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HUMAN CAPITAL ACCUMULATION, FERTILITY AND GROWTH: A RE-ANALYSIS

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Abstract

This paper develops an economic growth model with endogenous fertility. In doing so, it provides a new explanation for the relation between fertility, economic development and human capital accumulation. The model emphasizes the role returns on human capital play in economic development through individuals' allocation of time between acquiring human capital and production and rearing of children. In the model, production and rearing children are time intensive and accumulating human capital requires time and has a cost. Individuals' stock of human capital depends positively on the time allocated to education and on their parents' stock of human capital. Moreover, increases in the parents' stock of human capital raises the rate of return on human capital investment. As a result, individuals choose to allocate more time to education and less to producing and rearing children as their parents' stock of human capital increases. The model also demonstrates that individuals' choices on fertility and education may lead to multiple equilibria. Specifically, even if individuals' utility depends relatively more on their own consumption rather than on the number of children that they have, countries that have a low enough initial stock of human capital converge to a development trap with large families, little human capital and low output per capita.

HUMAN CAPITAL ACCUMULATION, FERTILITY AND GROWTH: A RE-ANALYSIS

Murat F. Iyigun[1]

1. Introduction

The economics literature has long recognized the importance of fertility and education in the process of economic development. It has provided some explanations for why fertility is negatively related to the level of economic development and the accumulation of human capital. This paper provides an alternative theory. It emphasizes the role returns to human capital play in economic development through individuals' allocation of time between acquiring human capital and production and rearing of children. It argues that, because individuals' productive years in acquiring human capital and having children coincide, individuals face a trade-off between getting educated and producing and rearing children.

The earliest theoretical contribution on fertility and economic growth was made by Thomas Malthus in the nineteenth century. According to the Malthusian model, death rates fall and fertility rises when incomes exceed the equilibrium level of per capita income. However, empirical evidence has revealed that fertility rates and economic development were negatively related during the past century and a half. It has also provided strong evidence in support of educational investment as a determinant of economic growth. See, for example, Barro (1991) and Mankiw, Romer and Weil (1992).

Economists have developed theoretical models that incorporate the interactions among fertility, educational investment and economic growth. Becker and Barro (1988) construct a model in which parents are altruistic and the discount factor that parents

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apply to future generations' utility depends negatively on the number of descendants. According to their model, technological progress leads to a lower rate of fertility and a higher rate of consumption. Becker, Murphy and Tamura (1990) consider a model in which rates of return on human capital are high relative to rates of return on children when the stock of human capital is high and in which individuals' discount rate of future generations' utility is identical to the one developed in Becker and Barro (1988). They show that families find it optimal to have fewer children and to educate each child more in economies with high levels of human capital. They also show that high fertility rates lead to slower economic growth. The important feature of both of these models is the specific nature in which the discount factor of parents depends on the number of their offspring. Sundstrom and David (1988) and Azariadis and Drazen (1990) explain the negative relation between the fertility rate and economic development by focusing on individuals' desire to provide for their old age. In those models, increases in the wage rate improves the bargaining power of children with their parents and reduces their value for their parents. Galor and Weil (forthcoming) consider a model in which household fertility is determined by the relative wages of men and women. They consider a production function in which capital is more complementary to women's labor input than it is to men's. Thus, increases in the level of capital per worker increase women's relative wages and reduce fertility by raising the cost of children relatively more than household income.

This paper follows the papers discussed above in examining the link between fertility and economic development. In doing so, it provides a new and simple explanation for the observed negative relation: Individuals' most productive time in their life in acquiring human capital and having children coincide. Therefore, they face a trade-off between getting educated and having more children. Moreover, if the returns on human capital depend positively on the stock of human capital, then producing and rearing children becomes more costly as the stock of human capital increases. As a result, individuals devote more time to acquiring human capital and less to producing and rearing children.

2. Overview

In the model presented in the following section, I consider a three period overlapping generations model in which individuals receive utility from consumption in the last period of their lives and from the number of children they have. In this economy, individuals are born and reared in the first period, they devote time to education and producing and rearing children in the second period, and they work and consume in the last period. I assume that production and rearing of children are time intensive and accumulating human capital requires time and has a cost.

