under age 15, between 15 and 64, and aged 65 or above. The age group between 15 and 64 is chosen to be the middle-age population, as in the literature on savings and dependency rates. The old-age dependency rate refers to those over middle age relative to the middle-age population, and the total dependency rate is the sum of those under age 15 and those over middle age relative to the total population. In addition to these variables, the World Bank data set also has information on the ratio of aggregate savings to output that is of particular interest here.

The World Bank data are annual observations with missing information for some variables that are used here. For some demographic variables, their observations are usually updated less frequently than those from National Accounts. We construct a panel data set by taking a five-year

⁷We have also conducted GMM estimations. However, the instrumental variables (IVs) (the lagged values and differences of the lagged independent variables in Tables 2-4) in the GMM estimations do not pass the Hansen over-identification restriction test. Generally speaking, it is difficult to find valid IVs for cross-country growth regressions.

average from the annual observations in the World Bank's data set.⁸ The advantage of five-year averages is to reduce the short-term cyclical influence on growth, savings, and investment. To make each period five years, we use the data from 1963 to 2003, including eight 5-year periods. Due to missing values, we use 149 countries and 779 observations for the savings regressions, 149 countries and 775 observations for the investment regressions, and 150 countries and 793 observations for the growth regressions. As the equations for savings, investment, and growth include one-period lagged variables, all regressions actually use seven periods of the averaged data.

In the full sample, the mean values (standard deviations) of life expectancy, the old-age dependency rates, the aggregate saving rates, and the annual growth rates are 62 years (11.63), 0.10 (0.06), 0.165 (0.15), and 0.015 (0.038), respectively. There was a great deal of variation across countries. Life expectancy during the period from 1993 to 1998 was below 50 years in 24 countries, between 50 and 70 years in 67 countries, and above 70 years in 66 countries. The old-age dependency rates ranged from 0.02 to 0.28; the mean values of the old-age dependency rates were 0.05 in the 41 countries with low life expectancy, 0.08 in the 19 countries with mid life expectancy, and 0.15 in the 31 countries with high life expectancy. The mean values of the saving rates and the growth rates in the countries with low life expectancy (0.06 and 0.015 respectively) were much lower than in the countries with high life expectancy (0.21 and 0.024 respectively). Fertility rates were much higher in low life expectancy countries than in high life expectancy countries: 5.89, 3.73 and 2.12 in countries with low, mid, and high life expectancy, respectively. Variation over time was relatively moderate, apart from a sharp decline in fertility. From the period from 1963 to 68 to the period from 1998 to 2003, life expectancy increased by about 10 years, the old-age dependency rate increased by about 2 percentage points, fertility declined by more than 40%, and the saving (growth) rates declined from 18% to 16% (0.027% to 0.018%).⁹ Summary statistics are provided in Table 1.

⁸In this paper, all economic variables are first normalized to the local 2000 price level, and then converted into the 2000 US dollar using the 2000 exchange rate. There is a second way of conversion: economic variables are first converted into the US dollar by the current exchange rate, and then normalized to the 2000 US price level. We use the first way of conversion to avoid the complication of exchange rate variation. We also run regressions using the second way of conversion (not reported in tables), and find the results are qualitatively similar.

⁹There was remarkably high growth in the 1960s, in contrast to the slow growth in the following three decades.

4. Estimation results

4.1. *Saving regressions*

The saving regressions are reported in Table 2. We begin with a saving regression on two explanatory variables: previous fertility and life expectancy.¹⁰ These two variables were used in previous studies on investment (e.g., Barro and Sala-i-Martin, 1995). The result is reported in Regression (1) in Table 2: previous fertility has a negative effect on the aggregate saving rate, whereas life expectancy has a significant positive effect.

In Regression (2), we use previous fertility and the old to middle-age population ratio but drop life expectancy as in Leff (1969) and Ram (1982). It shows that the estimated coefficient on previous fertility is about the same in magnitude as that in Regression (1). The estimated coefficient on the old-age dependency rate is not significantly different from zero, which may lead to the conclusion that old-age dependency does not affect the aggregate saving regression as in Ram (1982, 1984).

