Macroeconomic Dynamics, **20**, 2016, 1341–1358. Printed in the United States of America.
doi:10.1017/S1365100514000911

EFFECT OF PUBLIC HEALTH INVESTMENT ON ECONOMIC DEVELOPMENT VIA SAVINGS AND FERTILITY

HIDEKI NAKAMURA
Osaka City University

YUKO MIHARA
Okayama University of Science

This study considers adult mortality and analyzes the effect of public health investment on economic development, whereby investment increases savings but decreases fertility through a decrease in adult mortality. As the labor force increases, investment temporarily decreases capital per unit of labor. However, the decrease in fertility increases capital per unit of labor in subsequent periods. By considering these two opposing effects of decreasing fertility, we clarify the conditions required for investment to improve economic development via increasing savings and decreasing fertility. We examine panel estimation and present some weak evidence for our model.

Keywords: Public Health Investment, Life Expectancy, Savings, Fertility, Panel Estimation

1. INTRODUCTION

The main reason for examining the connection between public health investment and economic development in developing economies is to evaluate the extent of any health challenges. For instance, the governments of many developing economies combat diseases that have high mortality rates. However, the situation can vary substantially. For example, life expectancy and economic development differ considerably between East Asian and Pacific economies and sub-Saharan African economies. As shown in Table 1, East Asian and Pacific economies achieved high economic growth with a decline in the poverty headcount ratio. The fertility rate in these economies also declined and life expectancy increased steadily. Significant gaps now exist in GDP per capita between these economies and their sub-Saharan African counterparts because the economies of the latter have stagnated. Fertility

We thank the seminar participants at Fukushima University and Osaka University of Economics for their comments. The Editor, William Barnett, provided helpful suggestions to improve the paper. Address correspondence to: Hideki Nakamura, Faculty of Economics, Osaka City University 3-3-138 Sugimoto, Sumiyoshi, Osaka 558-8585, Japan; e-mail: hnakamur@econ.osaka-cu.ac.jp.

 1365-1005/16

TABLE 1. Economic growth, fertility, education, and health of developing economies

	1960s	1970s	1980s	1990s	2000s
East Asian and Pacific countries					
Per capita GDP growth	0.53	5.45	6.15	6.57	7.89
Fertility rate	5.96	4.37	3.07	2.19	1.84
Poverty headcount ratio			87.42	70.61	41.4
Secondary school enrollment				52.95	59.28
Life expectancy	51.53	63.22	66.70	69.21	72.31
Public health expenditure / GDP				1.66	1.86
	1960s	1970s	1980s	1990s	2000s
Sub-Saharan countries					
Per capita GDP growth	2.0	1.30	−1.10	−0.88	2.31
Fertility rate	6.66	6.78	6.62	6.08	5.54
Poverty headcount ratio			73.73	77.25	73.68
Secondary school enrollment				19.95	25.22
Life expectancy	42.09	46.14	49.29	49.96	52.16
Public health expenditure / GDP				2.36	2.62

Note: Whereas the World Bank presents the cross-country average data, we calculate the averages between 10 years wherever possible. Per capita GDP growth shows the rate of growth. Poverty headcount ratio is represented at $2 a day (% of population). Secondary school enrollment represents the net rate. Life expectancy is that at birth (years).

rates remain high in sub-Saharan African economies; the poverty headcount ratios well illustrate the prevalence of poverty, and life expectancy has increased slightly.

Some controversy surrounds the empirical effect of health on economic development [see Acemoglu and Johnson (2007), Weil (2007), Lorentzen et al. (2008), Angeles (2010), and Cervellati and Sunde (2011)]. To address this, this study first theoretically investigates the conditions required for positive effects of public health investment.[1] When adult mortality decreases because of public health investment, individuals seek to have fewer children, and thereby increase their savings, given that the marginal utility of consumption rises in their retirement years. Thus, public health investment has a temporarily negative effect on the amount of capital per unit of labor because the decrease in the time spent on childrearing implies an increase in the labor force. However, given capital stock, the decline in the fertility rate can increase capital per labor unit. Thus, the decline in fertility has two opposing effects on the amount of capital per labor unit in subsequent periods. When life expectancy is not low, the latter effect can dominate the former, and thus, the decline in fertility increases capital per labor unit. If capital per labor unit exceeds a threshold, capital accumulation can continue via the increase in savings and the decrease in fertility.

Our analysis involves two important assumptions. First, public health investment can raise the probability of survival. However, we show that even with this assumption, health investment does not always assist economic development. Second, we consider the existence of traditional technology as a means of characterizing less developed economies. When traditional technology is used because of low capital per labor unit, income does not rise.

In the second part of the analysis, we use panel estimation to examine our model. We find that in low-income economies, public health investment may work to increase life expectancy but decrease fertility. However, the effect of public health investment on savings is weak. We confirm the two opposing effects of fertility rates in the previous and current periods on output per capita. We also find that in the low-income economies, the fertility rate may affect per capita output more strongly than savings.

To begin with, we posit the following. Considering public health investment, Chakraborty (2004) examines how a decline in adult mortality affects economic development through a rise in savings.[2] This study explores the effect of public health investment through its impact on savings and fertility. In our model, there is a temporary negative effect of a decline in fertility on output per capita, such that the escape from poverty depends on life expectancy. Using panel estimation, we examine not only the effect of public health investment on life expectancy, fertility, and savings, but also the effect of savings and fertility on per capita output.

Several studies have explored the conditions for demographic transition and economic development [see Galor and Weil (2000); Hazan and Berdugo (2002); Galor (2005); Moav (2005); Momota (2009); Nakamura and Seoka (2014)]. While we consider savings and fertility with life expectancy, we clarify the conditions for economic development. Our empirical analysis examines the structural change in the effect of savings and fertility on per capita output between high-income and low-income economies.

The remainder of the paper is organized as follows. Section 2 explains our model. In Section 3, we consider two stages of economic development: constant income and the start of a rise in income. We also consider the commencement of education investment. We conduct regression analyses on our model in Section 4. We conclude in Section 5 with a brief summary of the analysis.

