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

Murat F. Iyigun

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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.
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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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\(^1\)The author is Economist in the Division of International Finance, Board of Governors of the Federal Reserve System. I have benefited from discussions with Pierfederico Asdrubali, Oded Galor, Herschel I. Grossman, Harl Ryder and David N. Weil. All of the remaining errors in the paper are my personal responsibility. This paper represents the views of the author and should not be interpreted as reflecting those of the Board of Governors of the Federal Reserve System or other members of its staff. Please send all correspondence to: Division of International Finance, Board of Governors of the Federal Reserve System, Mail Stop 23, Washington, D.C. 20551. Phone: (202) 452-3798. Fax (202) 452-6424.
devote more time to acquiring human capital and less to producing and rearing children. As a result, individuals become more costly as the stock of human capital increases. This observation is consistent with the idea that human capital is a productive input that contributes to economic development. The returns on human capital are higher when the number of children is lower.

Moreover, the returns on human capital and having more children are trade-offs. Therefore, they face a trade-off between the returns on human capital and having more children. This observation is consistent with the idea that human capital is a productive input that contributes to economic development. The returns on human capital are higher when the number of children is lower.

This paper follows the papers discussed above in examining the link between fertility and economic development and reducing fertility by raising the real wages of women. This link is examined by considering 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 real wages whereas increases in the level of capital per worker increase men's real wages. 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 real wages whereas increases in the level of capital per worker increase men's real wages.

Sundstrom and David (1988) and Azariadis and Drazen (1999) explain the negative relation between the fertility rate and economic development by focusing on individuals' utility. They also show that high fertility rates lead to slower economic growth. The important feature of both these models is that when the discount factor of parents depends on the number of their offspring, it is optimal to have fewer children and to educate each child more in order to make generations wealthier. They also consider a model in which the stock of human capital is high and in which individuals' discount rate of future consumption is high. In this model, the returns on human capital are high relative to rates of return on children when the number of children is low. Therefore, they face a trade-off between the returns on human capital and having more children.

According to their model, technological progress leads to a lower rate of fertility and a higher rate of consumption. Moreover, utility depends negatively on the number of descendants.
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 into 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
In the model described below, I show that there exists the possibility of multiple time to education and less on producing and rearing children.

Time to education and less on producing and rearing children.

In response, individuals allocate more time to education. But as the stock of human capital increases, the rate of return on human capital investment increases. The rate of return increases. As a result, individuals choose to allocate more time to producing and rearing children.

In this economy, individuals choose optimally the amount of time they devote to producing and rearing children and to education.

Another important feature of the model is the assumption that the human capital

[Tables I and II about here]

17.6 percent in 1979. Currently 4 percent of women workers had completed 4 years of college or more (up from 1989, 24 percent of women workers completed 4 years of college or more).
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

\[
Y_t = F(K_t, H_t) = H_t f(k_t); \quad k_t \equiv K_t/H_t
\]  

(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 \( f: R_+ \to R_+ \) satisfies the standard neoclassical assumptions. Namely, \( f'(k_t) > 0, \ f''(k_t) < 0, \ \lim_{k_t \to 0} = \infty \) and \( \lim_{k_t \to -\infty} := 0 \).
3.2. Individuals

\[ a = y(\gamma)f - (\gamma)f = \gamma n \]

and

\[ (\gamma)f = \gamma = \gamma \quad \Leftarrow \quad \gamma(\gamma)f = \gamma = \gamma \]

are also constant.

of physical capital to human capital, \( \gamma \), and the wage rate paid to human capital, \( \gamma \), and the wage rate paid to human capital. This implies that the ratio of physical capital to human capital is constant at \( \gamma \) as well. This is consistent with the assumption that the economy is open and small and the prevailing world rate of interest is constant. Since the small open economy permits unrestricted physical capital mobility, the interest rate is constant at \( \gamma \).

The economy under consideration is open and small and the prevailing world rate of interest is constant at \( \gamma \). Since the small open economy permits unrestricted physical capital mobility, the interest rate is constant at \( \gamma \).

(2) \[ \gamma(\gamma)f - (\gamma)f = \gamma n \quad \text{and} \quad \gamma(\gamma)f = \gamma \]

Thus, both factor earn their marginal products.

It is assumed that production is carried out in a perfectly competitive environment.
An individual of generation $t - 1$ who is born to a parent with $h_t$, units of human capital, invests $e_t$, $e_t \in [0,1]$, 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.

$$h_{t+1} = \mu + h_t e_t$$  \hspace{2cm} (5)

where $\mu$, $\mu \geq 0$, 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

$$e_t + zn_t \leq 1$$  \hspace{2cm} (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

$$u_{t-1} = u(n_t, c_{t+1}) = a \ln(n_t) + (1 - a) \ln(c_{t+1})$$  \hspace{2cm} (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:

$$c_{t+1} + (1 + \bar{r}) x e_t \leq \bar{w} h_{t+1}$$  \hspace{2cm} (8)
The evolution of the amount of time allocated to education, $\eta$, in turn determines the evolution of the human capital stock, $\eta$. The evolution of the human capital stock, $\eta$, is governed by an autonomous, non-linear, first-order difference equation.