At this point, it is important to note that the crucial component of the model is not that individuals allocate their time between education and having children in the second period of life. Rather, the important feature of the model discussed below is that producing and rearing children take away some time from individuals' investment in human capital. Including in the analysis the added assumption that individuals work in the second period as well will not alter the qualitative nature of the results. With that added assumption the model will be consistent with the "demand" model of household fertility outlined in Birdsall (1988) in that producing and rearing children are not only time intensive but they also take away time from employment. Similarly, the results of the model discussed in the next section are not dependent on the assumption that the time costs of rearing children do not spillover in to the last period of life.

Demographic trends in the U.S. and most other industrialized countries reveal that working women are more educated and have fewer children than their counterparts two decades ago. For example, *1993 Handbook on Women Workers: Trends and Issues* (1994) states ".....many women delay marriage, and when they do marry, they have fewer children than mothers had in previous generations. In the mid-seventies a trend began toward delayed childbearing and births among women in their later childbearing years rose markedly in the 1980's. Between 1980 and 1988, births among women aged 30 to 34 increased from 35 to 45 per 1,000 women.....During the 1980's the proportion

of ..... women workers completing 4 or more years of college increased steadily. In 1989, 24 percent of women workers had completed 4 years of college or more (up from 17.6 percent in 1979);....."

[Tables I and II about here.]

Another important feature of the model is the assumption that the human capital production function in any given period of time depends positively on the time individuals spend on education and on their parents' stock of human capital. Time spent on education and the parental human capital stock are assumed to be complements in human capital formation. The role parental human capital plays in the formation of human capital has been explored both theoretically and empirically. For the empirical significance of parental human capital, see for example, Coleman et al. (1966), Becker and Tomes (1986) and Fuchs and Reklis (1994).

In this economy, individuals choose optimally the amount of time they devote to producing and rearing children and to education. The optimal amount of time allocated to education depends positively on the rate of return on human capital investment. When the parental stock of human capital is low, the return on human capital investment is also low. Therefore, individuals choose to allocate more time to producing and rearing children and less to education. But as the stock of human capital increases, the rate of return on human capital investment increases. In response, individuals allocate more time to education and less on producing and rearing children.

In the model described below, I show that there exists the possibility of multiple

steady-state equilibria. If individuals' utility depends more on their own consumption rather than on the number of children that they have, then the initial stock of human capital of each country will determine the evolution of the country's economy. More specifically, countries that start out with a low initial stock of human capital will converge to a development trap in which the average family size is large and in which the stock of human capital and per capita income are low. In contrast, those countries that start with a higher value of the initial stock of human capital will converge to a steady-state in which the average family size is smaller and the stock of human capital and per capita income are higher.

The remainder of the paper is organized as follows: The next section describes the technology of production and the behavior of individuals. Section Four discusses the evolution of the economy. And, Section Five concludes.

3. The Model

3.1. Production

The output of the economy is a single homogeneous good produced by a CRS production function that uses physical and human capital as inputs. The output produced at time t, Y_t, is given by

$$Y_t = F(K_t,\ H_t) = H_t\ f(k_t); \qquad k_t \equiv K_t/H_t \tag{1}$$

where K_t and H_t respectively denote the quantities of physical and human capital employed in production at time t. The production function f: $R_+ \rightarrow R_+$ satisfies the standard neoclassical assumptions. Namely, $f'(k_t) > 0$, $f''(k_t) < 0$, $\lim_{k_t \rightarrow 0} = \infty$ and $\lim_{k_t \rightarrow \infty} = 0$.

It is assumed that production is carried out in a perfectly competitive environment. Thus, both factor earn their marginal products.

$$r_t = f'(k_t) \qquad \text{and} \qquad w_t = f(k_t) - f'(k_t)k_t \tag{2}$$

where r_t and w_t respectively denote the interest rate on physical capital and the wage rate paid to human capital.