2. MODEL

2.1. Individuals

Our model is a three-period closed-economy overlapping-generations model with endogenous adult mortality. We assume that individuals born in period $t-1$ always live in period t. However, their survival in period $t+1$ depends on survival probability. We assume that the probability that an individual born in period $t-1$ survives in $t+1$ depends on the public health investment in period t,

$$p_t = p(h_t), \tag{1}$$

where we assume that $p(0) > 0$, $\lim_{h_t \to \infty} p(h_t) \leq 1$, $p'(h_t) > 0$, $p''(h_t) < 0$, and $\lim_{h_t \to 0} p'(h_t) < \infty$. p_t is survival probability and h_t is per capita public health investment.

https://doi.org/10.1017/S1365100514000911 Published online by Cambridge University Press

Public health investment increases survival probability with diminishing returns. However, it is not impossible for individuals to survive, even with no investment. The marginal effect evaluated at zero investment is finite because of physiological constraints.

The financing of public health investment is through a proportionate tax on the wage rate,

$$h_t = \tau w_t, \tag{2}$$

where τ is the tax rate ($0 < \tau < 1$) and w_t is the wage rate.

Given the survival probability, parents born in period $t-1$ are concerned for their consumption in periods t and $t+1$ and their fertility. We consider the cost of childrearing to be an opportunity cost. Parents obtain income from child labor when children work in the first period. Labor income is used for taxes, consumption, and savings. At the end of period t, each individual deposits his/her savings into a mutual fund. The mutual fund invests these savings in capital. Because the fund earns a gross return r_{t+1} on its investment, perfect competition ensures that, at equilibrium, the gross rate of return is $r_{t+1}/p_t \equiv R_{t+1}$. If individuals survive through period $t+1$, they consume their interest income.

The utility maximization problem of an individual born in period $t-1$ is

$$\max_{c_{yt}, s_t, n_t} U_t \equiv \beta[\alpha \ln c_{yt} + (1-\alpha)\ln n_t] + (1-\beta)p_t \ln c_{ot+1}, \tag{3}$$

$$\text{s.t.} \qquad (1 - zn_t)w_t + bn_t w_t - \tau w_t = c_{yt} + s_t, \tag{4}$$

$$R_{t+1}s_t = c_{ot+1}, \tag{5}$$

where we assume that $0 < \alpha < 1$, $0 < \beta < 1$, $0 < z < 1$, $0 < b < z$, and $0 < 1 - (z-b)n_t < 1$. z is the duration of childrearing per child and b is the productivity of child labor. c_{yt} and c_{ot+1} are consumption in periods t and $t+1$, respectively, n_t is the fertility rate in period t, and s_t is savings in period t.

The first-order conditions are as follows:

$$c_{yt} = \frac{\alpha\beta}{\beta + p_t(1-\beta)}(1-\tau)w_t, \tag{6}$$

$$s_t = \frac{p_t(1-\beta)}{\beta + p_t(1-\beta)}(1-\tau)w_t, \tag{7}$$

$$n_t = \frac{\beta(1-\alpha)(1-\tau)}{[\beta + p_t(1-\beta)](z-b)}. \tag{8}$$

An increase in the survival probability increases the marginal utility of consumption in period $t+1$. The consumption in period t then declines to increase savings and, consequently, the consumption in period $t+1$. When the survival probability rises, parents choose to have fewer children. Child labor increases the fertility rate.

2.2. Firms

Two types of technology can be used: traditional and modern. A firm determines which type of technology should be used to minimize costs. A linear production function in which only labor is used is assumed for the traditional technology,

$$Y_t = A_{\mathrm{T}} l_{\mathrm{T}t}, \tag{9}$$

where we assume that $0 < A_{\mathrm{T}}$. Y_t is the output and $l_{\mathrm{T}t}$ is the input of labor for the traditional technology. We assume that only the traditional technology uses child labor.

In addition, we assume a Cobb–Douglas production function for modern technology,

$$Y_t = A_{\mathrm{M}} x_t^{\nu} l_{\mathrm{M}t}^{1-\nu}, \tag{10}$$

where we assume that $0 < A_{\mathrm{M}}$ and $0 < \nu < 1$. x_t and $l_{\mathrm{M}t}$ denote the inputs of capital and labor for the modern technology, respectively.

When the traditional technology in (9) is used, the wage rate equals the shift parameter A_{T}:

$$w_t = A_{\mathrm{T}} \equiv w_0. \tag{11}$$

Modern technology implies the following first-order conditions:

$$r_t = \nu A_{\mathrm{M}} \left(\frac{x_t}{l_{Mt}} \right)^{\nu-1}, \tag{12}$$

$$w_t = (1-\nu) A_{\mathrm{M}} \left(\frac{x_t}{l_{Mt}} \right)^{\nu}. \tag{13}$$

Two cases are possible at equilibrium: first, technologies of both types are indifferently applied and second, only the modern technology is chosen. When capital per labor unit is smaller than the threshold represented by k_{I}, both types of technology are used,

$$k_t \leq k_{\mathrm{I}} \equiv \left[\frac{A_{\mathrm{T}}}{A_{\mathrm{M}}(1-\nu)} \right]^{1/\nu}, \tag{14}$$

where $k_t \equiv K_t/L_t$ is the capital per labor unit in period t. K_t and L_t are the capital stock and labor force, respectively.

A rise in the productivity of traditional technology increases the threshold, whereas a rise in the productivity of modern technology decreases the threshold. The wage rate is constant as long as (14) holds. The interest rate is also a constant:

$$r_t = \nu A_{\mathrm{M}} \left[\frac{A_{\mathrm{T}}}{A_{\mathrm{M}}(1-\nu)} \right]^{(\nu-1)/\nu} \equiv r_0.$$

The savings in period $t-1$ form the capital stock in period t, whereas individuals born in period $t-1$ become the labor force in period t. When traditional technology is available, children born in period t are also included in the labor force as child labor:

$$s_{t-1}N_{t-1} = K_t, \tag{15}$$

$$(1 - zn_t)N_t + bn_tN_t = L_t, \tag{16}$$

where N_t is the size of the population born in period $t-1$.

As capital per labor unit increases, the ratio of firms using modern technology increases. When $k_t > k_{\mathrm{I}}$ holds, only modern technology is used, and the interest rate decreases and the wage rate increases with the accumulation of capital per labor unit:

$$r_t = \nu A_{\mathrm{M}} k_t^{\nu-1}, \tag{17}$$

$$w_t = (1-\nu)A_{\mathrm{M}} k_t^{\nu}. \tag{18}$$

3. SAVINGS, FERTILITY, AND OUTPUT WITH PUBLIC HEALTH INVESTMENT

3.1. Constant Income

We now investigate whether public health investment can cause income to begin to rise. When income is constant, we denote this as Stage I. We assume that the government starts to invest in public health in Stage I. The fertility rate in (8) is rewritten as

$$n_t = \frac{\beta(1-\alpha)(1-\tau)}{[\beta + p_{\mathrm{I}}(1-\beta)](z-b)} \equiv n_{\mathrm{I}}, \tag{19}$$

where $p_{\mathrm{I}} \equiv p(\tau A_{\mathrm{T}})$.