In Regression (3), that follows our correct specification, we include both life expectancy and old-age dependency. The estimated coefficient on life expectancy is nearly the same as in Regression (1) where the old-age dependency variable is absent. The old-age dependency ratio continues to have a negative yet insignificant effect on savings.

In Regression (4), we add another important determinant of savings - the lagged log per capita GDP. It appears that the saving rate increases with per capita GDP, which has a highly significant coefficient as suggested in the model in the Appendix whereby survival increases with consumption. Interestingly, when controlling for per capita GDP, the effect of fertility becomes much smaller. This suggests that much of the effect of fertility is actually the income effect. In other words, countries with high income levels have lower fertility. An even more remarkably different result occurs with the coefficient on the old-age dependency rate: it is significantly negative in Regression (4) as in Leff (1969). The absolute value of this coefficient in Regression (4) more than doubles that in

¹⁰In the literature on empirical growth, most studies use one-period lagged fertility as an independent variable (see e.g., Levine and Renelt (1992), Bloom and Williamson (1998), Islam (1995), and Li and Zhang (2006)). We have also experimented by using 10-year and 15-year lagged fertility variables. The primary results do not change with these further lags.

Regression (3). Another interesting aspect of the result is that the coefficient on life expectancy does not change.

Our findings can reconcile two seemingly contradictory empirical results from previous research. On the one hand, it is found that the saving rate has a “hump” shape with age from micro data and time-series data.¹¹ In these studies, the saving rate falls with age or with the old-age dependency rate, as the life-cycle model predicts (Modigliani, 1970).¹² Our finding is consistent with these studies in that the old-age dependent effect is also negative. On the other hand, by using micro data, some find that the elderly do not dissave as much as the life-cycle models would predict.¹³ One explanation is that the retirees may face longer life expectancy and thus have to save more (Davies, 1981). These two lines of research suggest that we should include both the old-age dependency ratio and life expectancy in the savings equation.

To examine the sensitivity of the estimation results, we now add four more explanatory variables that are frequently used in this type of research to the saving regression: terms-of-trade growth, primary school enrollment, the labor force participation rate, and the mortality rate below age five. The terms of trade growth variable measures the growth rate of the price index for exports minus the growth rate of the price index for imports. A large positive value of terms of trade growth indicates a strong external demand for domestic products relative to imports, a situation that is conducive to exports and investment, and hence to GDP growth. Primary school enrollment (of the adult population) is used as a proxy for the human capital of the middle-age population and is expected to have a positive effect on the saving rate by raising the rate of return on savings through human capital. A large labor force participation rate may increase savings by increasing income per capita, and may thus increase the saving rate. However, a larger labor force could also mean a higher unemployment rate and thus a lower saving rate. As we control for the income level, labor

¹¹See, e.g., Attanasio (1998) that uses micro data from the United States, Horioka (1997) that uses time-series data from Japan and Thornton (2001) that uses time-series data from the United States.

¹²For the effect of youth dependency on savings, there is no consensus for the empirical results (Deaton, 1992; Higgins, 1998). For example, Deaton (1992, p.51) argues: “Although there are some studies that find demographic effects, the results are typically not robust, and there is no consensus on the direction of the effect on saving.” We have also experimented by using the youth dependency rate, and found that it has no significant effect on savings. As it is not our focus, we do not include the specifications with the youth dependency rate in the tables.

¹³See a survey by Browning and Crossley (2001).

force participation may well have a negative effect on the saving rate. These additional variables are added sequentially.

In Regressions (5) to (7), the signs of these additional variables are as expected. More importantly, the inclusion of these additional variables does not change the substance of the estimation results for the key variables under investigation. The values of the coefficients on life expectancy, fertility, and the old-age dependency rate are quite stable throughout Regressions (5) to (7), and the significance levels of these coefficients are similar.

