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הפקולטה למדעי החברה אוניברסיטת תל-אביב

TECHNOLOGICAL PROGRESS, MOBILITY AND ECONOMIC GROWTH*

by

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ABSTRACT

This paper analyses the relationship between technological progress, the transmission of income inequality across generations, and economic growth. The analysis demonstrates that the interplay between technological progress and two components that determine individual earnings - parental human capital and individual ability - governs the evolutionary patterns of intergenerational earnings mobility, the pace of technological progress, and economic growth. In periods of major technological inventions the ability effect is the dominating factor. The decline in the relative importance of initial parental conditions (i.e., the driving force behind the persistence of inequality) enhances mobility and generates a larger concentration of individuals with high levels of ability and human capital in technologically advanced sectors, stimulating further technological progress and economic growth. In periods of technological innovations, however, once existing technologies become more accessible, the parental specific human capital effect is the dominating factor, mobility is diminished and inequality becomes more persistent. The reduction in the concentration of human capital in technologically advanced sectors diminishes the likelihood of major technological breakthroughs and slows down future economic growth. User friendliness, therefore, becomes unfriendly to future economic growth.

1. Introduction

This paper analyses the interaction between technological progress, intergenerational earnings mobility and economic growth. It argues that technological progress may play a significant role in the determination of the evolutionary patterns of intergenerational earnings mobility, and that earnings mobility may govern the pace of technological progress, and output growth.

The paper rests on several observations that are largely supported by empirical evidence:[1] (a) Individual earnings increase with ability. (b) Individual earnings increase with parental human capital; the closer parental and offspring's sectors of employment, the stronger the parental effect. (c) Major technological progress (i.e., inventions) increase the relative return to ability and thus diminish the relative return to parental specific human capital. (d) Improved accessibility of technologies (i.e., innovations) decrease the relative return to ability, while enhancing the relative return to parental specific human capital. (e) Technological progress (or the rate of adoption of new technologies) is positively related to the average level of human capital in technologically advanced sectors.

The analysis demonstrates that the interplay between technological progress and two components that determine individual earnings – parental human capital and individual ability – governs the evolution of intergenerational earnings mobility, the pace of technological progress, and economic growth. In periods of major technological progress (i.e., inventions), ability is the dominating factor. The decline in the relative importance of initial parental-environmental conditions (the driving force behind the persistence of inequality) enhances mobility and generates a higher concentration of high-ability, better educated individuals in technologically advanced sectors, stimulating further technological progress and economic growth. However, once existing technologies become more

[1] Section 2 discusses the empirical support for these observations.

accessible (i.e., periods of technological innovations),[2] the importance of ability declines, the parental human capital effect is the dominating factor, mobility is diminished, and inequality becomes more persistent. The reduction in the concentration of high-ability, highly educated individuals in technologically advanced sectors diminishes the likelihood of major technological breakthroughs that may reverse this pattern of persistent inequality.

The paper explores the unexamined relationship between technological progress and intergenerational earnings mobility. In addition, it contributes to existing research strands within the field of economic growth: income inequality and growth (e.g., Galor and Zeira; 1993, Benabou, 1996; and Durlauf, 1996), technological progress and growth (e.g., Stokey, 1988; Romer, 1990; Grossman and Helpman, 1990; Aghion and Howitt, 1992; and Barro and Sala-i- Martin, 1995), and mobility and growth (Durlauf, 1993; Fershtman, Murphy and Weiss, 1996; and Owen and Weil, 1994).[3]

In contrast to the existing literature on income distribution and growth, the paper explores a different technological link in the relationship between inequality and economic growth. It demonstrates the role of inequality in the determination of output growth via its effect on mobility, the allocation of talents across occupations, and the frequency of technological breakthroughs. Unlike the existing recent literature on technological progress and growth, which focuses primarily on the role of research and development in generating technological progress and thus economic growth, the present analysis demonstrates the role of intergenerational earnings mobility in mobilizing high-ability individuals into technologically advanced sectors in which growth-enhancing new technologies are developed (or adopted).

The analysis is based on a model of a small, open, overlapping-generations economy

[2]Mokyr (1990) provides a different context in which the distinction between technological inventions and technological innovations play a major role.

[3]The studies on mobility and growth follow the seminal contributions on intergenerational earnings mobility by Becker and Tomes (1986) and Loury (1981).

that operates in a perfectly competitive world in which economic activity extends over an infinite discrete time. In every period the economy produces a single homogeneous good, using physical capital and efficiency units of labor in the production process. The good is produced in several sectors, which differ in production technologies, and it can be used for consumption or saving.

In every period a generation is born. A generation consists of a continuum of individuals whose abilities are distributed uniformly over a bounded interval. Individuals, within as well as across generations, are identical in their preferences and in their production technology of human capital. They may differ, however, in ability and in parental type of human capital. Individuals live for two periods. In the first period of their lives, they are endowed with a unit of time. They devote part of their time endowment to the acquisition of human capital and subsequently supply the remaining time endowment in the labor force. The resulting wage income is allocated between consumption and savings. Individuals' level of human capital and thus their wage income in the first period of their life depends upon their ability, sector of employment, and the parental sector of employment. In the second period individuals retire, using their entire savings for consumption.

Individuals face a sectoral choice in the first period of their life. They must satisfy the human capital requirements in their chosen sector and devote a fraction of their unit time-endowment to the formation of such human capital. Thereafter, they supply the resulting efficiency units of labor over the remaining fraction of their unit-time endowment. The individual's effective number of efficiency units of labor in a particular sector depends upon the degree of complementarity between the sectoral technology and ability, as well as on the parental sector of employment. The interaction between individuals within a dynasty is via the parental externality, whereas the interaction across dynasties emerges via the effect of the average level of human capital in technologically advanced

sectors on the rate of technological progress.

2. Empirical Evidence

The paper rests on several assumptions that are largely supported by empirical evidence:

(a) *Individual earnings increase with ability*

The positive effect of ability on individuals' earnings is well documented in the literature. Griliches and Mason (1972) provide some direct evidence about the positive role of ability. The vast literature about returns to human capital supplies some indirect evidence, provided that education is positively correlated with ability.

(b) *Individual earnings increase with parental human capital; the closer the parental and the offspring's sectors of employment, the stronger the parental effect*

The importance of parental specific human capital is indirectly supported by several studies. The evidence reveals the existence of a higher likelihood of children to choose their parents' occupation (e.g., Laband and Lentz, 1983, 1989; and Blau and Duncan (1967)). Thus, if sectoral choice is based upon a higher earning potential, this indirect evidence suggests that the parental specific human capital does have a significant effect on individuals' earnings.

(c) *Major technological progress (i.e., inventions) increase the relative return to ability (and thus diminish the relative return to the parental human capital), whereas increased accessibility of technologies (i.e., innovations) decrease the relative return to ability (and thus enhance the relative return for the parental human capital)*

Juhn, Murphy and Pierce (1993) provide evidence regarding the changing role of ability and human capital in the determination of earnings in the United States in the past three decades. Their study suggests that the timing of the increased premium to unobserved components of skills (ability) differs from the timing of changes in the premia to education and labor market experience. In particular, returns to ability have increased steadily

since 1970 and it preceded the increase in the return to education since 1980. This evidence, therefore, is consistent with the relation between technological progress and changes in the relative return to ability.

Bartel and Lichtenberg (1987, 1991), using pooled cross-sectional industry level data, demonstrated that industries with relatively young or immature technologies pay higher wages to worker of a given age and education than do industries with mature technologies. A one-standard-deviation decrease in the mean age of an industry's equipment leads to a three-percent increase in wages within each demographic group. This evidence is consistent with the hypothesis that the reward to ability is higher in new technologies. [4] Clearly, alternative theories will be consistent with this evidence as well.

In addition, the evolution of the wage structure in the United States during the 20th century, as documented by Goldin and Margo (1992) and Katz and Murphy (1992), is largely consistent with the above observation. These studies reveal that the wage differential between skilled and unskilled labor widened until the 1930s, narrowed during the fourth, fifth, and sixth decades of the 20th century and have been widening again in the past two decades. In light of empirical observations suggesting that major technological breakthroughs are often associated with energy-saving technologies or with network externalities (David, 1990), one may identify the source of these two waves of widening inequality with major technological advances: the first may be associated with the increase in the industrial use of network electricity, while the second wave may be attributed to the soaring use of electronics (Krueger, 1993). The period of narrowing inequality, in contrast, may be identified as a period of improved accessibility of existing technologies.