As shown in Figure 1, the fertility rate is constant in Stage I. Given the savings, population, and fertility rate in period -1, capital per labor unit in period 0 is represented as

$$k_0 = \frac{K_0}{L_0} = \frac{s_{-1}N_{-1}}{[1-(z-b)n_{\mathrm{I}}]N_0} = \frac{s_{-1}}{[1-(z-b)n_{\mathrm{I}}]n_{-1}}. \tag{20}$$

We assume that individuals do not initially have public health care. Furthermore, we assume that $k_{-1} < k_{\mathrm{I}}$. This means that the economy is initially in a poverty trap.

The question is whether public health investment helps the economy take off by increasing the capital per labor unit. Health investment necessarily increases the survival probability by assumption. Parents then seek to have fewer children to increase savings. That is, we have $\partial n_{\mathrm{I}}/\partial \tau < 0$. This implies an increase in the labor force.

PROPOSITION 1 *(Initial effect of public health investment on economic development in Stage I). An increase in the survival probability resulting from public health investment decreases capital per labor unit in period* 0 *for any* τ*:*

$$\frac{\partial k_0}{\partial p_{\mathrm{I}}}\frac{\partial p_{\mathrm{I}}}{\partial \tau} < 0. \tag{21}$$

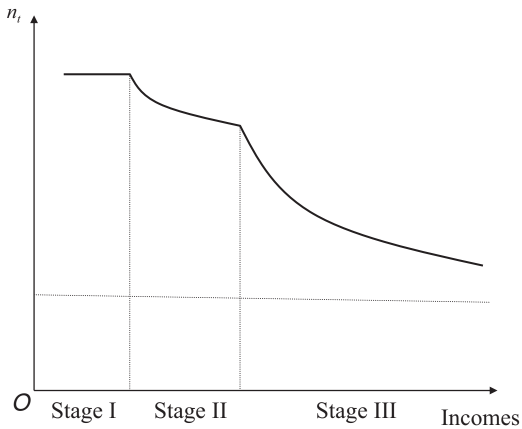

FIGURE 1. Fertility rate.

Public health investment initially has a negative effect on economic development because the increase in the labor force disrupts the accumulation of capital per labor unit. Health investment also affects savings. The savings in (7) are rewritten as

$$s_t = \frac{p_{\mathrm{I}}(1-\beta)(1-\tau)A_{\mathrm{T}}}{\beta + p_{\mathrm{I}}(1-\beta)} \equiv s_{\mathrm{I}}. \tag{22}$$

Then public health investment increases savings through the increase in survival probability. However, taxes decrease savings. As a result, an increase in the tax rate increases savings when the tax rate is low.

If the following condition holds for any tax rate, the economy will remain in poverty:

$$k_t = \frac{s_{\mathrm{I}} N_{t-1}}{[1-(z-b)n_{\mathrm{I}}]N_t} = \frac{s_{\mathrm{I}}}{[1-(z-b)n_{\mathrm{I}}]n_{\mathrm{I}}} < k_{\mathrm{I}}. \tag{23}$$

If it is impossible for capital per labor unit to exceed threshold k_{I} in period 1, then it remains constant in the subsequent periods. The presence of child labor then makes it more difficult for capital per labor unit to surpass the threshold because of the increase in fertility.

A decline in the fertility rate has two opposing effects on capital per labor unit. Although an increase in the labor force decreases the capital per labor unit, the decline in the fertility rate increases the capital per labor unit. We assume that

$$\frac{\beta(1-\alpha)(1-\tau)}{\beta + p_{\mathrm{I}}(1-\beta)} < \frac{1}{2}. \tag{A.1}$$

This assumption can hold easily with a high survival probability. Under Assumption (A.1), the latter effect from the decline in fertility dominates the former.[3] We then have $\partial k_t/\partial n_{\mathrm{I}} < 0$. This implies that public health investment can increase capital per labor unit via the decline in the fertility rate.

https://doi.org/10.1017/S1365100514000911 Published online by Cambridge University Press

PROPOSITION 2 *(Effect of survival probability on economic development in Stage I). Suppose economies are identical in all respects except their initial survival probabilities. Under Assumption (A.1), the economy with a lower survival probability is less likely to escape from poverty.*

Proof. We define the survival probabilities of economies A and B as $P_{\mathrm{A}t}$ and $P_{\mathrm{B}t}$, respectively. We assume that

$$P_{\mathrm{A}}(0) > P_{\mathrm{B}}(0). \tag{24}$$

As the economies are identical in all other respects, for any τ, we have $P_{\mathrm{A}t} > P_{\mathrm{B}t}$.

Under Assumption (A.1), we have $\frac{\partial k_t}{\partial n_{\mathrm{I}}}\frac{\partial n_{\mathrm{I}}}{\partial P_{\mathrm{I}}} > 0$. We also have $\frac{\partial s_{\mathrm{I}}}{\partial p_{\mathrm{I}}} > 0$. Thus, we obtain the following inequality:

$$\frac{s_{\mathrm{I}}}{[1-(z-b)n_{\mathrm{I}}]n_{\mathrm{I}}}\Big|_{P_t=P_{\mathrm{A}t}} > \frac{s_{\mathrm{I}}}{[1-(z-b)n_{\mathrm{I}}]n_{\mathrm{I}}}\Big|_{P_t=P_{\mathrm{B}t}}.$$

This implies that (23) can hold more easily in economy B, in which the initial survival probability is low. ■

Thus, the initial environment of health crucially affects economic development.[4] In an economy with a low initial survival rate, a large amount of public health investment would be necessary for the economy to take off.

3.2. Start of a Rise in Income

If the following condition holds, the economy can escape poverty and income can start to rise:

$$k_{\mathrm{I}} < k_t = \frac{s_{\mathrm{I}}}{(1-zn_t)n_{\mathrm{I}}}, \tag{A.2}$$

where $n_t = \frac{\beta(1-\alpha)(1-\tau)}{[\beta+p(\tau w_t)(1-\beta)]z}$.