What are the quantitative implications of these estimation results for the aggregate saving rate? The value of the coefficient on life expectancy (in years) is 0.002 in the saving regression, while the aggregate saving rate is in decimal points. Thus, a one-year extension of life expectancy leads to a two-tenth of a percentage point increase in the aggregate saving rate. At this pace, it needs roughly a ten-year difference in life expectancy to explain a two percentage-point difference in the aggregate saving rate in favor of those with high life expectancy. The difference in life expectancy across countries may exceed 40 years, which may explain an eight percentage-point difference in the aggregate saving rate.

The plausible value of the estimated coefficient on the old-age dependency rate is about -0.6. This means that a one percentage point increase in this rate leads to roughly a six-tenth of a percentage point decline in the aggregate saving rate. The difference in the dependency rate across countries can be as high as ten percentage points that may account for a six percentage-point difference in the aggregate saving rates in favor of those with low old-age dependency rates.

To further make sense of the estimation results, we compare two groups of countries with life expectancy at birth in the period from 1993 to 1998 below 50 years (24 countries) or above 70 years (66 countries). In the low life expectancy group, the mean value of life expectancy was 44.9 years and the mean value of the aggregate saving rate was 5.8 percent. In the high life expectancy group, the mean value of life expectancy was 74.7 and the mean value of the aggregate saving rate was 21.2 percent. Correspondingly, the mean value of the old-age dependency rate was 5.5 percent in the low life expectancy group, but 15.4 percent in the other group. This 30-year difference in life

expectancy may explain a six percentage-point difference in the mean value of the aggregate saving rate in favor of the high life expectancy group. However, the ten percentage-point difference in the old-age dependency rates may give the low life expectancy group a six percentage-point advantage in the mean value of the aggregate saving rate. The net gain in the mean of the aggregate saving rate is about zero in this example.

A time series view on this quantitative assessment may also be relevant, given that variations over time are part of the panel estimation. Increasing longevity over a century long period could increase life expectancy at birth from 45 to 75 years and could gradually increase the old-age dependency rate from 5 to 15 percent, as it did in some industrial nations during the 1900s. The 30-year extension in life expectancy could increase the aggregate saving rate by 6 percentage points, but this is not the net increase in the aggregate saving rate that results from increasing longevity. The 10 percentage point increase in the old-age dependency rate should cut this gain by 6 percentage points with a one-generation time lag (20 to 30 years perhaps) that leaves a zero net gain.

4.2. *Investment regressions*

The investment regression results are reported in Table 3. In Regression (1), fertility has a significant negative effect on the investment rate, whereas life expectancy has a significant positive effect, as in Regression (1) of Table 2 with the same specification of the right-hand side variables. This result is consistent with that in Barro and Sala-i-Martin (1995). In Regression (2) where life expectancy is excluded, the estimated coefficients for the previous fertility and the old-age dependency variables are as expected. In Regression (3), based on our specification for the investment equation, the estimated coefficients for life expectancy and the old-age dependency rate are both significant and of the expected signs.

When the five additional variables are controlled for sequentially in Regressions (4) to (7), the life expectancy and old-age dependency rate variables maintain their significant roles in the investment regressions with the expected signs, whereas fertility continues to have a negative coefficient, though insignificant in most specifications. This indicates that both life expectancy and old-age dependency

are important for investment.

4.3. *Growth regressions*

We report the growth regression results in Table 4. In Regression (1), the middle-age to total population variable is excluded but life expectancy is controlled for, as was typically the case in growth regressions (e.g. Ehrlich and Lui, 1991; Barro and Sala-i-Martin, 1995). In this growth regression, the lagged per capita GDP variable has the expected negative sign and is significant at the one percent level, which suggests that there is convergence in income per capita. Population growth has a significant negative effect, whereas life expectancy has a significant positive effect. Thus, in such a simple model, both the signs of population growth and life expectancy are consistent with our theory's predictions.