(d) *Technological progress (or the rate of adoption of new technologies), is positively related to average level of human capital in technologically advanced sectors.*

Indirect evidence is provided by Schultz (1975) and Bartel and Lichtenberg (1987) who

[4]See Bartel and Sicherman (1996) for some recent direct evidence.

demonstrated that educated individuals have a comparative advantage in implementing new technologies.

3. The Basic Structure of the Model

Consider a small, open, overlapping-generations economy that operates in a perfectly competitive world in which economic activity extends over an infinite discrete time. In every period the economy produces a single homogeneous good, using physical capital and efficiency units of labor in the production process. The good is produced in several sectors that differ in their production technologies, and it can be used for consumption and investment. The supply of physical capital in every period is the aggregate saving of individuals in the economy in addition to net international borrowing, whereas the supply of efficiency units of labor in every period is the outcome of the economy's aggregate investment in human capital and the allocation of labor across sectors.

3.1 Production

Production occurs within a period using constant-returns-to-scale neoclassical production technologies subject to an endogenous technological progress. The output produced at time t, Y_t, is the aggregate output produced in all the existing J sectors.

$$Y_t = \sum_{j=1}^{J} F(K_t^j, H_t^j(\lambda_t)) \equiv \sum_{j=1}^{J} H_t^j(\lambda_t) f(k_t^j); \quad k_t^j \equiv K_t^j / H_t^j(\lambda_t), \tag{3.1}$$

where K_t^j and H_t^j are the quantities of capital and efficiency units of labor employed in production in sector j at time t, and $\lambda_t = (\lambda_t^1, \lambda_t^2, ..., \lambda_t^J)$ is the vector of technological coefficients in all J sectors at time t. Changes in λ_t reflect an endogenous labor-augmenting technological change at time t. The production function $f(k_t^j)$ is increasing, strictly concave, and satisfies the neoclassical boundary conditions that assure the existence of an interior solution to the producers' profit-maximization problem.

Producers operate in a perfectly competitive environment. Given the wage rate and the rate of return to capital in sector j at time t, w_t^j and r_t^j respectively, producers

in this sector choose the level of employment of capital, K_t^j, and labor, H_t^j, so as to maximize profits. That is, $\{K_t^j, H_t^j\} = \text{argmax}\ [H_t^j(\lambda_t^j)f(k_t^j) - w_t^j H_t^j - r_t^j K_t^j]$. The inverse demand for factors of production in sector j is therefore

$$\begin{aligned} r_t^j &= f'(k_t^j) \equiv r(k_t^j); \\ w_t^j &= [f(k_t^j) - f'(k_t^j)k_t^j] \equiv w(k_t^j). \end{aligned} \tag{3.2}$$

3.2 Factor Prices

Suppose that the world rental-rate is stationary at level $\overline{r}$. Since the small economy permits unrestricted international lending and borrowing, its rental rate is stationary as well at the rate $\overline{r}$. Namely,

$$r_t^j = \overline{r}. \tag{3.3}$$

Consequently, the ratio of capital to efficiency units of labor in sector j at time t, k_t^j, is stationary at level $\overline{k} \equiv f'^{-1}(\overline{r})$ and the wage rate per efficiency labor in sector j, w_t^j, is

$$w_t^j = w(\overline{k}) \equiv \overline{w}. \tag{3.4}$$

3.3 Consumption, Savings, and Investment in Human Capital

In each period a generation is born. It consists of a continuum of individuals of measure 1.[5] Individuals, within as well as across generations, are identical in their preferences and their production technology of human capital. They may differ, however, in their ability and in their parental level of human capital. Individuals live for two periods. In the first period, individuals acquire education, work and consume and in the second period individuals retire, using their entire savings for consumption.[6]

[5] For simplicity there is no population growth. Clearly, the qualitative results of this paper are not sensitive to changes in this assumption.

[6] In the absence of capital markets imperfections, a bequest motive does not directly alter the effect of technological progress on the persistence of inequality.

Individuals' preferences are defined over the vector of consumption in the two periods of their lives. The preferences of individual i who is born at time t (a member i of generation t) are represented by the intertemporal utility function, $u^{t,i} = u(c_t^{t,i}, c_{t+1}^{t,i})$, where $c_j^{t,i}$ is the consumption of a member i of generation t in period j, $j = t,\ t+1$. The utility function is strictly monotonically increasing, strictly quasi concave, and satisfies the conventional boundaries conditions that assure the existence of an interior solution for the utility maximization problem.

In the first period of their lives individuals are endowed with a unit of time. They devote a fraction of their time endowment to the acquisition of human capital and thereafter supply the remaining time endowment in the labor force. The resulting wage income is allocated between consumption and savings. The wage income earned during the first period of their life depends upon their ability, their sector of employment, and the parental sector of employment.

Members of generation t face a sectoral choice in the first period of their life. If they intend to join sector j they must satisfy the human capital requirements in this sector and devote a fraction θ^j of their unit time-endowment to the formation of human capital. Subsequently, they supply the resulting efficiency units of labor over the remaining fraction of their unit time-endowment, $(1-\theta^j)$. The effective number of efficiency units of labor that a member i of generation t may supply in sector j, $(h_t^i)^j$, depends upon the complementarity of technology j to individual i's ability, a_t^i, and on the parental sector of employment.[7]

Suppose, for simplicity, that the effective number of efficiency units of labor that a member i of generation t may supply has a simple linear representation:

$$(h_t^i)^j = \phi^j(a_t^i, (\gamma^i)^j) = (\gamma^i)^j \alpha_t^j + \beta_t^j a_t^i, \tag{3.5}$$

[7]This simple formulation abstracts from the effect of the parental level of human capital on the *general* level of human capital of the offspring, focusing on the transmission of the parental *specific* human capital. As established in Section 6, the incorporation of the parental effect on the *general* level of human capital of the offspring does not change the qualitative nature of the analysis.

where $\alpha_t^j > 0$ and $\beta_t^j > 0$, $\forall j$ and $\forall t$,[8] and $(\gamma^i)^j$ reflects the parental effect on individual i who is employed in sector j:

$$(\gamma^i)^j = \begin{cases} \gamma > 1 & \textit{if the parent works in sector } j \\ 1 & \textit{otherwise.} \end{cases} \tag{3.6}$$

Thus, given ability, individuals whose sector of employment is identical to that of their parents have a larger number of efficiency units.[9] This formulation captures the idea that the parental human capital effect is stronger the closer the sectors of occupation of parent and child.[10] Furthermore, individuals' level of human capital is an increasing function of their level of ability.

The labor income generated by an individual i of generation t at time t in technology j, $(I_t^i)^j$, is the wage rate per efficiency unit of labor at time t, w_t, times the number of efficiency units the individual supplies in sector j, $(1-\theta^j)(h_t^i)^j$.

$$(I_t^i)^j = w_t(1-\theta^j)(h_t^i)^j = \overline{w}(1-\theta^j)(h_t^i)^j, \tag{3.7}$$

where $(1-\theta^j)$ is the fraction of the individual's time endowment that is devoted to employment in technology j.

Labor income is allocated between savings, $(s_t^i)^j$, and consumption, $(c_t^{t,i})^j$. The saving of a member i of generation t employed in technology j at time t, $(s_t^i)^j$, is therefore

$$(s_t^i)^j = \overline{w}(1-\theta^j)(h_t^i)^j - (c_t^{t,i})^j. \tag{3.8}$$

[8]The technological parameter λ_t^j that appears in the production technology (3.1) is therefore of the form $\lambda_t^j = [\alpha_t^j, \beta_t^j]$.

[9]Thus, the effect of the parental specific human capital is assumed to be independent of the individual's level of ability. Section 5.1 demonstrates that the qualitative results are unaffected if a more general formulation is employed.

[10]A similar trade-off exists in a related study by Chari and Hopenhayn (1991). In their model the tradeoff is between working in a more advanced technology benefiting from the complementarity of only a few skilled individuals, and working in backward technology with a larger concentration of skills.