When $k_t > k_{\mathrm{I}}$ holds, income starts to rise. We denote this as Stage II. Only modern technology is used. As the wage rate increases with the accumulation of capital per labor unit, public health investment increases, and thus survival probability also increases, so that we have $p_t = p(\tau w_t)$. The fertility rate then decreases because of the increase in survival probability.

Capital per labor unit in the following periods is represented as

$$k_{t+1} = \frac{s_t}{(1-zn_{t+1})n_t}. \tag{25}$$

The savings in Stage II are represented as

$$s_t = \frac{p_t(1-\beta)(1-\tau)w_t}{\beta+p_t(1-\beta)}. \tag{26}$$

An increase in the income level increases savings. Furthermore, health investment increases savings through the increase in survival probability.

https://doi.org/10.1017/S1365100514000911 Published online by Cambridge University Press

The fertility rate in Stage II is represented as

$$n_t = \frac{\beta(1-\alpha)(1-\tau)}{[\beta + p_t(1-\beta)]z}. \tag{27}$$

As shown in Figure 1, the fertility rate in Stage II decreases with the increase in survival probability. Although the decrease in the fertility rate in period t increases capital per labor unit, the decrease in the fertility rate in period $t+1$ decreases capital per labor unit through an increase in the labor force. Thus, the decline in the fertility rate again has the same two opposing effects on the accumulation of capital per labor unit.

The dynamics of capital per labor unit can be expressed as

$$f(k_{t+1}) = g(k_t), \tag{28}$$

where

$$f(k_{t+1}) \equiv k_{t+1}[1 - \frac{\beta(1-\alpha)(1-\tau)}{\beta + p_{t+1}(1-\beta)}], \quad g(k_t) \equiv \frac{z(1-\beta)}{\beta(1-\alpha)} p_t(1-\nu)A_{\mathrm{M}}k_t^{\nu},$$

$p_t = p(\tau w(k_t))$, and $w(k_t) \equiv (1-\nu)A_{\mathrm{M}}k_t^{\nu}$. We have $g(0) = 0$ and $g'(k_t) > 0$. We also have $f(0) = 0$, $f'(k_{t+1}) > 0$, and

$$0 < \lim_{k_{t+1}\to 0} f'(k_{t+1}) = 1 - \frac{\beta(1-\alpha)(1-\tau)}{\beta + p(0)(1-\beta)} < 1.$$

We assume that

$$\nu \leq \frac{1}{3}. \tag{A.3}$$

This assumption ensures that $g''(k_t) < 0$. The inequality $\nu < 1/2$ ensures that $\lim_{k_t\to 0} g'(k_t) = \infty$ and $\lim_{k_t\to\infty} g'(k_t) = 0$.

In addition, we assume the specific survival probability

$$p(h_t) = \frac{o + h_t}{1 + h_t}, \tag{A.4}$$

where we assume that $0 < o < 1$. Under Assumption (A.4), we obtain $0 < \lim_{k_{t+1}\to\infty} f'(k_{t+1}) < 1$, $f''(k_{t+1}) \geq 0$, and $\lim_{k_{t+1}\to\infty} f''(k_{t+1}) = 0$.

Figure 2 illustrates the dynamics of capital per labor unit. The slope of $g(k_t)$ is eventually lower than that of $f(k_{t+1})$ as capital per labor unit increases. Under Assumptions (A.3) and (A.4), there necessarily exists a stable steady state, such that given the initial capital per labor unit k_i, capital per labor unit monotonically increases and converges to the steady-state value k^*.[5] Survival probability increases because of the accumulation of capital per labor unit. The increase in survival probability further assists the accumulation of capital per labor unit through the increase in savings and decrease in the fertility rate under Assumptions (A.1) and (A.2).

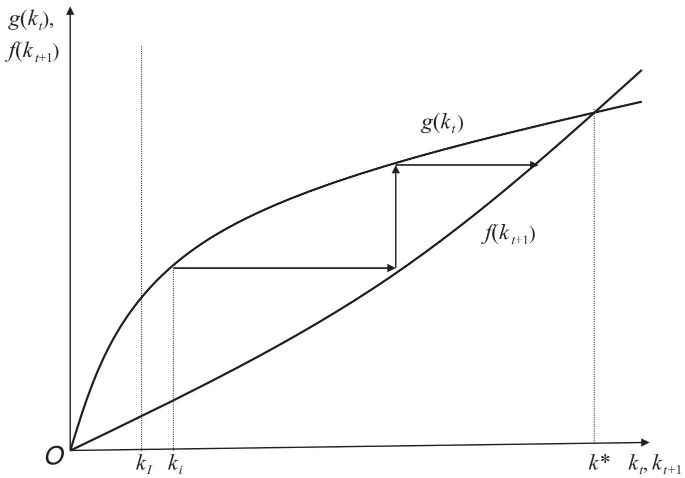

FIGURE 2. Dynamics of capital per labor unit.

Let us consider the tax rate that increases the capital per labor unit at the steady-state value. Because the survival probability in Stage II is higher than that in Stage I, Assumption (A.1) implies the following inequality:

$$\frac{\beta(1-\alpha)(1-\tau)}{\beta + p(\tau w(k^*))(1-\beta)} < \frac{1}{2}. \tag{29}$$

Given (29), the decline in the fertility rate from public health investment can increase the capital per labor unit at the steady-state value because the positive effect of the decline in the fertility rate dominates its negative effect.

We assume that, given the steady-state capital per labor unit, there exists a tax rate, denoted by τ_s, that maximizes savings at the steady-state value:

$$\beta(1-\tau_s)p'(\tau_s w(k^*))w(k^*) = [\beta + p(\tau_s w(k^*))(1-\beta)]p(\tau_s w(k^*)). \tag{A.5}$$

We have $\partial^2 s_t/\partial\tau^2 < 0$ for $\tau = \tau_s$.