In Regression (2), we exclude the life expectancy variable and include the middle-age to total population ratio. In the literature on growth empirics, however, life expectancy was usually used without controlling for the middle-age to total population ratio. Again, the lagged per capita GDP variable has a negative sign and is significant. The middle-age to total population variable has a significant positive effect on growth, which is consistent with our theory. The population growth variable has a negative growth effect, though the effect becomes insignificant.¹⁴

In Regression (3), both life expectancy and the middle-age to total population ratio are included. The estimated coefficients for both variables have the expected signs and are significant at the one percent level. Interestingly, the coefficients on both variables become smaller compared to Regressions (1) and (2) when only one of the two variables is included. Regressions (1) to (3) suggest that it is necessary to control for both the middle-age to total population ratio and life expectancy in a growth regression. Without controlling for both, as in Regressions (1) and (2), the effect of either variable is over-estimated. Both population growth and lagged per capita GDP

¹⁴One may be concerned about the possibility that population growth and the ratio of middle-age to total population could be endogenous. Generally speaking, there is no perfect way to solve this issue, as it is very difficult to find good instrumental variables in cross-country data. To partially address this issue, we use lagged population growth and a lagged ratio of middle-age to total population in the growth regressions, and find that the main results do not change with these lags controlled for.

have the expected signs and the coefficient on the latter is significant.

We next add four additional variables to the growth equation: terms-of-trade growth, primary school enrollment, the labor force participation rate, and the mortality rate below age 5. The first three of these additional variables are expected to have positive effects on per capita GDP growth. However, the child mortality rate may have either a positive or negative effect on growth. On the one hand, a higher child mortality rate will reduce the young dependency ratio and thus raise the growth rate. On the other hand, a high child mortality rate implies poor health conditions in a country that should be harmful to growth. Thus, the sign of the coefficient on this variable in the growth equation is purely an empirical question.

The results with the additional variables are reported in Regressions (4) to (7). The lagged per capita GDP variable continues to have a negative and significant coefficient for all these specifications. The population growth variable becomes significant in all these regressions when controlling for these additional variables. The coefficient on the log middle-age to total population ratio becomes insignificant, though it remains positive. The life expectancy variable continues to have a positive and highly significant coefficient, though the magnitude becomes smaller.

As both the growth rate and the demographic variables are in logarithmic form, the coefficients on these demographic variables measure the elasticity of per capita GDP growth regarding these variables. If we take model (4) as an example, a one-percent increase in the middle-age to total population ratio will raise the annual growth rate of per capita GDP by 0.03 percent. Similarly, the elasticity of per capita GDP growth with respect to life expectancy is 0.024.

Some examples may be useful for illustrative purposes. First, let us assess the growth implication of the variations in life expectancy and in the total dependency rate across countries. In a comparison of the 24 countries with low life expectancy with the 66 countries with high life expectancy, the mean value of life expectancy was roughly 67% higher in the latter than in the former group, and the middle age to total population ratio was about 13 percentage points higher in the latter than in the former (0.52 versus 0.65). The 67% higher life expectancy may increase the growth rate by 1.6%, and the 13 percentage points higher middle to old-age population rate

may increase the growth rate by $0.032 \times 13\%/0.52$, i.e. 0.8%, which creates a total increase in the growth rate by 2.4%. Second, we assess the growth implication of the variations in life expectancy and in the total dependency rate over time. From 1968 to 2003, life expectancy increased from 56.2 to 65.9 years (or a 17% rise) and the total dependency rate declined slightly from 0.44 to 0.38 by 6 percentage points (largely due to the decline in fertility). The 17% rise in life expectancy can increase the growth rate by 0.4% and the 6 percentage points decline in the total dependency rate can increase the growth rate by 0.4%, which creates an overall 0.8% increase in the growth rate. Thus, both assessments deliver a positive message.

5. Concluding remarks

In this paper, we have investigated the effects of life expectancy, population growth, and the population age structure on savings, investment, and per capita output growth. A distinctive feature of this study is the careful specification of the regression equations regarding both longevity and dependency rates that are based on a growth model with overlapping generations. A key result of the theoretical model is its demonstration of the separate roles of life expectancy and old-age dependency. As far as life-cycle savings are concerned, an increase in the former increases the savings of middle-aged agents, whereas an increase in the latter increases dissavings of old-aged agents. The econometric implication is that both variables should be included as regressors. An additional unique feature of this study is the use of the World Development Indicators panel data set that has much more expansive information on the aggregate saving rates and many other variables than in the previous empirical work.