Consumption of a member i of generation t employed in technology j at time $t+1$, $(c_{t+1}^{t,i})^j$, is therefore the gross return on the savings from time t according to the international interest factor, $\overline{R} \equiv 1 + \overline{r}$:

$$(c_{t+1}^{t,i})^j = \overline{R}[\overline{w}(1-\theta^j)(h_t^i)^j - (c_t^{t,i})^j]. \tag{3.9}$$

Given the interest factor, $\overline{R}$, the wage rate per efficiency unit of labor, $\overline{w}$, and the parental sector of employment, an individual i of generation t whose ability is a_t^i and who is employed in sector j chooses the level of savings, $(s_t^i)^j$, so as to maximize his intertemporal utility function, namely,

$$(s_t^i)^j = \text{argmax } u[\overline{w}(1-\theta^j)\phi^j(a_t^i,(\gamma^i)^j) - (s_t^i)^j, \ (s_t^i)^j\overline{R}] \tag{3.10}$$

$$\text{subject to:} \quad 0 \leq (s_t^i)^j \leq \overline{w}(1-\theta^j)\phi^j(a_t^i,(\gamma^i)^j).$$

Given the assumptions about the utility function and the production function of human capital, there exists a unique and interior solution to the maximization problem that is characterized by the necessary and sufficient conditions

$$(s_t^i)^j = s(\overline{w}(1-\theta^j)\phi^j(a_t^i,(\gamma^i)^j), \ \overline{R}). \tag{3.11}$$

The indirect utility function of a member i of generation t who is employed in technology j, $(V_t^i)^j$, is therefore:[11]

$$(V_t^i)^j = v(\overline{w}(1-\theta^j)\phi^j(a_t^i,(\gamma^i)^j),\overline{R}). \tag{3.12}$$

3.4 Sectoral Choice

A member i of generation t whose ability level is a^i and whose parent was employed in a particular sector chooses the sector of employment that maximizes his

[11]It should be noted that since individuals' utility functions are identical within as well as across generations, the indirect utility function v is independent of the individual's type and sector of employment.

intertemporal utility function. That is, the individual chooses sector j that generates the highest indirect utility level, $(V_t^i)^j$:

$$(V_t^i)^j = max[(V_t^i)^1, (V_t^i)^2, ..., (V_t^i)^J]. \tag{3.13}$$

Since the functional form of the indirect utility function is identical across individuals, and since all individuals face the interest factor $\overline{R}$, it follows from the definition of the indirect utility function in (3.12) that income generated in the chosen sector j, $\overline{w}(1-\theta^j)\phi^j(a_t^i, (\gamma^i)^j)$, must be larger than the individual may obtain in any other sector. Alternatively (given identical wages per efficiency unit of labor across sectors), the chosen sector j must generate the highest *net* number of efficiency units of labor employed, $(1-\theta^j)\phi^j(a_t^i, (\gamma^i)^j)$, i.e.,

$$(1-\theta^j)\phi^j(a_t^i, (\gamma^i)^j) = max[(1-\theta^1)\phi^1(a_t^i, (\gamma^i)^1), ..., (1-\theta^J)\phi^J(a_t^i, (\gamma^i)^J)]. \tag{3.14}$$

3.5 Incentives for Upward and Downward Mobility

Suppose that ability is distributed uniformly over the unit interval, i.e.,[12]

$$a_t^i \sim U[0,1]. \tag{3.15}$$

Remark 3.1. If all individuals are employed in sector j and they are offspring of parents who were also employed in sector j, it follows from (3.1) and the uniform distribution of individuals over the feasible range of abilities $[0,1]$, that the number of efficiency units of labor in the economy is $(1-\theta^j)(\gamma\alpha_t^j + \beta_t^j/2)$. Furthermore, in light of the stationarity of the world interest rate, output per worker produced at time t is $y_t = [(1-\theta^j)(\gamma\alpha_t^j + \beta_t^j/2)]f(\overline{k})$.

[12]The implications of serial correlation in ability are explored in Section 5.

As will become apparent in the course of the following analysis, the co-existence of more than two technologies in every given period does not change the qualitative analysis. Therefore, in order to simplify the exposition, the following assumptions are made so as to ensure that precisely two technologies are employed in production in every time period.

Assumption 3.1. $\forall j = 1, 2, ..., J$, *and* $\forall t$

- $(1-\theta^j)[\gamma\alpha_t^j + \beta_t^j a_t^i] = (1-\theta^{j+1})[\alpha^{j+1} + \beta_t^{j+1} a_t^i]$, *for some* $a_t^i \equiv a_t^H \in (0,1)$.
- $(1-\theta^j)[\alpha_t^j + \beta_t^j a_t^i] = (1-\theta^{j+1})[\gamma\alpha^{j+1} + \beta_t^{j+1} a_t^i]$, *for some* $a_t^i \equiv a_t^L \in (0,1)$.

If a new technology $j+1$ *emerges in period* t

- $(1-\theta^j)\beta_t^j > (1-\theta^{j-1})\beta_t^{j-1}$.
- $(1-\theta^j)\alpha_t^j > (1-\theta^{j-1})\gamma\alpha_t^{j-1}$.

Hence, (a) There exists an individual who has an (interior) level of ability, a_t^H, and whose parent is employed in sector j, who is indifferent between employment in sectors j and $j+1$. (b) There exists an individual with an (interior) level of ability, a_t^L, whose parent is employed in sector $j+1$, who is indifferent between employment in sectors j and $j+1$. (c) The appearance of technology $j+1$ causes technology j to dominate technology $j-1$. for all levels of ability. Thus, (a) and (b) imply that at least two technologies are employed in any given period, whereas (c) implies that *at most* two technologies are employed in every time period.

Thus, in any given period t two technologies co-exist; an old technology, j, and a newer technology, $j+1$. The relationship between the two technologies is stated in the following assumption.

Assumption 3.2. $\forall\gamma > 1,\ \forall j = 1, 2, ..., J,$ *and* $\forall t$

- $\theta^j < \theta^{j+1}$.
- $(1-\theta^j)\beta_t^j < (1-\theta^{j+1})\beta_t^{j+1}$.
- $(1-\theta^j)\alpha_t^j > (1-\theta^{j+1})\alpha_t^{j+1}$.
- $(1-\theta^{j+1})(\alpha_t^{j+1} + \beta_t^{j+1}/2) < (1-\theta^j)(\gamma\alpha_t^j + \beta_t^j/2) < (1-\theta^{j+1})(\gamma\alpha_t^{j+1} + \beta_t^{j+1}/2)$.

Thus, consistent with some empirical observations surveyed in Section 2: (a) employment in the newer technology requires more education; (b) the marginal return to ability is higher in the new technology, (c) the newer technology provides a smaller reward for the less able than does the older one; (d) the newer technology is more efficient, i.e., the output produced by the entire society with the newer technology, $j+1$, is larger than that produced by the entire society with the old technology j, provided that parents and offspring are employed in the same technology; (e) the newer technology is *moderately* more efficient, i.e., the output produced by society as a whole with the newer technology, $j+1$, is larger than that produced by the entire society with the old technology j, provided that parents and their offspring are employed in the same technology in both cases. However, the output produced by the entire society with the older technology would be higher if all parents were employed in the old technology.

Remark 3.2. The assumption that inventions increase the return to ability is related to the argument raised in the context of the superstar market (e.g., Rosen, 1981, and Lazear and Rosen, 1981). In this literature the introduction of a new technology allows highly able individuals to capture nearly the entire rent.