The economy under consideration is open and small and the prevailing world interest rate is constant at $\bar{r}$. Since the small open economy permits unrestricted physical capital mobility, its interest rate is constant at $\bar{r}$, as well. This implies that the ratio of physical capital to human capital, k_t, and the wage rate paid to human capital, w_t, are also constant.

$$r_t = \bar{r} = f'(k_t) \quad \Rightarrow \quad k_t = \bar{k} = f'^{-1}(\bar{r}) \tag{3}$$

and,

$$w_t = f(\bar{k}) - f'(\bar{k})\bar{k} = \bar{w} \tag{4}$$

3.2. Individuals

Individuals live for three periods in overlapping generations and are endowed with one unit of time in every period. In the first period, they are born and reared. In the second period, they allocate their time between acquiring human capital and producing and rearing children. And, in the final period, they work and consume.

In the second period of life, individuals born at time t - 1 invest in human capital. The acquisition of human capital requires physical capital as well as time input. If individuals choose to invest in education in the second period, they borrow the required physical capital at the prevailing interest rate, $\bar{r}$, in order to finance their education.

An individual of generation t - 1 who is born to a parent with h_t, units of human capital, invests e_t, $e_t \epsilon [0,1]$, units of time in acquiring h_{t+1} units of human capital. These h_{t+1} units constitute the individuals labor supply in the last period of life.

$$h_{t+1} = \mu + h_t \, e_t \tag{5}$$

where μ, $\mu \geq 0$, denotes the amount of human capital that an individual possesses when the individual allocates no time to the acquisition of human capital.

Let z denote the total amount of time required to have and raise one child and n_t denote the total number of children that the individual chooses to have. Since, in the second period, individuals allocate their one unit of time between acquiring human capital and having and raising children, it follows that

$$e_t + z n_t \leq 1 \tag{6}$$

Individuals receive utility from the number of children that they have and from consumption in the third period. There is no uncertainty and no bequest motive. The utility of an individual of generation t - 1 is

$$u_{t-1} = u(n_t, c_{t+1}) = a \, ln(n_t) + (1-a) \, ln(c_{t+1}) \tag{7}$$

where $a > 0$ and where c_{t+1} denotes the consumption of the individual in the last period.

Individuals maximize their utility as given by equation (7), subject to (6) and the following budget constraint:

$$c_{t+1} + (1+\bar{r}) \, x \, e_t \leq \bar{w} \, h_{t+1} \tag{8}$$

where x denotes the cost per unit of time devoted to the acquisition of human capital.

The optimal amount of time allocated to education by the individual, e_t, is then given by the following:

$$e_t = \phi(h_t) = \begin{cases} 0 & \text{if } h_t \leq h^* = \frac{\mu}{A} + \frac{1+\bar{r}}{\bar{w}} x \\ \frac{A[\bar{w}h_t - (1+\bar{r})x] - \bar{w}\mu}{(1+A)[\bar{w}h_t - (1+\bar{r})x]} & \text{if } h_t > h^* \end{cases} \tag{9}$$

where $A = \frac{1-a}{a}$.

Note that the amount of time allocated to education, e_t, is a non-decreasing function of the parental human capital stock, h_t. Namely,

$$\frac{\partial e_t}{\partial h_t} = \phi'(h_t) = \begin{cases} 0 & \text{if } h_t \leq h^* \\ \frac{1}{1+A} \; \frac{\bar{w}^2 \mu}{[\bar{w}h_t - (1+\bar{r})x]^2} > 0 & \text{if } h_t > h^* \end{cases} \tag{10}$$

Also note that the total number of children that the individual has, n_t, is a non-increasing function of the parental human capital stock:

$$\frac{\partial n_t}{\partial h_t} = -\frac{1}{z} \frac{\partial e_t}{\partial h_t} = -\frac{1}{z} \phi'(h_t) = \begin{cases} 0 & \text{if } h_t \leq h^* \\ -\frac{1}{z} \; \frac{1}{1+A} \; \frac{\bar{w}^2 \mu}{[\bar{w}h_t - (1+\bar{r})x]^2} < 0 & \text{if } h_t > h^* \end{cases} \tag{11}$$