The theoretical implications are supported by the data. In particular, an increase in longevity has a positive effect on savings, investment and growth, whereas an increase in dependency rates reduces them. In the saving regressions, the magnitude of the longevity effect appears to be similar to that of the old-age dependency effect, which suggests that the net effect of these two opposing forces could be zero. Another important finding is that both the population age structure and life expectancy are contributing factors to economic growth.

Population aging has been worrisome in the public policy arena, particularly regarding savings, investment, and growth, and has motivated calls for reform in the tax system and in the old-age support system. While our results on the dependency rate are indeed consistent with this negative image of population aging, the new evidence in this study on longevity offers some relief in terms of the individual's positive response to rising life expectancy. The overall message of our results on aggregate savings and growth, both in terms of theory and evidence, is more optimistic than those that have focused solely on population aging.

Appendix

As argued in Gersovitz (1983), the positive relationship between the saving rate and the survival rate is no longer assured once the latter rises with consumption at low consumption levels. To consider this, suppose that $P_t = 1 - \exp(-c_t)$ for $c_t < \tilde{c}$ where $\tilde{c} > 0$. Here, $P \in (0, 1)$ for all $c \in (0, \tilde{c})$; $P' > 0$ and $P'' < 0$. To distinguish it from the average rate of survival, denote the latter as \bar{P} .

Using the budget constraints $c_t = W_t - s_t$ and $z_{t+1} = R_{t+1}s_t/\bar{P}_t$, the problem of maximizing lifetime utility, $\max \log c_t + P_t\beta \log z_{t+1}$, becomes:

$$\max_{s_t} \log(W_t - s_t) + [1 - \exp(-(W_t - s_t))]\beta \log(R_{t+1}s_t/\bar{P}_t).$$

The first-order condition of this problem is:

$$-1/c_t - \exp(-c_t)\beta \log(R_{t+1}s_t/\bar{P}_t) + P_t\beta/s_t = 0.$$

Note that $\exp(-c) = 1 - P$. Also, note that $s_t = \Gamma_{s,t}W_t$ and $c_t = (1 - \Gamma_{s,t})W_t$. Using the expression of R_{t+1} in addition to these notes, we can rewrite the first-order condition as

$$-\frac{1}{(1 - \Gamma_{s,t})W_t} - \beta(1 - P_t) \log \left[\frac{\alpha A (\Gamma_{s,t}W_t)^{1-(1-\alpha)(1-\theta)} N_t^{(1-\alpha)(1-\theta)}}{\bar{P}_t} \right] + \frac{P_t\beta}{\Gamma_{s,t}W_t} = 0.$$

Observe that the LHS is rising with P_t and \bar{P}_t but falling with $\Gamma_{s,t}$. In equilibrium, $P_t = \bar{P}_t$ by symmetry. Rewriting $P_t = 1 - \exp[-(1 - \Gamma_{s,t})W_t]$, the first-order condition implicitly determines the equilibrium solution for $\Gamma_{s,t}$ as a function of a predetermined wage rate W_t and an exogenous fertility rate N_t . When income rises, both the rate of survival and the saving rate may rise, a case we briefly illustrate below.

Differentiating P_t with respect to W_t , we have:

$$\frac{\partial P_t}{\partial W_t} = (1 - P_t) \left(1 - \Gamma_{s,t} - W_t \frac{\partial \Gamma_{s,t}}{\partial W_t} \right) = (1 - P_t)[1 - \Gamma_{s,t}(1 + \epsilon_{s,w})],$$

where $\epsilon_{s,w} \equiv (\partial \Gamma_{s,t} / \partial W_t)(W_t / \Gamma_{s,t})$ is the income elasticity of the saving rate. Clearly, $\partial P_t / \partial W_t > 0$ if the income elasticity of the saving rate is such that $\epsilon_{s,t} < (1 - \Gamma_{s,t}) / \Gamma_{s,t}$.