Figure 1 depicts the efficiency units of an individual in a given technology as a function of ability. For each technology the solid line represents the efficiency units of individuals whose sector of employment is identical to that of their parents, whereas the dashed line represents the efficiency units of individuals whose sector of employment differ from that of their parents. As follows from Assumption 3.2, the newer technology,

$j+1$, is represented by a steeper line of efficiency units of labor over the range $[0,1]$, a lower intercept, and a larger area under the line (provided that parents and their offspring are employed in the same technology in both cases).[13]

Given individuals' levels of ability, and their parental sector of employment, it follows from Section 3.4 that individuals born at time t choose their sector of employment so as to maximize their first-period income, or alternatively, the number of efficiency units of labor employed. Thus, as depicted in Figure 1, in every period t there exists an upper threshold level a_t^H above which upward mobility takes place (i.e., individuals whose parents were employed in sector j choose employment in the technologically advanced sector $j+1$), and a lower threshold level a_t^L below which downward mobility takes place.

$$a_t^H = \frac{\gamma(1-\theta^j)\alpha_t^j - (1-\theta^{j+1})\alpha_t^{j+1}}{(1-\theta^{j+1})\beta_t^{j+1} - (1-\theta^j)\beta_t^j}, \tag{3.16}$$

and

$$a_t^L = \frac{(1-\theta^j)\alpha_t^j - \gamma(1-\theta^{j+1})\alpha_t^{j+1}}{(1-\theta^{j+1})\beta_t^{j+1} - (1-\theta^j)\beta_t^j}. \tag{3.17}$$

Individuals whose ability level is higher than a_t^L and lower than a_t^H remain in their parental sector of employment.

4. The Evolution of the Economic System

This section analyzes the joint evolution of technological progress, intergenerational mobility, inequality, the sectoral average level of human capital, and the economy's aggregate output. Section 4.1 focuses on the characterization of the dynamical system when technologies are stationary over time and new technologies do not emerge. In this scenario incentives for mobility are stationary and the evolution of aggregate output is

[13] It should be noted that a lower intercept need not result from a lower α, but rather from higher educational requirements being associated with the new technology.

dictated by these stationary incentives and their implied demographic changes. Section 4.2 extends the analysis to account for technological innovations within existing sectors that affect the incentives for mobility and hence the evolution aggregate output. Section 4.3 characterizes the dynamical system in the presence of *endogenous* technological breakthroughs (that are the outcome of changes in the average level of human capital in the technologically advanced sectors), as well as technological innovations. Technological progress in this scenario affects intergenerational earnings mobility and output, the average level of human capital, and thus the future rate of technological progress.

4.1. Stationary Technologies

This subsection focuses on the evolution of intergenerational earnings mobility, inequality, output per-capita, and the level of human capital in technologically advanced sectors when technologies are stationary across time.

4.1.1 The Evolution of Output Per Worker

Suppose that Assumption 3.1 holds and in any given period t two technologies co-exist; an old technology, j, and a newer technology, $j+1$, where the relationship between the two technologies is stated in Assumption 3.2. Stationarity of technologies implies that the technological parameters in every technology j are stationary (i.e., $\alpha_t^j = \alpha^j$ and $\beta_t^j = \beta^j$, $\forall t$), and consequently incentives for upward and downward mobility are stationary as well (i.e., $a_t^H = a^H$ and $a_t^L = a^L$, $\forall t$).

Let n_t be the proportion of generation t that is born to parents who worked in technology j (i.e., the level of employment in sector j at time $t-1$), and let $(1-n_t)$ be the proportion born to parents who worked in technology $j+1$ (i.e., the level of employment in sector $j+1$ at time $t-1$). In order to trace the equation of motion that governs the evolution of the dynamical system, suppose without loss of generality that $n_0 = 1$ (i.e., all individuals at time zero are born to parents who were employed in technology j).

Remark 4.1. As will be shown below, the steady-state level of output is independent of the initial distribution of individuals between the two technologies and thus the choice of n_0 is merely a simplifying device.

As is apparent from Figure 1, in period 0, $(1-a^H)$ individuals choose employment in sector $j+1$, whereas a^H choose employment in sector j. The output per worker produced at time 0 is therefore:

$$y_0 = \left\{(1-\theta^j)\int_0^{a^H}(\gamma\alpha^j+\beta^j a^i)da^i + (1-\theta^{j+1})\int_{a^H}^1(\alpha^{j+1}+\beta^{j+1}a^i)da^i\right\} f(\overline{k}). \quad (4.1)$$

As follows from the allocation of individuals between the two sectors in period 0, in period 1 there are two groups of individuals, each with a parental lead in a different technology. The number of individuals born in period 1 with a parental lead in technology j, n_1, equals a^H, whereas the number of those born with a parental lead in technology $j+1$ is $[1-a^H]$. Thus, given that ability is i.i.d. across generations, it follows from Figure 1, that output per worker in period 1 is:

$$\begin{aligned} y_1 &= [a^H\left\{(1-\theta^j)\textstyle\int_0^{a^H}(\gamma\alpha^j+\beta^j a^i)da^i + (1-\theta^{j+1})\int_{a^H}^1(\alpha^{j+1}+\beta^{j+1}a^i)da^i\right\} \\ &+ (1-a^H)\left\{(1-\theta^{j+1})\textstyle\int_{a^L}^1(\gamma\alpha^{j+1}+\beta^{j+1}a^i)da^i + (1-\theta^j)\int_0^{a^L}(\alpha^j+\beta^j a^i)da^i\right\}]f(\overline{k}). \end{aligned} \quad (4.2)$$

More generally, as long as both technologies remain stationary, since ability is i.i.d across generations, the number of individuals in each technology in period $t-1$ is sufficient to determine the composition of individuals within each technology in period t. Output per worker in period t is therefore:

$$\begin{aligned} y_t &= [n_t\left\{(1-\theta^j)\textstyle\int_0^{a^H}(\gamma\alpha^j+\beta^j a^i)da^i + (1-\theta^{j+1})\int_{a^H}^1(\alpha^{j+1}+\beta^{j+1}a^i)da^i\right\} \\ &+ (1-n_t)\left\{(1-\theta^{j+1})\textstyle\int_{a^L}^1(\gamma\alpha^{j+1}+\beta^{j+1}a^i)da^i + (1-\theta^j)\int_0^{a^L}(\alpha^j+\beta^j a^i)da^i\right\}]f(\overline{k}), \end{aligned} \quad (4.3)$$

where n_t is the proportion of individuals whose parents were employed in sector j in period t.

As long as technologies are stationary, changes in output are the outcome of a change in size and composition of the working population within each sector. The time path of per-worker output $\{y_t\}_{t=0}^{\infty}$ is fully determined by the time path of the proportion of individuals born with a parental lead in the older technology, $\{n_t\}_{t=0}^{\infty}$.

The number of individuals, n_{t+1}, born at time $t+1$ to parents who work in the older technology, j, is

$$n_{t+1} = a^H n_t + a^L(1-n_t) = a^L + (a^H - a^L)n_t \tag{4.4}$$

Thus, n_{t+1}, the number of individuals born at time $t+1$ to parents who are employed in the backward sector (i.e., the level of employment in sector j at time t), is given by the number of individuals in the technologically inferior sector at time $t-1$ whose offspring remain in the same sector, $n_t a^H$, in addition to the number of individuals in the technologically advanced sector at time $t-1$ whose offspring experienced downward mobility, $(1-n_t)a^L$.

The steady-state level of employment, n in technology j, as derived from (4.4) is therefore

$$n = \frac{a^L}{1-(a^H - a^L)}. \tag{4.5}$$

The time path of employment in the technologically inferior sector, $\{n_t\}_{t=0}^{\infty}$, is therefore governed by the one-dimensional linear difference equation (4.4) as drawn in Figure 2. Since $0 < a^H - a^L < 1$, it follows from (4.4) that the steady-state equilibrium, n, is *globally* stable and n_t converges monotonically to its steady-state value n regardless of the initial condition n_0.

The time path of output per worker, $\{y_t\}_{t=0}^{\infty}$, is fully determined by the time path of $\{n_t\}_{t=0}^{\infty}$, according to (4.3). Since n_t converges monotonically to a steady-state equilibrium, it follows that y_t converges monotonically to a steady-state equilibrium as well. In particular, if the initial level of employment in sector j, n_0, is higher than the steady-state level (as should be expected if the economy starts operation with a single technology),

then employment in the technologically inferior sector declines monotonically, whereas output increases monotonically in the transition to the steady state.

Remark 4.2. The steady-state equilibrium is characterized by intergenerational mobility, where upward mobility at level $(1-a^H)n$ offsets downward mobility at level $a^L(1-n)$, so as to maintain the aggregate employment unchanged.