The evolution of this economy, and in particular, the evolution of the stock of human capital, is a non-decreasing function of the parental human capital stock.

Also note that the total number of children that the individual has, $n_t$, is given by

$$n_t = \frac{\phi}{1-\phi}$$

Note that the amount of time allocated to education, $\eta$, is a non-decreasing function of the parental human capital stock, $\eta$. Namely, given by the following:

Given by the following:

The optimal amount of time allocated to education by the individual is then

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

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

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

Along the dynamic path, \( h_t \), evolves monotonically. Namely,

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

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

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

\[
\psi(0) = \mu \geq 0
\]

and,

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

\[
\lim_{h_t \to \infty} \psi'(h_t) = \frac{A}{1 + A}
\]

In this economy, a steady-state equilibrium is is defined as a stationary stock of human capital, \( \bar{h} \) such that
equation (19) is satisfied. Moreover, as implied by equation (11), \( \lim_{n \to \infty} \phi (\eta) \) is negative. \( \phi (\eta) > (\eta) \) and \( \lim_{n \to \infty} \phi (\eta) < (\eta) \). As established above, if \( \phi (\eta) > (\eta) \), then \( \phi (\eta) < (\eta) \). In this model, there exists multiple steady-state equilibrium if \( \phi (\eta) > (\eta) \).

Individuals decrease from the number of their offspring, relative to that of consumption and capital production. The function evaluated at \( \phi \) increases as the weight of the utility that individuals receive from the number of their offspring. Moreover, equation (12) implies that the slope of the human capital production function evaluated at \( \phi \) is strictly increasing with \( \phi \). In this economy, \( \phi (\eta) \) strictly monotonically increases as \( \eta \to \infty \) or as \( \eta \to -\infty \). This implies that the slope of the human capital production function evaluated at \( \phi \) is strictly increasing with \( \phi \).

Furthermore, equation (12) implies that there exists a range of parameter \( \eta \) where \( \phi (\eta) \) is increasing. This implies that there exists a steady-state equilibrium in which individual choose to allocate no time to education, denoted by \( \phi (\eta) \). Once this happens, the stock of human capital is in its steady-state, \( \eta \), the amount of time that individuals allocate to education, the total number of children that they choose to have per capita income reach their steady-state levels, respectively denoted by \( \hat{e} \), \( \hat{e} \).

Once the stock of human capital is in its steady-state, \( \eta \), the amount of time that individuals allocate to education, the total number of children that they choose to have per capita income reach their steady-state levels, respectively denoted by \( \hat{e} \), \( \hat{e} \).

\[
\eta < \frac{\alpha}{x(\eta + 1)} \frac{1 - \nu}{\nu}
\]

Equation (12) holds if and only if \( x \frac{\alpha}{\eta x + 1} + \frac{\nu}{\eta} = \phi (\eta) \). For some \( \eta > (\eta) \), there exists a steady-state equilibrium in this economy if \( \eta > (\eta) \) and there exists a steady-state equilibrium if \( \eta < (\eta) \). Since \( \phi (\eta) \) is a continuous function of the human capital stock, \( \phi (\eta) \) is well-defined.
\[
\frac{A}{1+A} < 1. \text{ Therefore, it follows that for some range of parameter values, and specifically for sufficiently small values of the weight of the utility that individuals' receive from the number of their offspring, } \alpha, \text{ there exists a second steady-state equilibrium, denoted by } \bar{h}_2, \text{ where } \bar{h}_2 > \bar{h}_1.
\]

[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

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

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

and,

\[
\bar{y}_1 = \bar{\omega}\bar{h}_1 = \bar{\omega}\mu \quad < \quad \bar{y}_2 = \bar{\omega}\bar{h}_2 \quad (22)
\]

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
countries that start out with a low initial stock of human capital will converge to a
each country will determine the evolution of the country's economy. More specifically,
rather than on the number of their offspring, then the initial stock of human capital of
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children they have. In this economy, individuals are born and reared in the first period,
receive utility from consumption in the last period of their lives and the number of
in the three periods over-lapping generations model presented above, individuals face
a trade-off between getting educated and having children.
capital coincide. The immediate consequence of this observation is that individuals face
that individuals' most productive periods in both having children and acquiring human
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.
Table I: Years of school completed by women 25 and older in the labor force by age

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

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:

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

Source: 1993 Handbook on Women Workers: Trends and Issues
Figure 1: The evolution of the stock of human capital
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