4. The Evolution of the Economy

The evolution of this economy, and, in particular, the evolution of the stock of human capital, $\{h_t\}_{t=0}^{\infty}$, is governed by an autonomous, non-linear, first-order difference equation. The evolution of the human capital stock, $\{h_t\}_{t=0}^{\infty}$, in turn determines the evolutions of the amount of time allocated to education, $\{e_t\}_{t=0}^{\infty}$, the total number of

children individuals choose to have, $\{n_t\}_{t=0}^{\infty}$, and of per capita income, $\{y_t\}_{t=0}^{\infty}$. We derive equation (12) by combining equations (5) and (9):

$$h_{t+1} = \psi(h_t) = \begin{cases} \mu & \text{if } h_t \leq h^* \\ \mu + h_t \left\{ \frac{A[\bar{w}h_t - (1+\bar{r})x] - \bar{w}\mu}{(1+A)[\bar{w}h_t - (1+\bar{r})x]} \right\} & \text{if } h_t > h^* \end{cases} \tag{12}$$

where the initial stock of human capital, h_0, is historically given.

Along the dynamic path, h_t, evolves monotonically. Namely,

$$\frac{\partial h_{t+1}}{\partial h_t} = \psi'(h_t) = \begin{cases} 0 & \text{if } h_t \leq h^* \\ \frac{A[\bar{w}h_t - (1+\bar{r})x] - \bar{w}\mu}{(1+A)[\bar{w}h_t - (1+\bar{r})x]} + \frac{\mu}{1+A} \frac{\bar{w}^2 h_t}{[\bar{w}h_t - (1+\bar{r})x]^2} > 0 & \text{if } h_t > h^* \end{cases} \tag{13}$$

$$\frac{\partial^2 h_{t+1}}{\partial h_t^2} = \psi''(h_t) = \begin{cases} 0 & \text{if } h_t \leq h^* \\ -\frac{2(1+\bar{r})x\ \bar{w}^2\ \mu}{(1+A)[\bar{w}h_t - (1+\bar{r})x]^3} < 0 & \text{if } h_t > h^* \end{cases} \tag{14}$$

Furthermore, as obtained from equations (12) and (13)

$$\psi(0) = \mu \geq 0 \tag{15}$$

and,

$$\lim_{h_t \to h^*} \psi'(h_t) = \frac{1}{(1+A)\bar{w}\mu} \left[A\bar{w}\mu + A^2(1+\bar{r})x \right] > 0 \tag{16}$$

$$\lim_{h_t \to \infty} \psi'(h_t) = \frac{A}{1+A} \tag{17}$$

In this economy, a steady-state equilibrium is is defined as a stationary stock of human capital, $\bar{h}$ such that

$$\bar{h} = \psi(\bar{h}) \tag{18}$$

Once the stock of human capital is in its steady-state, $\bar{h}$, the amount of time that individuals allocate to education, the total number of children that they choose to have and per capita income reach their steady-state levels, respectively denoted by $\bar{e}$, $\bar{n}$, $\bar{y}$ as well.

Since $\psi(h_t)$ is a continuous function of the human capital stock, h_t, there exists a steady-state equilibrium in this economy if $\psi(0) > 0$ and there exists h_t suct that $\psi(h_t) < h_t$ for some $h_t > 0$. Thus, if $\mu > 0$, then $\psi(0) > 0$. In addition, as implied by equation (12) $\psi(h^*) < h^* = \frac{\mu}{A} + \frac{1+\bar{r}}{\bar{w}}\, x$ if and only if

$$\frac{A}{A-1} \quad \frac{(1+\bar{r})x}{\bar{w}} > \mu \tag{19}$$

Consequently, if equation (19) is satisfied then without further parameter restrictions, there exists a steady-state equilibrium in which individuals choose to allocate no time to education, denoted by $\bar{h}_1$, where $\bar{h}_1 = \mu$.

Moreover, equations (12) through (17) imply that there exists a range of parameter values for which the dynamical system is characterized by multiple steady-state equilibria. In this economy, $\psi(h_t)$ is strictly monotonic $\forall h_t > h^*$ and $\lim_{h_t \to h^*} \psi'(h_t) = \infty$ as $A \to \infty$ (or alternatively, as $a \to 0$). This implies that the slope of the human capital production function evaluated at h^* increases as the weight of the utility that individuals receive from the number of their offspring, a, relative to that of consumption of individuals decreases.