Differentiating the first-order condition with respect to W_t and collecting terms, we have:

$$\begin{aligned} \frac{\partial \Gamma_{s,t}}{\partial W_t} &= \frac{F}{G}, \quad \text{where} \\ F &\equiv \frac{\beta(1-P_t)\{1-\Gamma_{s,t}-[1-(1-\alpha)(1-\theta)]\Gamma_{s,t}\}}{\Gamma_{s,t}W_t} + \frac{\beta(1-P_t)^2(1-\Gamma_{s,t})}{P_t} + \\ &\quad \frac{[P_t\beta(1-\Gamma_{s,t})-\Gamma_{s,t}][(1-\Gamma_{s,t})W_t-1]}{\Gamma_{s,t}(1-\Gamma_{s,t})W_t^2}, \\ G &\equiv \frac{P_t\beta}{\Gamma_{s,t}^2W_t} + \frac{\beta(1-P_t)^2W_t}{P_t} + \frac{\beta(1-P_t)[1-(1-\alpha)(1-\theta)]}{\Gamma_{s,t}} + \frac{1}{(1-\Gamma_{s,t})^2W_t} + \\ &\quad \frac{\beta(1-\Gamma_{s,t})-\Gamma_{s,t}}{\Gamma_{s,t}(1-\Gamma_{s,t})}. \end{aligned}$$

When reaching this expression of $\partial \Gamma_{s,t}/\partial W_t$, we have used the first-order condition to substitute out the log terms. Both the numerator F and the denominator G are likely to be positive for the following reasons. First, the first term of F is positive under a realistic restriction $\Gamma_{s,t} < 1/2$, while the second term is always positive. In the last term of F , the first factor is likely to be very small because $[P_t\beta(1-\Gamma_{s,t})-\Gamma_{s,t}] = 0$ when P_t is exogenously given as in the main text; see (2). When P_t is an increasing function of consumption, we expect the saving rate to be lower since current consumption now contributes to utility also indirectly from enhancing the chance of survival. That is, $[P_t\beta(1-\Gamma_{s,t})-\Gamma_{s,t}] > 0$ is expected when survival is a function of consumption. Now, the last term of F may be negative only when the wage income W_t is low enough such that the second factor becomes negative, i.e. $[(1-\Gamma_{s,t})W_t-1] = c_t - 1 < 0$. Even in this case, $F > 0$ may hold. When $c_t \geq 1$, $F > 0$. Further, $G > 0$ because all the first four terms are positive and the last term is positive by noting that $[\beta(1-\Gamma_{s,t})-\Gamma_{s,t}] > [P_t\beta(1-\Gamma_{s,t})-\Gamma_{s,t}]$.

In sum, as income rises, workers may increase current consumption (savings) less (more) than proportionately such that both the rate of survival and the saving rate can rise at the same time. This case may apply to low income families across countries and hence suggest a positive role of income in the saving-rate equation in the empirical specification. However, in the main text we focus on exogenous factors that influence the probability of survival. Given the relatively small (large) difference in average life expectancy (per capita GDP) between China and the United States, these exogenous factors are likely to be highly relevant in the determination of the rate of survival.

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Table 1: Summary Statistics

	Mean	Standard deviation	Minimum	Maximum	Number of observations
Savings GDP ratio	0.165	0.152	-0.928	0.754	1099
Investment GDP ratio	0.226	0.086	-0.174	0.916	1093
Annual growth rate of per capita GDP	0.015	0.038	-0.423	0.208	1110
Annual population growth rate	0.019	0.015	-0.054	0.172	1544
Fertility rate	4.161	1.985	0.969	10.13	1483
Life expectancy	62.323	11.630	31.2	81.3	1453
Old (aged 65+) to middle-age (15-64) population	0.100	0.057	0.018	0.284	1376
Middle-age to total population	58.471	6.540	46.032	73.345	1376