PROPOSITION 3 *(Effect of public health investment on capital per labor unit in Stage II). Let us consider an economy in Stage II. Under Assumptions (A.3) and (A.4), there exists stable steady-state capital per labor unit. Furthermore, under Assumptions (A.1) and (A.5), an increase in the tax rate increases the steady-state capital per labor unit for $\tau \leq \tau_s$.*

Proof. Using (28), we define the following function:

$$F(k^* : \tau) \equiv f(k^* : \tau) - g(k^* : \tau). \tag{30}$$

We then have the following partial derivative:

$$\frac{\partial k^*}{\partial \tau} = -\frac{\partial F(k^* : \tau)/\partial \tau}{\partial F(k^* : \tau)/\partial k^*}. \tag{31}$$

As shown in Figure 2, the partial derivative of (30) with respect to k^* takes a positive value:

$$\frac{\partial F(k^* : \tau)}{\partial k^*} = \frac{\partial f(k^* : \tau)}{\partial k^*} - \frac{\partial g(k^* : \tau)}{\partial k^*} > 0. \tag{32}$$

The partial derivative of (30) with respect to τ can be represented as

$$\frac{\partial F(k^* : \tau)}{\partial \tau} = -(1 - zn)\frac{\partial \frac{s}{(1-zn)n}}{\partial \tau} = -(1 - zn)k^* \left[\frac{\frac{\partial s}{\partial \tau}}{s} - \frac{\frac{\partial (1-zn)n}{\partial \tau}}{(1 - zn)n} \right]. \tag{33}$$

Assumption (A.1), implying (29), can ensure that $\frac{\partial (1-zn)n}{\partial n} > 0$. We then have $\frac{\partial (1-zn)n}{\partial \tau} < 0$ because of $\frac{\partial n}{\partial \tau} < 0$. Assumption (A.5) implies that $\frac{\partial s}{\partial \tau} \geq 0$ for $\tau \leq \tau_s$. Thus, from (31), (32), and (33), we have $\frac{\partial k^*}{\partial \tau} > 0$ for $\tau \leq \tau_s$. ■

An increase in the tax rate can increase the steady-state capital per labor unit through the increase in savings and the decline in the fertility rate. That is, public health investment assists economic development by enhancing the accumulation of capital per labor unit.[6]

3.3. Start of Education Investment

In this section, we extend the model by considering investment in education. We denote the stage in which individuals receive education as Stage III. First, we describe human capital formation. Education investment can raise the human capital stock of children,

$$E(e_{t-1}) = (1 + e_{t-1})^{\gamma}, \tag{34}$$

where we assume that $0 < \gamma < 1$. $E(e_{t-1})$ is the human capital stock of an individual born in period $t - 1$ and e_{t-1} is the education received in period $t - 1$.

Parents decide upon their consumption and savings, the number of children to have, and their children's education. The utility maximization problem of an individual born in period $t - 1$ is written

$$\max_{c_{yt}, s_t, n_t, e_t} U_t \equiv \beta[\alpha \ln c_{yt} + (1 - \alpha) \ln n_t E(e_t)] + (1 - \beta) p_t \ln c_{ot+1}, \tag{35}$$

$$\text{s.t.} \qquad (1 - zn_t)w_t E(e_{t-1}) - \tau w_t E(e_{t-1}) = c_{yt} + q_t e_t n_t + s_t, \tag{36}$$

$$\frac{r_{t+1}}{p_t} s_t = c_{ot+1}, \tag{37}$$

where q_t denotes the unit cost of education investment.

The unit cost of education investment is assumed to be given initially as $q_t = \bar{w}$. Education investment is convex because human capital stock is positive, even

https://doi.org/10.1017/S1365100514000911 Published online by Cambridge University Press

with no education investment. The threshold of the capital per labor unit at which education investment starts is represented as k_{II}:

$$\gamma z(1-\nu)A_{\mathrm{M}}k_{\mathrm{II}}^{\nu}=\bar{w}. \tag{38}$$

When the income level is high enough to satisfy $\gamma z w_t > \bar{w}$, it becomes possible for parents to invest in education for their children. When educational investment commences, we assume that $q_t = w_t$. Then we have the following first-order conditions:

$$c_{yt}=\frac{\alpha\beta}{\beta+p_t(1-\beta)}(1-\tau)w_tE(e_{t-1}), \tag{39}$$

$$s_t=\frac{p_t(1-\beta)}{\beta+p_t(1-\beta)}(1-\tau)w_tE(e_{t-1}), \tag{40}$$

$$n_t=\frac{\beta(1-\alpha)(1-\tau)}{\beta+p_t(1-\beta)}\frac{1-\gamma}{z-1/E(e_{t-1})}, \tag{41}$$

$$e_t=\frac{\gamma}{1-\gamma}zE(e_{t-1})-\frac{1}{1-\gamma}. \tag{42}$$

Fertility decreases with the increase in the human capital level of parents because of the increase in the cost of childrearing. The increase in survival probability also decreases the fertility rate. Thus, as shown in Figure 1, the fertility rate in Stage III decreases with income. The decline in the fertility rate induces parents to increase educational investment in their children.

We assume that

$$k^{*}>k_{\mathrm{II}}. \tag{A.6}$$

Under Assumptions (A.2) and (A.6), individuals start investing in education. A high survival probability implies that it is easy for individuals to commence educational investment because the steady-state capital per labor unit is high. As shown in (42), once educational investment starts, the education level monotonically increases and converges to the steady-state value.

The production function can be represented as

$$Y_t=A_{\mathrm{M}}K_t^{\nu}[E(e_{t-1})L_t]^{1-\nu}. \tag{43}$$

The dynamics of capital per labor unit can be expressed as follows:

$$u(k_{t+1},e_t)=v(k_t,e_{t-1}), \tag{44}$$

where $p_t=p(\tau(1-\nu)A_{\mathrm{M}}k_t^{\nu}E(e_{t-1})^{1-\nu})$,

$$u(k_{t+1},e_t)\equiv k_{t+1}[1-\frac{\beta(1-\alpha)(1-\tau)}{\beta+p_{t+1}(1-\beta)}\frac{z(1-\gamma)}{z-1/E(e_t)}],$$

$$v(g_t,e_{t-1})\equiv\frac{(1-\beta)}{\beta(1-\alpha)}\frac{z-1/E(e_{t-1})}{1-\gamma}p_t(1-\nu)A_{\mathrm{M}}k_t^{\nu}E(e_{t-1})^{1-\nu}.$$

https://doi.org/10.1017/S1365100514000911 Published online by Cambridge University Press

As the dynamics of education level is autonomous, the stability of the dynamics, as represented by (44), is essentially the same as that of (28). Because educational investment increases income, savings increase. The fertility rate decreases further with the increase in educational investment. Thus, there is further accumulation of capital per labor unit with educational investment.