4.1.2 The Evolution of Human Capital Within Each Sector

This sub-section analyzes the evolution of human capital within each sector in the presence of stationary technologies. This analysis forms the basis for the discussion of the evolution of an economy where the average level of human capital in technologically advanced sectors governs technological progress, and where technological progress, in turn, governs the evolution of intergenerational mobility, and thus the concentration of human capital in technologically advanced sectors.

In the economy described above, the average level of ability and the average level of human capital are necessarily higher in technologically advanced sectors. The argument runs as follows: Since ability is i.i.d across generations, the average level of ability among individuals born to parents in the technologically advanced sector is equal to the average in the population as a whole. However, the average ability in the new technology is higher due to inward mobility of individuals whose ability is higher than average in the economy, and outward mobility of individuals whose ability is lower than average in the economy. Furthermore, since the level of education required for employment in the technologically advanced sector is higher, and since human capital is a function of both education and ability, the average level of human capital in the technologically advanced sector is higher.

Remark 4.3. If the initial employment in sector j is higher than the steady-state level, n, the average ability of workers in the newer technology as well as the average ability of workers in the older technology are *declining* over the path to the steady state. Since it

follows from (4.4) that the group of potential entrants to sector $j+1$, n_t, decreases over time, and since the proportion of entrants to sector $j+1$ out of this group is constant at level $(1-a^H)$, the group of actual entrants, $[(1-a^H)n_t]$, decreases over time as will the average level of ability within technology $j+1$. Similarly, since $(1-n_t)$ increases over time while a^L is constant, the number of low-ability entrants into technology j increases, decreasing the average ability within this technology as well. The average ability within each sector therefore decreases over time.[14] Moreover, since the average level of human capital is a function of education as well as ability, the decrease in average ability lowers the average level of human capital in each technology over time.

4.2. Technological Innovations

This section analyzes the evolution of the economic system in the presence of technological innovations. Technological progress is decomposed into two categories: (a) major technological breakthroughs - inventions (discussed in Section 4.3), and (b) gradual technological progress within each technology - innovations. The analysis distinguishes between two types of innovations: (i) gradual technological progress in the frontier of existing technologies, and (ii) a gradual transformation of complex technologies into accessible ones. One component of innovations consists of improvements in the frontier of a given technology; the other consists of improvements in the accessibility of existing technology to a wider range of individuals.[15]

The process that is customarily termed "innovation," therefore, embraces two opposing effects: on one hand, new production frontiers are being explored, increasing the return to ability; on the other hand, accessibility is improved, lowering the return to ability. In order to clearly distinguish between inventions and innovations, the latter are

[14]Ability within the economy is, of course, fixed. Each group's average is decreasing, but the size of the higher average group is growing while the size of the low average group is decreasing.

[15]Technologies may at first be difficult to use by the less able. However, over time as the fundamental elements of this technology become clearer to existing users, the mysteries of the new technologies can be shared by a wider range of individuals. A good manual, or a friendly interface, may contribute more to output growth than yet another generation of software.

assumed to be associated primarily with increased accessibility, i.e., a reduction in the return to ability that is accompanied with a non-declining output.

Innovations that are assumed to be a function of the time spent in using the technology (e.g., learning by doing) satisfy the following assumption:

Assumption 4.1. $\forall j = 1, 2, ..., J$, *and* $\forall t$,

- $\beta^j_{t+1} < \beta^j_t$.
- $\alpha^j_{t+1} > \alpha^j_t$.
- $\alpha^j_{t+1} + \beta^j_{t+1}/2 = \alpha^j_t + \beta^j_t/2$.
- $\beta^{j+1}_t - \beta^{j+1}_{t+1} \geq \beta^j_t - \beta^j_{t+1}$.

Hence, as depicted in Figure 3 (for technology $j+1$), innovations: (a) reduce the marginal return to ability, (b) provide higher rewards for the less able, and (c) do not change the level of output produced, in the absence of parental effect.[16] (d The rate of innovation is faster in the newer technology, i.e., in every period t the reduction in the marginal return to ability and therefore, as follows from (c) and (d), the increase in the return to the less able are higher in technology $j+1$.

Suppose (without loss of generality, given the last two elements of Assumption 4.1) that technology j is at its long-run stationary state (i.e., $\alpha^j_t = \alpha^j$ and $\beta^j_t = \beta^j$), whereas over time technology $j+1$ becomes more accessible while maintaining a constant productivity level. If the output produced by all individuals employed in sector $j+1$, without the parental effect, were equal to that produced in sector j with the parental effect, and if, as stated in Assumption 4.1, in the absence of parental effect, an increase in accessibility is not associated with changes in output, then (as depicted in Figure 3), $a^H_t = 1/2$, $\forall t$. In this hypothetical configuration (which is weakly inconsistent with Assumptions 3.2), the increase in the accessibility of technology $j+1$ over time tilts the

[16]Thus, reflecting the implicit empirical evidence on the relative strength of the accessibility effect, the analysis focuses on the role of innovations in transforming existing technologies into accessible ones rather than generating improvement in the technological frontier that increase output. Incorporating the latter into the analysis is rather straightforward.

steeper lines clockwise around $1/2$ shifting a^L leftward, while maintaining the level of a^H at $1/2$. Hence, downward mobility (from technology $j+1$ to technology j) decreases, whereas upward mobility remains at the same constant rate. The average level of ability and thus the average level of human capital in the leading sector is therefore reduced during the transition to a stationary state.

As follows from Assumption 3.2, the output produced by all individuals employed in sector $j+1$ without the parental effect is smaller than that produced in sector j with the parental effect. Hence, as depicted in figure 4, $a_t^H > 1/2$. $\forall t$. In light of Assumption 4.1, an increase in accessibility in this configuration is represented by a clockwise rotation around the point $1/2$, rather than around a_t^H, generating a leftward shift in a_t^L, and a rightward shift in a_t^H. Upward mobility decreases, along with a reduction in downward mobility, and the average level of ability and human capital decreases in the leading sector.

Thus, as technologies become more accessible due to innovations, mobility diminishes, inequality declines, and the average level of ability and human capital in the leading sector decrease as well.[17] The reduction in employment in the technologically inferior sector, as established in Remark 4.3, enhances the reduction in mobility and inequality that is due to increased accessibility, further decreasing the average level of human capital in the technologically advanced sector.

Improved accessibility therefore decreases mobility and increases equality of income. Hence, improved accessibility to technologies generates two opposing effects with respect to indexes of inequality in society: equality of opportunities declines, whereas equality of income increases.

[17]If the first two elements of Assumption 3.2 are relaxed and technology $j+1$ is allowed to become as accessible as technology j (i.e., $a^L = 0$ and $a^H = 1$) mobility ultimately ceases. Furthermore, downward mobility and upward mobility need not stop at the same time. Rather, as long as accessibility is not associated with changes in output, downward mobility stops first. However, if parental lead is proportional to ability, downward mobility need not stop before upward mobility.

4.3. Inventions, Innovations, Mobility, and Output Dynamics

This section analyzes the evolution of the economy when the set of existing technologies expands over time due to *endogenous* inventions, and the existing set of technologies in every period undergoes technological innovations. The occurrence of major technological breakthroughs - inventions - is assumed to be an increasing function of the average level of human capital in technologically advanced sectors.[18]

Suppose that two technologies $j-1$ and j co-exist in period 0. As discussed in Section 4.2, these technologies undergoes innovations over time, their accessibility improves and hence their return to ability drops. Mobility therefore declines, the average level of human capital in the leading sector decreases, and the probability for the arrival of a new invention decreases as well.

Suppose that a new technology $j+1$ is invented in period t. [19] This renders technology $j-1$ obsolete (Assumptions 3.1 and 3.2) and the more advanced technologies, $j+1$ and j, remain on the scene. The introduction of the new technology in period t, as implicitly analyzed in Section 4.1, increases the return to ability in the technologically advanced sector, and thus reverses the pattern of declining mobility and increases income inequality.[20] The pace of upward and downward mobility grows, the concentration of high-ability high human capital individuals in the new leading sector increases, and inequality rises as well. Thereafter, a process of innovations takes place and reduces the level of mobility and inequality till the next invention is introduced.