In this model, there exists multiple steady-state equilibria if $\psi(h^*) < h^*$, $\exists h_t > h^*$ such that $\psi(h_t) > h_t$ and $\lim_{h_t \to \infty} < 1$. As established above, $\psi(h^*) < h^*$ if equation (19) is satisfied. Moreover, as implied by equation (17), $\lim_{h_t \to \infty} \psi(h_t) =$

$\frac{A}{1+A} < 1$. Therefore, it follows that for some range of parameter values, and specifically for sufficiently small values of the weight of the utility that individuals' receive from the number of their offspring, a, there exists a second steady-state equilibrium, denoted by $\bar{h}_2$, where $\bar{h}_2 > \bar{h}_1$.

[Figure 1 about here.]

Finally, given that $\bar{h}_2 > \bar{h}_1$, and by examining equations (9) - (11), it is easy to verify that

$$\bar{e}_1 = 0 \quad < \quad \bar{e}_2 = \frac{A[\bar{w}\bar{h}_2 - (1+\bar{r})x] - \bar{w}\mu}{(1+A)[\bar{w}\bar{h}_2 - (1+\bar{r})x]} \tag{20}$$

$$\bar{n}_1 = \frac{1}{z} \quad > \quad \bar{n}_2 = \frac{1}{z}\left[1 - \frac{A[\bar{w}(\bar{h}_2 - (1+\bar{r})x] - \bar{w}\mu}{(1+A)[\bar{w}\bar{h}_2 - (1+\bar{r})x]}\right] \tag{21}$$

and,

$$\bar{y}_1 = \bar{w}\bar{h}_1 = \bar{w}\mu \quad < \quad \bar{y}_2 = \bar{w}\bar{h}_2 \tag{22}$$

5. Summary

The existing papers in the economics literature that examine the interplay between fertility and economic development focus on various explanations for why fertility declines as the economy grows. However, none of these explanations have focused on the fact

that individuals' most productive periods in both having children and acquiring human capital coincide. The immediate consequence of this observation is that individuals face a trade-off between getting educated and having children.

In the three period over-lapping generations model presented above, individuals receive utility from consumption in the last period of their lives and the number of children they have. In this economy, individuals are born and reared in the first period, they devote time to education and producing and rearing children in the second period, and, they work and consume in the last period. It is assumed that production and rearing of children are time intensive and accumulating human capital requires time and has a cost.

An important feature of the model is the assumption that the human capital production function in any given period of time depends positively on the time individuals spend on education and on their parents stock of human capital. Time spent on education and the parental human capital stock are assumed to be complements in human capital formation. Individuals choose optimally the amount of time they devote to producing and rearing children and to education. The optimal amount of time allocated to education depends positively on the rate of return on human capital investment. When the parental stock of human capital is low, the return on human capital investment is also low. Therefore, individuals choose to allocate more time to producing and rearing children and less to education. But as the stock of human capital increases, the rate of return on human capital investment increases. In response, individuals allocate more time to education and less to producing and rearing children.

The model shows that that there exists the possibility of multiple steady-state equilibria. If individuals' utility depends relatively more on their own consumption rather than on the number of their offspring, then the initial stock of human capital of each country will determine the evolution of the country's economy. More specifically, countries that start out with a low initial stock of human capital will converge to a

development trap in which the average family size is large, and the stock of human capital and the per capita income are low. In contrast, those countries that start with a higher value of the initial stock of human capital will converge to a steady-state in which the average family size is smaller and the stock of human capital and per capita income are higher.