4. REGRESSION ANALYSIS

In this section, we estimate our model using panel data. The available data cover 61 countries in 1995, 2000, 2005, and 2010. We select 12 countries for a low-income subsample in which per capita gross domestic product (GDP) in 2010 is less than 3,000 US$.[7] We employ panel estimation with fixed effects, first examining how public and private health investment affect life expectancy:

$$\ln p_{it+1} = \beta_{pi} + \beta_{ph} \ln h_{it} + \beta_{pph} \ln ph_{it} + \epsilon_{it}, \tag{45}$$

where $t = 1995, 2000, 2005$ and $i = 1, 2, \ldots, 61$. p_{it+1} is the life expectancy at birth, h_{it} is per capita public health expenditure, ph_{it} is per capita private health expenditure (these data are calculated using per capita GDP and the ratios of health expenditure), and ϵ_{it} is an error term with a mean of zero and a variance of σ.

We expect that $\beta_{ph} > 0$ and $\beta_{pph} > 0$. Column [i] in Table 2 details the results. Public health investment has a highly significant impact on life expectancy. In addition, private health investment is positive and significant. Furthermore, we examine whether private and public health investment have stronger impacts on life expectancy in the low-income countries. In the estimation of (45), we include $\beta_{ph,\mathrm{low}} \ln h_{it}$ for the low-income economies ($i = 1, 2, \ldots, 12$) to examine the structural change in the effect of public health investment. The null hypothesis, $\beta_{ph,\mathrm{low}} = 0$, is rejected, whereas the alternative hypothesis is represented as $\beta_{ph,\mathrm{low}} > 0$. Thus, public health investment has a stronger impact on life expectancy in the low-income subsample than in the full sample.

Next, by considering (41), the fertility rate is specified as

$$\ln n_{it+1} = \beta_{ni} + \beta_{nh} \ln h_{it} + \beta_{nph} \ln ph_{it} + \beta_{ne} \ln e_{it} + \epsilon_{it}, \tag{46}$$

where $t = 1995, 2000, 2005$, and $i = 1, 2, \ldots, 61$. n_{it} is the fertility rate and e_{it} is the percentage of the population with secondary schooling.

We expect that $\beta_{nh} < 0$, $\beta_{nph} < 0$, and $\beta_{ne} < 0$. Column [ii] in Table 2 provides the results. The effect of public health investment is negative but not significant. Secondary schooling is negative and significant. However, private health investment is positive with a high t-value. The effect of private health investment on fertility may be positive in developed economies. Because we reject the Hausman test, there may be correlation between the individual effects and explanatory variables. The additional effects of public and private health investment are negative and significant in the low-income subsample. Thus, public health investment could decrease the fertility rate in less developed economies.[8]

https://doi.org/10.1017/S1365100514000911 Published online by Cambridge University Press

TABLE 2. Panel estimation results with fixed effects

[i] $\ln p_{it+1}$		[ii] $\ln n_{it+1}$		[iii] $\ln s_{it+1}$		[iv] $\ln y_{it+1}$	
$\hat{\beta}_{ph}$	0.0339	$\hat{\beta}_{nh}$	−0.0522	$\hat{\beta}_{sh}$	0.0822	$\hat{\beta}_{ys}$	0.0843
	(4.06**)		(−1.37)		(0.65)		(3.70**)
$\hat{\beta}_{pph}$	0.0263	$\hat{\beta}_{nph}$	0.0811	$\hat{\beta}_{sph}$	0.159	$\hat{\beta}_{yna}$	0.474
	(4.32**)		(2.98)		(1.74*)		(3.65**)
		$\hat{\beta}_{ne}$	−0.219			$\hat{\beta}_{ynb}$	−0.793
			(−3.38**)				(−6.34**)
						$\hat{\beta}_{ye}$	0.336
							(4.08**)
$\bar{R}^2$	0.985	$\bar{R}^2$	0.970	$\bar{R}^2$	0.979	$\bar{R}^2$	0.996
$\hat{\sigma}$	0.0171	$\hat{\sigma}$	0.0756	$\hat{\sigma}$	0.254	$\hat{\sigma}$	0.0932
H test	0.13(2)	H test	15.66**(3)	H test	40.26**(2)	H test	261.82**(4)
$\hat{\beta}_{ph,\text{low}}$	0.0327	$\hat{\beta}_{nh,\text{low}}$	−0.105	$\hat{\beta}_{sh,\text{low}}$	0.156	$\hat{\beta}_{ys,\text{low}}$	−0.138
	(2.35**)		(−1.67*)		(0.71)		(−3.20)
$\hat{\beta}_{pph,\text{low}}$	0.0025	$\hat{\beta}_{nph,\text{low}}$	−0.0797	$\hat{\beta}_{sph,\text{low}}$	0.104	$\hat{\beta}_{yna,\text{low}}$	−0.162
	(0.24)		(−1.75*)		(0.67)		(−0.66)
		$\hat{\beta}_{ne,\text{low}}$	−0.168			$\hat{\beta}_{ynb,\text{low}}$	−0.422
			(−1.44)				(−1.94*)
						$\hat{\beta}_{ye,\text{low}}$	−0.060
							(−0.41)

Note: ˆ represents an estimate. The numbers in () are the t-values. $*$, $**$ represent significance at the 5% and 1% levels, respectively. H test is the Hausman test, which is distributed as a χ^2 distribution. The number in () is the degree of freedom. In the structural change tests, we report only the estimates of the low-income subsample. We estimated $\beta_{yna,\text{low}}$ and $\beta_{ynb,\text{low}}$ with $\beta_{ys,\text{low}}$.

Third, we investigate the effects of public and private health investment on per capita savings:

$$\ln s_{it+1} = \beta_{si} + \beta_{sh} \ln h_{it} + \beta_{sph} \ln ph_{it} + \epsilon_{it}, \tag{47}$$

where $t = 1995, 2000, 2005$, and $i = 1, 2, \ldots, 60$.[9] s_{it} is per capita savings.

We do not include per capita GDP as an explanatory variable in (47) because of its high correlation with per capita private and public health expenditure. We expect that $\beta_{sh} > 0$ and $\beta_{sph} > 0$. Column [iii] in Table 2 provides the results. Public health investment is positive but insignificant. Private health investment is positive and significant. The structural change test implies that it is difficult to detect the positive effect of public health investment on savings even in the low-income subsample. The amount of investment may not be enough to have a positive effect on savings because life expectancy remains low.

Finally, by considering (25) and (43), we specify per capita GDP as follows:

$$\ln y_{it+1} = \beta_{yi} + \beta_{ys} \ln s_{it} + \beta_{yna} \ln n_{it+1} + \beta_{ynb} \ln n_{it} + \beta_{ye} \ln e_{it} + \epsilon_{it}, \tag{48}$$

where $t = 1995, 2000, 2005$, and $i = 1, 2, \ldots, 61$. y_{it} is per capita GDP, in which GDP is measured in constant 2005 US$.