Innovations that make existing technologies more accessible reduces mobility, increase equality, and decrease the average level of ability and human capital in the leading

[18]This is a feature common in the literature (e.g., Lucas, 1988; Galor and Tsiddon, 1994; and Tamura, 1996.

[19]Since individuals are employed only in the first period of their life and since occupational choices are made in the beginning of the first period of life, when the existing technologies are known, individuals do not face uncertainty in their optimization.

[20]Individuals whose parents were employed in sector $j-1$ have no parental lead in either sector j or in sector $j+1$. If their level of ability exceeds a^*, where a^* is the ability level such that $(1-\theta^j)[\alpha_t^j+\beta_t^j a^*] = (1-\theta^{j+1})[\alpha^{j+1}+\beta_t^{j+1}a^*]$, they choose sector $j+1$; otherwise, they choose sector j.

sector. This, in turn, reduces the probability of an invention. Thus "user friendliness" becomes unfriendly to future economic growth. Inventions improve the efficiency of the allocation of talents across sectors since the placement of high-ability individuals in the leading sector increases the probability that a new invention will occur. However, this positive effect dissipates gradually via the process of innovations. Technological progress is endogenously serially correlated. An observed technological change increases the probability of an additional change occurring in the immediate future. If the technological change, however, fails to materialize, the probability of a future invention decreases. These bursts in economic growth are positively correlated with the returns to education, an outcome of the strong correlation between ability and education in the period in which the new technology is introduced. As technology matures and becomes more accessible, it employs proportionally less of the highly-able individuals and therefore the return to education declines.

Periods of inventions are characterized by a rapid pace of output growth associated with increased inequality and enhanced intergenerational mobility, whereas periods of innovations, in contrast, are characterized by a slower pace of output growth associated with a decreasing inequality and diminished intergenerational mobility.[21]

5. Intergenerational Correlation in Abilities

This section explores the implications of intergenerational correlation in ability on mobility, technological progress, and economic growth.

Suppose that the ability of individual i at time $t+1$ is given by:

$$a^i_{t+1} = pa^i_t + (1-p)\epsilon_t \qquad where \quad \epsilon_t \sim U[0,1] \tag{5.1}$$

and $p \in [0,1]$. That is, the ability of an individual is a weighted average of parental

[21] A related study (Jovanovic and MacDonald, 1994) derives the implications of innovations and the subsequent process of imitation on earning inequality across firms. Similarly to the current model, they show that imitation narrows earnings inequality across firms, whereas inventions tend to increase this inequality.

ability and a random draw from the (uniform) distribution of abilities in the population. Clearly, if $p = 0$, ability is not serially correlated across generations, and it is distributed uniformly over the interval $[0, 1]$.

Remark 5.1. Under the specification of the serial correlation in ability provided in (5.1), if the initial distribution of ability is uniform over the interval $[0, 1]$, the distribution of ability in each cohort is time invariant and it is uniformly distributed over the interval $[0, 1]$. The realization of the ability of each individual, nevertheless, depends on the degree of serial correlation in ability.

Consider initially the evolution of intergenerational earnings mobility, inequality, output per capita, and the level of human capital in technologically advanced sectors when technologies are stationary across time. Suppose that Assumption 3.1 holds and in any given period t two technologies co-exist: an old "user friendly" technology, j, and a newer technology, $j + 1$, where the relationship between the two technologies is as stated in Assumption 3.2. As long as technologies are stationary, the stationarity of the distribution of ability across time implies that changes in output are the result of a change in the size and composition of the working population in each sector. As is the case when ability is not serially correlated, the time path of per-worker output $\{y_t\}_{t=0}^{\infty}$ is fully determined by the time path of the proportion of individuals born with a parental lead in the older technology, $\{n_t\}_{t=0}^{\infty}$.

In the absence of serial correlation in ability across generations (i.e., p=0), the dynamics of employment in the old sector, as established in (4.4), is $n_{t+1} = a^L + (a^H - a^L)n_t$, whereas if ability is perfectly correlated across generations (i.e., $p = 1$ and $a^i_{t+1} = a^i_t$), the dynamics of employment in the old sector is $n_{t+1} = n_t$. Given the specification of the intergenerational correlation in ability, it can be shown that the dynamics of employment in the old sector is a weighted average of the dynamics of employment in the case of no correlation in ability and of perfect correlation in ability.

That is,

$$n_{t+1} = (1-p)[a^L + (a^H - a^L)n_t] + pn_t. \tag{5.2}$$

Hence, employment in the old sector, j, is governed by the first-order linear difference equation:

$$n_{t+1} = (1-p)a^L + [p + (1-p)(a^H - a^L)]n_t. \tag{5.3}$$

The time path of output per worker, $\{y_t\}_{t=0}^{\infty}$, is fully determined by the time path of $\{n_t\}_{t=0}^{\infty}$, according to (4.3). Since n_t converges monotonically to a steady-state equilibrium, it follows that y_t as well converges monotonically to a steady-state equilibrium. In particular, if the initial level of employment in sector j, n_0, is higher than the steady-state level (as expected if the economy starts operation with a single technology) then employment in the technologically inferior sector declines monotonically, whereas output increases monotonically in the transition to the steady state.

The importance of serial correlation in ability for mobility, technological progress and output growth can be examined by the comparison of the dynamical systems with and without serial correlation in ability. Since in the absence of serial correlation in ability $p = 0$, it follows from (5.3) that a dynamical system that relates n_{t+1} and n_t under serial correlation is steeper and has a lower intercept than in the case of no serial correlation depicted in Figure 2. Furthermore, the steady-state level of employment in the older sector $n = a^L/[1-(a^H - a^L)]$ is identical under the two configurations.

Thus, the evolution of employment towards its steady-state level slows down as a result of intergenerational correlation in ability. Employment in the technologically inferior sector declines slower at first. The stronger the serial correlation in ability, the slower the economy's convergence to its steady-state composition of employment. Furthermore, the steady-state level of mobility diminishes due to intergenerational correlation in ability. The larger the serial correlation in ability the lower the rate of mobility across technologies in the steady state.

Despite the fact that the steady-state level of employment in each sector is identical under both configurations, the larger the intergenerational correlation in ability the larger level of output. Serial correlation in ability reduces mobility and allows for better utilization of the parental lead that is otherwise lost due to mobility. For instance if $p = 1$ the introduction of a new stationary technology results in the movement of high-ability individuals (i.e., those with ability above a^H) to the advanced sector. However, since parents and children are identical in their level of ability there is no further mobility. Each worker produces an output level that is positively affected by the parental experience in this sector, and output is larger than it would have been with the same composition of employment in the two sectors but with a higher mobility rate.

Thus, as long as technologies are stationary, serial correlation in abilities reduces steady-state mobility, reduces the cost of reallocation of labor across sectors, and increases steady-state output. It has, however, no further effects compared with the case of ability not being correlated across generations. As discussed in Section 4, when technologies become more accessible due to the process of innovations, mobility diminishes and the average level of ability and human capital in the leading sector decreases as well. The reduction in employment in the technologically inferior sector, as documented in Remark 4.3, enhances the reduction in mobility and inequality due to increased accessibility, further decreasing the average level of human capital in the technologically advanced sector. Improved accessibility, therefore, decreases mobility and increases equality of income, generating two opposing effects with respect to indexes of inequality in society: equality of opportunities declines, whereas equality of income increases.

Serial correlation in ability across generations generates friction that slows the decline of average ability in the leading sector and accelerates the decline in the lagging sector. Since inventions are a function of the concentration of ability in the technologically advanced sector, and since serial correlation increases the average level of ability in

every time period, it increases the pace of inventions thereby enhancing output growth and, as elaborated earlier, mobility. Thus the transmission of ability across generations has an ambiguous effect on mobility. It reduces mobility directly by narrowing the distance between the abilities of parents and their offspring, and it enhances mobility by increasing the pace of inventions.

6. Robustness of the Basic Model

6.1 Non Linear Return to Ability

The results derived in the previous sections are based on the simplifying assumption that the effective number of efficiency units of labor that a member i of generation t may supply in sector j, $(h_t^i)^j$, is a linear function of individual i's ability. As is apparent from Figures 1-4, the qualitative results are unaffected as long as: (a) $(h_t^i)^j$ is an increasing concave function of ability over the interval [0,1], (b) the marginal return to ability in technology $j+1$ is strictly larger than that in technology j, for any given ability and for any time period prior to the steady-state, and (c) the return to an individual with zero level of ability is higher in technology j. This rather plausible set of assumptions will have to be violated in order to change the qualitative results.