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Table I: Years of school completed by women 25 and older in the labor force by age

Years of school completed	1979	1989
Women in labor force(000)	32,626	45,487
Percent		
Less than 4 years of high school	20.3	12.4
4 years of high school	45.1	42.2
1 to 3 years of college	17.0	21.5
4+ years of college	17.6	23.8

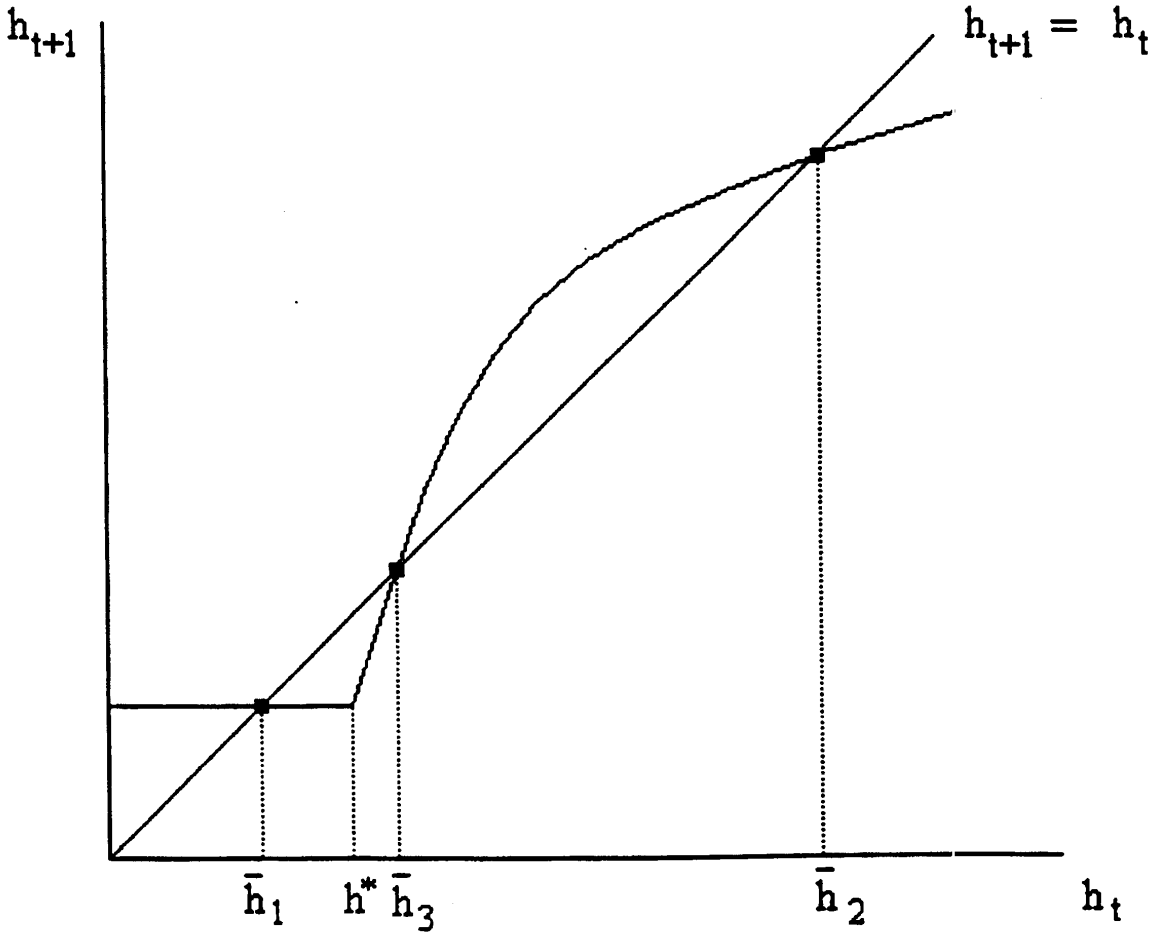
Source: 1993 Handbook on Women Workers: Trends and Issues

Table II: Labor force status of women in the labor force by age of youngest child:

Labor force status	Total	No children under 18	With children under 18
MARCH 1981			
Total	89,259	57,531	31,728
Percent	100.00	64.5	35.5
In labor force	46,414	27,992	18,422
Percent	100.00	60.0	40.0
MARCH 1991			
Total	98,970	65,424	33,548
Percent	100.00	66.1	33.9
In labor force	56,373	34,047	22,327
Percent	100.00	60.4	39.6

Source: 1993 Handbook on Women Workers: Trends and Issues

Figure I: The evolution of the stock of human capital



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