We expect the following relations: $\beta_{ys} > 0$, $\beta_{yna} > 0$, $\beta_{ynb} < 0$, and $\beta_{ye} > 0$. Column [iv] in Table 2 shows the results. Savings have a positive and significant impact on per capita GDP. The fertility rate in the current period is positive and significant, whereas the fertility rate in the previous period is negative and significant. Thus, the fertility rates of the current and previous periods have opposing effects on per capita output. Secondary schooling is positive and significant. As shown in the structural change test, the effect of savings is weaker in the low-income subsample. The amount of savings may not be sufficient to increase per capita output because of the prevalence of poverty and low life expectancy. When we examine the structural change in the effects of the fertility rates with the structural change in savings, the fertility rate in the previous period has a stronger impact on per capita output in the low-income subsample.

In addition, we apply GMM estimation for panel data. First, we examine life expectancy,

$$\ln \frac{p_{it+1}}{p_{it}} = \beta_{\mathrm{ph}} \ln \frac{h_{it}}{h_{it-1}} + \beta_{pph} \ln \frac{ph_{it}}{ph_{it-1}} + u_{it}, \tag{49}$$

where $t = 2000, 2005$, and $i = 1, 2, \ldots, 61$. u_{it} is an error term with a mean of zero and a covariance matrix.[10]

Column [i] in Table 3 details the results. The effects of public and private health investment are positive and significant. We cannot reject the null hypothesis of Hansen's J-test for overidentifying restrictions. Thus, the specification of (49) may not be invalid. We include $\beta_{ph,\mathrm{low}} \ln \frac{h_{it}}{h_{it-1}}$ in (49) for the low-income economies to examine the structural change. As shown, both public and private health investment have stronger impacts on life expectancy in the low-income subsample.

Next, we examine the fertility rate,

$$\ln \frac{n_{it+1}}{n_{it}} = \beta_{nh} \ln \frac{h_{it}}{h_{it-1}} + \beta_{nph} \ln \frac{ph_{it}}{ph_{it-1}} + \beta_{ne} \ln \frac{e_{it}}{e_{it-1}} + u_{it}, \tag{50}$$

where $t = 2000, 2005$, and $i = 1, 2, \ldots, 61$.[11]

Column [ii] in Table 3 shows the results. Both public and private health investment are positive with high t-values. That is, in the full sample, it is impossible to confirm negative effects of health investment on fertility. Secondary schooling is negative and significant. The hypothesis of overidentifying restrictions is not rejected. The additional effect of public health investment on fertility is negative and significant in the low-income subsample. Thus, investment may help decrease the fertility rate in less developed economies.

Third, we investigate savings,

$$\frac{s_{it+1} - s_{it}}{s_{it}} = \beta_{sh} \ln \frac{h_{it}}{h_{it-1}} + \beta_{sph} \ln \frac{ph_{it}}{ph_{it-1}} + u_{it}, \tag{51}$$

where $t = 2000, 2005$, and $i = 1, 2, \ldots, 61$.[12]

TABLE 3. GMM estimation results

[i] $\ln \frac{p_{it+1}}{p_{it}}$		[ii] $\ln \frac{n_{it+1}}{n_{it}}$		[iii] $\frac{s_{it+1}-s_{it}}{s_{it}}$		[iv] $\ln \frac{y_{it+1}}{y_{it}}$	
$\hat{\beta}_{ph}$	0.0710	$\hat{\beta}_{nh}$	0.114	$\hat{\beta}_{sh}$	−0.222	$\hat{\beta}_{ys}$	0.115
	(8.98**)		(2.21)		(−1.59)		(4.29**)
$\hat{\beta}_{pph}$	0.0099	$\hat{\beta}_{nph}$	0.115	$\hat{\beta}_{sph}$	0.360	$\hat{\beta}_{yna}$	0.301
	(1.74*)		(3.18)		(3.21**)		(2.78**)
		$\hat{\beta}_{ne}$	−0.508			$\hat{\beta}_{ynb}$	−0.508
			(−5.59**)				(−4.55**)
						$\hat{\beta}_{ye}$	0.521
							(6.78**)
J-test	7.60(10)	*J*-test	28.04(18)	*J*-test	27.18*(13)	*J*-test	36.33*(23)
$\hat{\beta}_{ph,\text{low}}$	0.0273	$\hat{\beta}_{nh,\text{low}}$	−0.287	$\hat{\beta}_{sh,\text{low}}$	1.084	$\hat{\beta}_{ys,\text{low}}$	−0.304
	(2.32**)		(−3.28**)		(3.44**)		(−6.67)
J-test	1.99(9)	*J*-test	20.29(17)	*J*-test	13.34(12)	*J*-test	30.45(22)
$\hat{\beta}_{pph,\text{low}}$	0.0217	$\hat{\beta}_{nph,\text{low}}$	−0.508	$\hat{\beta}_{sph,\text{low}}$	1.323	$\hat{\beta}_{yna,\text{low}}$	−0.583
	(1.69*)		(−4.37**)		(3.11**)		(−1.11)
J-test	3.44(9)	*J*-test	23.72(17)	*J*-test	18.18(12)	*J*-test	25.07(21)
		$\hat{\beta}_{ne,\text{low}}$	−0.875			$\hat{\beta}_{ynb,\text{low}}$	−0.915
			(−3.26**)				(−2.50**)
		J-test	23.52(17)			*J*-test	22.66(21)
						$\hat{\beta}_{ye,\text{low}}$	0.886
							(4.16**)
						J-test	33.68(22)

Note: ^ represents an estimate. The numbers in () are the t-values. *,** represent significance at the 5% and 1% levels, respectively. The J-test is distributed as a χ^2 distribution in which the number in () is the degree of freedom. We estimated $\beta_{yna,\text{low}}$ and $\beta_{ynb,\text{low}}$ with $\beta_{ys,\text{low}}$.

Column [iii] in Table 3 provides the results. Private health investment has a positive effect on savings. However, it is impossible to confirm a negative effect of public health investment. Although $\hat{\beta}_{sh,\text{low}}$ is positive and significant in the low-income subsample, the effect of public health investment on savings may be weak. We do not reject the hypotheses of overidentifying restrictions when we assume structural change in the low-income subsample.