6.2 Transferability of General Human Capital

The analysis abstracts from the effect of the parental level of human capital on the general stock of human capital of the offspring, focusing primarily on the effect on the level of specific human capital. Empirical evidence, however, suggests the existence of a strong parental effect in the formation the offspring's stock of general human capital (e.g., Becker and Tomes, 1986). As long as the Ben-Porath (1967)'s neutrality assumption is maintained (i.e., the marginal productivity of ability is equal in the production of human capital and in the labor force), the introduction of a parental effect on the general level of human capital will not alter the analysis qualitatively. Parental contribution to the formation of the offspring's general stock of human capital, however, alters the analysis

if it compensates for lack of ability. This environment is the focus of our study (Galor and Tsiddon, 1994).

6.3 Inventions as a Function of the General Level of Human Capital

The analysis in previous sections is based on the assumption that technological breakthroughs are an increasing function of the average level of ability in the technologically advanced sectors. If the rate of inventions, however, is based primarily on the average level of human capital in the economy as a whole, the qualitative results will be altered. As the economy evolves towards a steady-state, the leading sector gets larger. The leading technology demands more education, and hence the average level of human capital within society as a whole increases on the path to the new stationary state in contrast to the decline of the average level of human capital in the leading sector. Innovations, nevertheless, still decelerate the pace of inventions. Furthermore, the large variance in R&D spending across sectors and the strong correlation between sectoral spending on R&D and sectoral level of education may nonetheless support the approach adopted in the paper.

6.4 Technological Progress and Occupational Mobility

The existing structure of the model permits only a single working period. This rigid structure simplifies the exposition significantly and permits discussion of some of the prime aspects of the study in a straightforward fashion. However, this simplification prevents discussion of the effect of technological progress on an individual's occupational mobility (i.e., the effect of technological progress on the willingness of individuals to move from one sector of employment to another). A broad interpretation of the basic model permits the exploration of this important link. If one interprets the parental lead as sector-specific human capital acquired in the preceding period of employment in this sector, then upward mobility into technologically advanced sectors will occur among younger (i.e., with little specific human capital), more able individuals. Furthermore,

if ability complements sector-specific on-the-job-training, high-ability individuals may lock themselves into older technologies. This interpretation of the current analysis yields several intriguing results: (a) If older technologies requires less education than newer ones, this effect may generate a downward bias in the cross-sectors estimates of the returns to education. (b) In cohort analysis this lock-in effect will tend to artificially decrease the returns to education in older generations relative to younger ones. (c) A faster rate of invention may change the observed wage profile within a sector since it changes the quality mix of those who remain behind. These issues will be further explored in future research.

7. Concluding Remarks

This paper examines the unexplored interaction between technological progress, intergenerational earnings mobility, and economic growth. It demonstrates that earnings mobility governs the pace of technological progress and output growth, whereas technological progress determines the evolutionary patterns of intergenerational earnings mobility.

The analysis demonstrates that the interplay between technological progress and two components that determine an individual's earnings: parental human capital and the individual's ability, govern the evolution of intergenerational earnings mobility, the pace of technological progress, and economic growth. In periods of major technological inventions, the ability effect is the dominating factor. The relative importance of initial parental-environmental conditions (i.e., the driving force behind the persistence of inequality) diminishes and mobility and inequality therefore rise, generating a larger concentration of human capital in technologically advanced sectors, and stimulating further technological progress and economic growth. In periods of technological innovations, however, when existing technologies become more accessible, the parental human capital effect is the dominating factor, mobility is diminished and inequality decreases

while becoming more persistent. The reduction in the concentration of human capital in technologically advanced sectors diminishes the likelihood of major technological breakthroughs and slows down future economic growth. User friendliness, therefore, becomes unfriendly to future growth rates.

Periods of inventions are characterized by a rapid pace of output growth that is associated with increased inequality and enhanced intergenerational mobility. Periods of innovations are characterized by a slower pace of output growth that is associated with decreased inequality and diminished intergenerational mobility. Hence, inventions increase equality of opportunities and decrease equality of income while improved accessibility decreases equality of opportunities and increases equality of income.

The transmission of ability across generations has an ambiguous effect on mobility. It reduces mobility directly by narrowing the distance between the ability of a parent and that of a child, and it enhances mobility by increasing the pace of inventions. If ability is transmitted across generations, it reduces mobility and thus the reallocation cost of labor across sectors, and it increases output and raises the concentration level of ability in technologically advanced sectors. The pace of inventions is accelerated and mobility and output growth are enhanced.[22]

The study may shed some new light on the potential cause of the possible correlation between ability and wealth. The paper demonstrates that technological progress may provide an incentive for the sorting of abilities across sectors. That is, high-ability individuals are attracted by technologically advanced sectors . If ability is transmitted across generations, rapid technological progress strengthens the correlation between ability and wealth. Furthermore, a low level of mobility may reflect an efficient allocation of talents across occupations rather than inequality of opportunities.

[22]This results depend crucially on the assumption that transmission of ability is costless (e.g., genetic). If the transmission of ability represents capital market imperfections, social status, etc. the implications for mobility and output growth may differ significantly.

The study suggests therefore that a positive transitory technological shock may provide the necessary conditions for a take-off from a state of socio-economic stagnation. Furthermore, it argues that a society characterized by social impediments to mobility may have a distorted allocation of talents across occupations, may experience a lower frequency of technological innovations, and hence a lower rate of output growth. Thus, the presence of social barriers for mobility brings about economic impediments as well.

In addition, the paper contributes to the literature concerning income distribution and growth, and technological progress and economic growth. It explores a novel technological link in the relationship between inequality and economic growth. It demonstrates the role of inequality in the determination of output growth via its effect on mobility, the allocation of talents across occupations, and the frequency of technological breakthroughs. Furthermore, it examines the role of intergenerational earnings mobility in mobilizing high-ability individuals into technologically advanced sectors in which growth enhancing, new technologies are developed.

The paper may shed new light on the explanation for the cyclical pattern in the evolution of the wage differentials between skilled and unskilled labor in the United States. Unlike Mincer (1991, 1996), who argued that the two decade cycle reflects a supply response to a skill-biased technological change, the current analysis suggests that the life cycle of technology may govern this cyclical pattern as well. Initially, inventions increase the return to education, but as technology becomes more accessible the return to education declines. Furthremore, the paper suggests a novel testable hypothesis, namely, that the earning ratio of top earners to bottom earners is expected to be higher in technologically advanced sectors.[23]

[23]Some evidence in support of this hypothesis is provided by the literature on the market for Superstars (e.g., Frank and Cook, 1995). Other indirect evidence are provided by Bok (1993).