Data source: World Development Indicators 2005

Table 2: Saving Regressions (Fixed Effects)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Fertility (t-1)	-0.016*** (3.13)	-0.017*** (3.55)	-0.015*** (2.92)	-0.009* (1.82)	-0.004 (0.72)	-0.004 (0.85)	-0.005 (0.96)
Life expectancy (t)	0.002** (1.97)		0.002** (1.99)	0.002* (1.86)	0.002 (1.62)	0.002 (1.64)	0.002* (1.78)
Old to middle-age population (t)		-0.259 (1.22)	-0.266 (1.26)	-0.603*** (2.73)	-0.715*** (3.35)	-0.675*** (3.15)	-0.597** (2.46)
Log per capita GDP (t-1)				0.064*** (4.49)	0.091*** (6.36)	0.093*** (6.51)	0.094*** (6.53)
Terms of trade growth (t-1)					0.075*** (7.03)	0.076*** (7.14)	0.076*** (7.17)
Primary school enrollment (t)						-0.032* (1.93)	-0.029* (1.71)
Labor force participation rate (t)							-5.917 (0.53)
Mortality rate below age 5 (t)							0.005 (0.73)
Observations	779	779	779	779	779	779	779
Number of countries	149	149	149	149	149	149	149
R-squared	0.07	0.06	0.07	0.10	0.17	0.17	0.17

Absolute value of t-statistics in parentheses; * significant at 10%; ** significant at 5%; *** significant at 1%; All regressions control for country and time fixed effects.

Table 3: Investment Regressions (Fixed Effects)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Fertility (t-1)	-0.010** (2.30)	-0.010** (2.38)	-0.007* (1.75)	-0.009** (1.98)	-0.003 (0.74)	-0.004 (0.84)	-0.004 (0.98)
Life expectancy (t)	0.002** (2.08)		0.002** (2.16)	0.002** (2.21)	0.002* (1.95)	0.002** (1.97)	0.002* (1.93)
Old to middle-age population (t)		-0.665*** (3.72)	-0.671*** (3.76)	-0.594*** (3.14)	-0.703*** (3.90)	-0.676*** (3.74)	-0.472** (2.31)
Log per capita GDP (t-1)				-0.015 (1.23)	0.011 (0.92)	0.012 (1.03)	0.011 (0.92)
Terms of trade growth (t-1)					0.073*** (8.17)	0.074*** (8.25)	0.074*** (8.32)
Primary school enrollment (t)						-0.022 (1.60)	-0.019 (1.34)
Labor force participation rate (t)							-22.570** (2.38)
Mortality rate below age 5 (t)							-0.006 (1.00)
Observations	775	775	775	775	775	775	775
Number of countries	149	149	149	149	149	149	149
R-squared	0.07	0.08	0.09	0.09	0.18	0.18	0.19

Absolute value of t-statistics in parentheses; * significant at 10%; ** significant at 5%; *** significant at 1%; All regressions control for country and time fixed effects.

Table 4: Growth Regressions (Fixed Effects)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
log (1+population growth) (t)	-0.522*** (3.91)	-0.123 (0.72)	-0.146 (0.87)	-0.290** (2.17)	-0.289** (2.15)	-0.287** (2.13)	-0.285** (2.12)
log middle-age to total population (t)		0.109*** (4.72)	0.086*** (3.59)	0.032* (1.67)	0.032* (1.66)	0.031 (1.62)	0.032 (1.63)
log life expectancy (t-1)	0.056*** (4.80)		0.044*** (3.70)	0.024** (2.53)	0.024** (2.54)	0.026** (2.53)	0.026** (2.50)
log per capita GDP (t-1)	-0.006*** (4.05)	-0.005*** (3.60)	-0.008*** (5.03)	-0.004*** (3.23)	-0.004*** (3.29)	-0.004*** (3.24)	-0.004*** (3.21)
Trade growth (t)				0.060*** (21.11)	0.060*** (21.01)	0.059*** (20.89)	0.059*** (20.88)
Primary school enrollment (t)					0.003 (0.76)	0.003 (0.75)	0.003 (0.77)
Labor force participation rate (t)						0.368 (0.42)	0.369 (0.42)
Mortality rate below age 5 (t)							0.000 (0.19)
Observations	796	796	796	796	796	796	796
Number of countries	150	150	150	150	150	150	150
R-squared	0.19	0.20	0.21	0.31	0.32	0.32	0.33

Absolute value of t-statistics in parentheses; * significant at 10%; ** significant at 5%; *** significant at 1%; All regressions control for country and time fixed effects.