Finally, we consider per capita GDP,

$$\ln \frac{y_{it+1}}{y_{it}} = \beta_{ys} \ln \frac{s_{it}}{s_{it-1}} + \beta_{yna} \ln \frac{n_{it+1}}{n_{it}} + \beta_{ynb} \ln \frac{n_{it}}{n_{it-1}} + \beta_{ye} \ln \frac{e_{it}}{e_{it-1}} + u_{it}, \quad (52)$$

where $t = 2000, 2005$, and $i = 1, 2, \ldots, 61$.[13]

Column [iv] in Table 3 details the results. Savings are positive and significant. The fertility rates of the current and previous periods have opposing effects on per capita output. Secondary schooling is positive and significant. The structural change test implies that in the low-income subsample, the effect of savings on per capita output is weak. The fertility rate in the previous period has a stronger impact on per capita output in the low-income subsample. We do not reject the hypotheses of overidentifying restrictions under the assumptions of structural change in the low-income subsample. Therefore, the results detailed in the GMM estimation are similar to those obtained by applying panel estimation with fixed effects.

5. CONCLUDING REMARKS

This paper has considered life expectancy and explored the impact of public health investment on economic development through its effects on savings and fertility. Health investment decreases the fertility rate through an increase in life expectancy. The investment has a temporarily negative effect on capital per labor unit because of an increase in the labor force. However, given that life expectancy is not low, the decline in fertility increases capital per labor unit in subsequent periods. If capital per labor unit exceeds thresholds, individuals can escape poverty by increasing savings and decreasing fertility.

Using regression analysis, we found that in less developed economies, public health investment may increase life expectancy but decrease the fertility rate. We also found evidence of the opposing effects of fertility rates in the previous and current periods on output per capita. Savings may not work to increase per capita output in less developed economies, where the effect of public health investment on savings is weak. Thus, even when fertility rates decline successfully via public health investment, capital per labor unit may not accumulate sufficiently to escape poverty because of low life expectancy and the two opposing effects of declining fertility.

NOTES

1. We focus on public health investment, not private health investment, because low-income individuals do not typically undertake private health investment.

2. In his model, given a sufficiently high output elasticity of capital, there exists a poverty trap. See also Chen (2010).

3. It would not be difficult to have Assumption (A.1) with plausible values of parameters. However, the former effect weakens the effect of a decline in fertility on economic development.

4. In sub-Saharan African economies, the initial environment of health would be worse than that of East Asian economies because of the prevalence of AIDS and the Ebola virus.

5. We cannot preclude the possibility of multiple steady states without Assumptions (A.3) and (A.4).

6. When $\tau > \tau_s$ holds, we have $\partial s/\partial \tau < 0$. (33) is then able to take a zero value. Thus, it would be possible to obtain the tax rate that maximizes k^*.

7. The data are from the World Bank in 2014. The educational data are from Barro and Lee (2010) (version 1.2). The low-income subsample includes Cameroon, Guatamala, India, Indonesia, Mali, Mongolia, Morocco, Mozambique, Nepal, Niger, Paraguay, and Swaziland.

8. Public health investment is negative and significant in the low-income subsample, but not in the high-income subsample, when we consider the different effects of the two subsamples.

9. Per capita savings are calculated using per capita GDP and the savings rates. The sample contains 60 countries because of the negative value of Swaziland in 2010.

10. $\ln h_{i1995}$, $\ln \mathrm{ph}_{i1995}$, $\ln m_{i1995}$ (adult (female) mortality rate), and $\ln mm_{i1995}$ (adult (male) mortality rate) are used as instrumental variables for $\ln \frac{p_{i2005}}{p_{i2000}}$. In addition, $\ln h_{i2000}$, $\ln \mathrm{ph}_{i2000}$, $\ln m_{i2000}$, and $\ln mm_{i2000}$ are used for $\ln \frac{p_{i2010}}{p_{i2005}}$.

11. We use adult (male and female) mortality rates, life expectancy at birth, public and private health investment, secondary schooling, and savings as instrumental variables.

12. The sample contains 61 countries because we do not use the logarithm for savings. We use adult (male and female) mortality rates, life expectancy at birth, and public and private health investment as instrumental variables.

13. We use adult (male and female) mortality rates, life expectancy at birth, public and private health investment, savings, savings rates, fertility rates, and secondary schooling as instrumental variables. We do not iterate the covariance matrix of orthogonality conditions.

REFERENCES

Acemoglu, Daron and Simon Johnson (2007) Disease and development: The effect of life expectancy on economic growth. *Journal of Political Economy* 115, 925–985.

Angeles, Luis (2010) Demographic transitions: Analyzing the effects of mortality on fertility. *Journal of Population Economics* 23, 99–120.

Barro, Robert J. and Johng-Wha Lee (2010) A New Data Set for Educational Attainment in the World, 1950–2010. NBER working paper 15902.

Cervellati, Matteo and Uwe Sunde (2011) Life expectancy and economic growth: The role of the demographic transition. *Journal of Economic Growth* 16, 99–133.

Chakraborty, Shankha (2004) Endogenous lifetime and economic growth. *Journal of Economic Theory* 116, 119–137.

Chen, Hung-Ju (2010) Life expectancy, fertility, and educational investment. *Journal of Population Economics* 23, 37–56.

Galor, Oded (2005) From stagnation to growth: Unified growth theory. In P. Aghion and S. Durlauf (eds.), *Handbook of Economic Growth*, Vol. 1A, pp. 171–293. North-Holland: Amsterdam.

Galor, Oded and David N. Weil (2000) Population, technology, and growth: From Malthusian stagnation to the demographic transition and beyond. *American Economic Review* 90, 806–828.

Hazan, Moshe and Binyamin Berdugo (2002) Child labour, fertility, and economic growth. *Economic Journal* 112, 810–828.

Lorentzen, Peter, John McMillan, and Romain Wacziarg (2008) Death and development. *Journal of Economic Growth* 13, 81–124.

Moav, Omer (2005) Cheap children and the persistence of poverty. *Economic Journal* 115, 88–110.

Momota, Akira (2009) A population-macroeconomic growth model for currently developing countries. *Journal of Economic Dynamics and Control* 33, 431–453.

Nakamura, Hideki and Yoshihiko Seoka (2014) Differential fertility and economic development. *Macroeconomic Dynamics* 18, 1048–1068.

Weil, David N. (2007) Accounting for the effect of health on economic growth. *Quarterly Journal of Economics* 122, 1265–1306.