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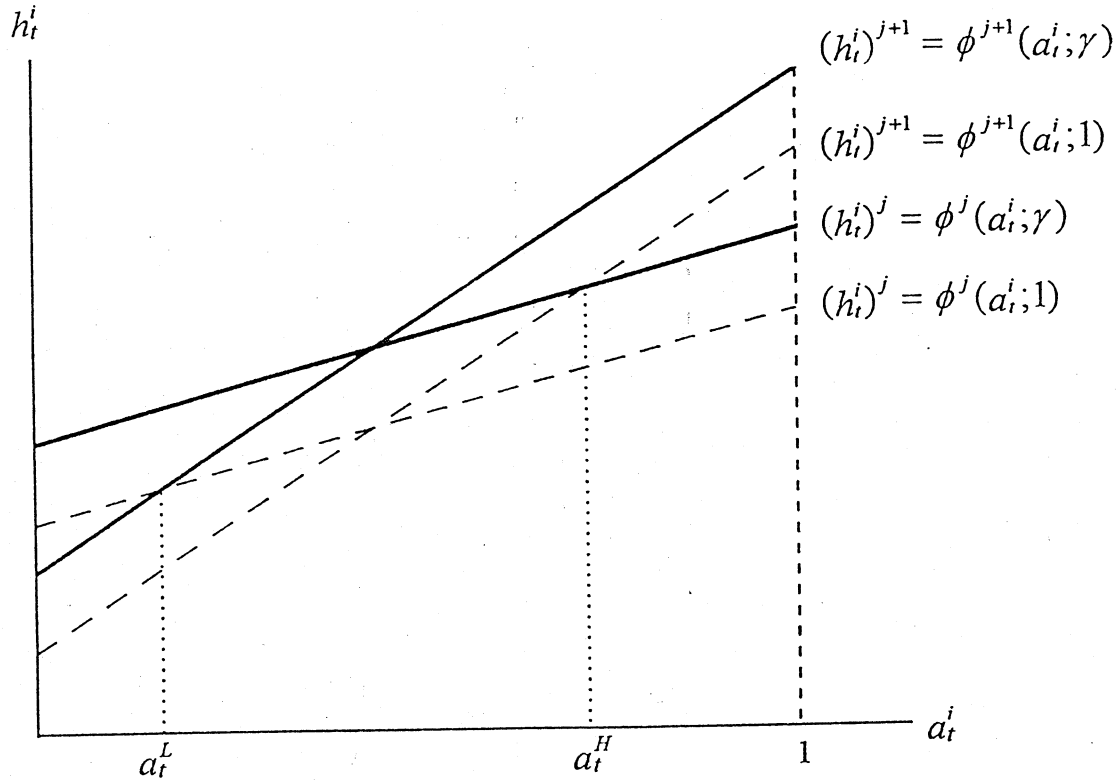
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Figure 1

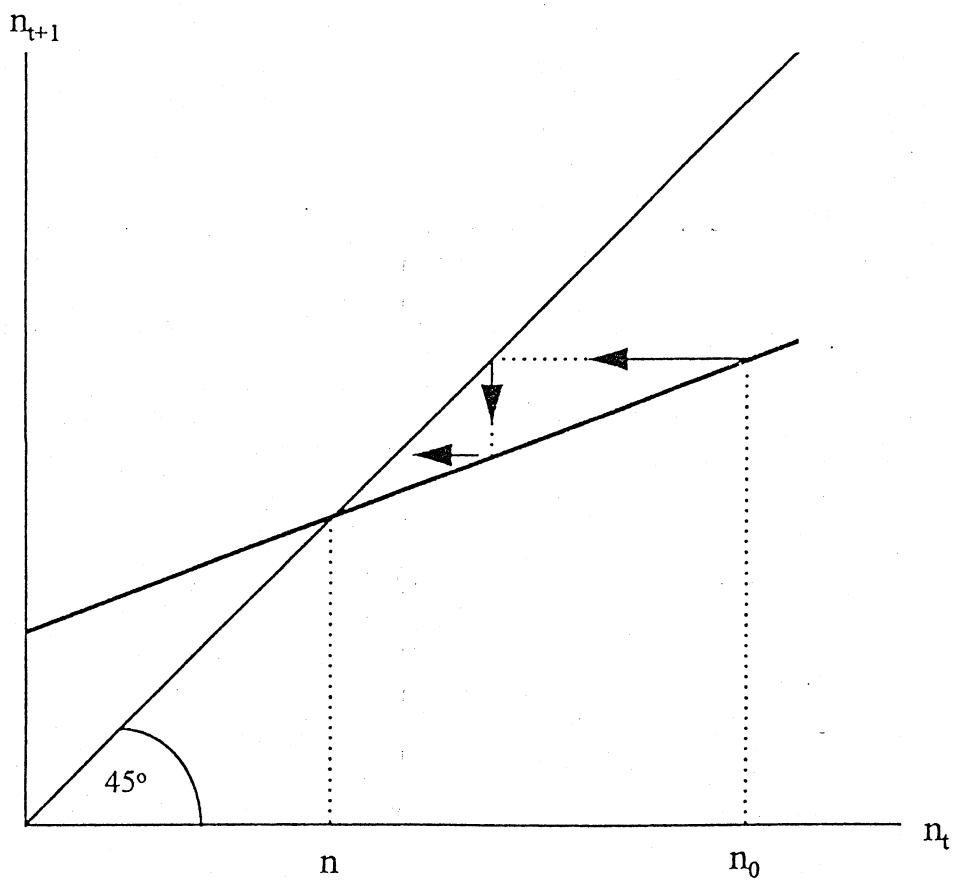

Figure 2

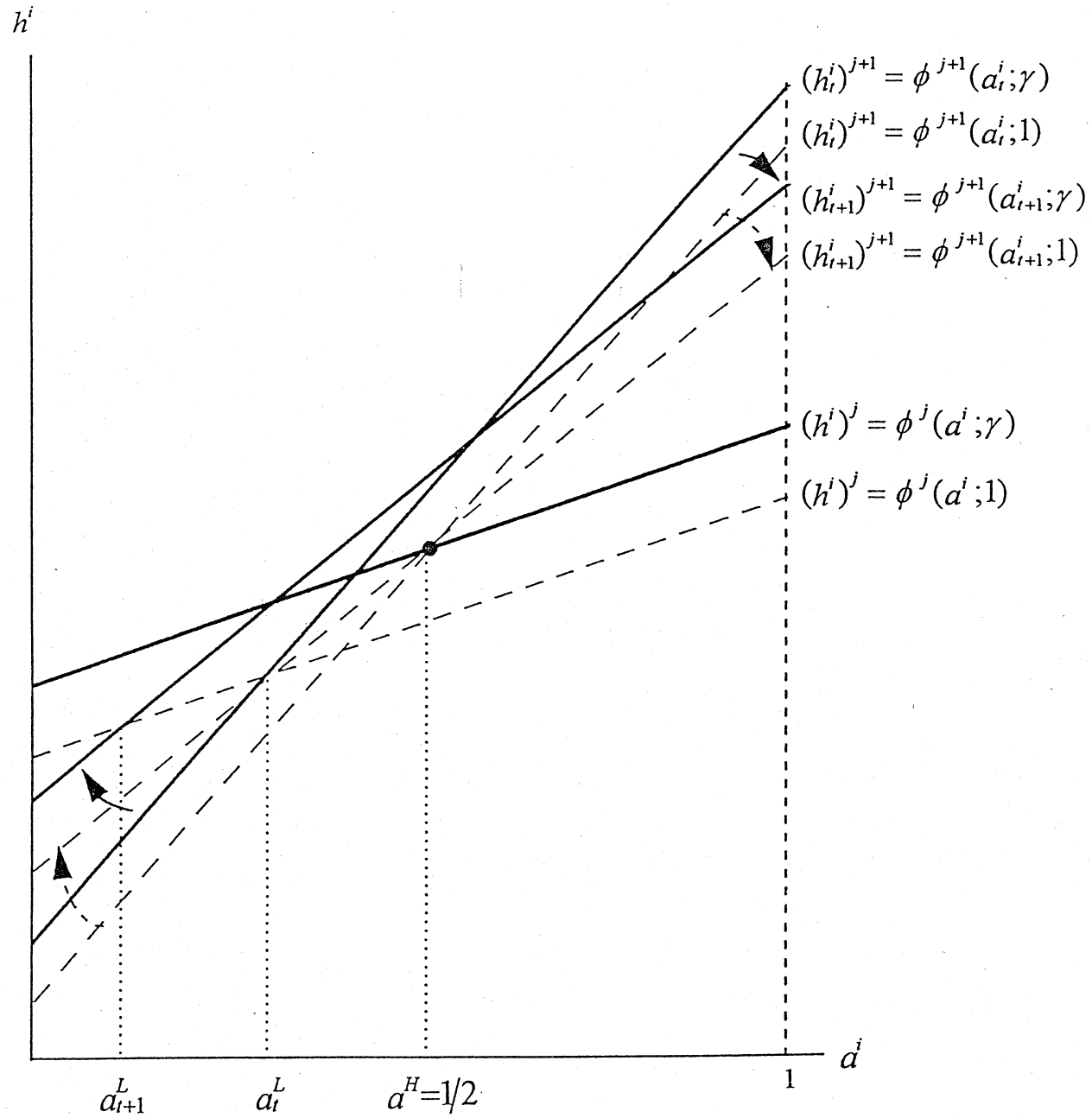
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Figure 3

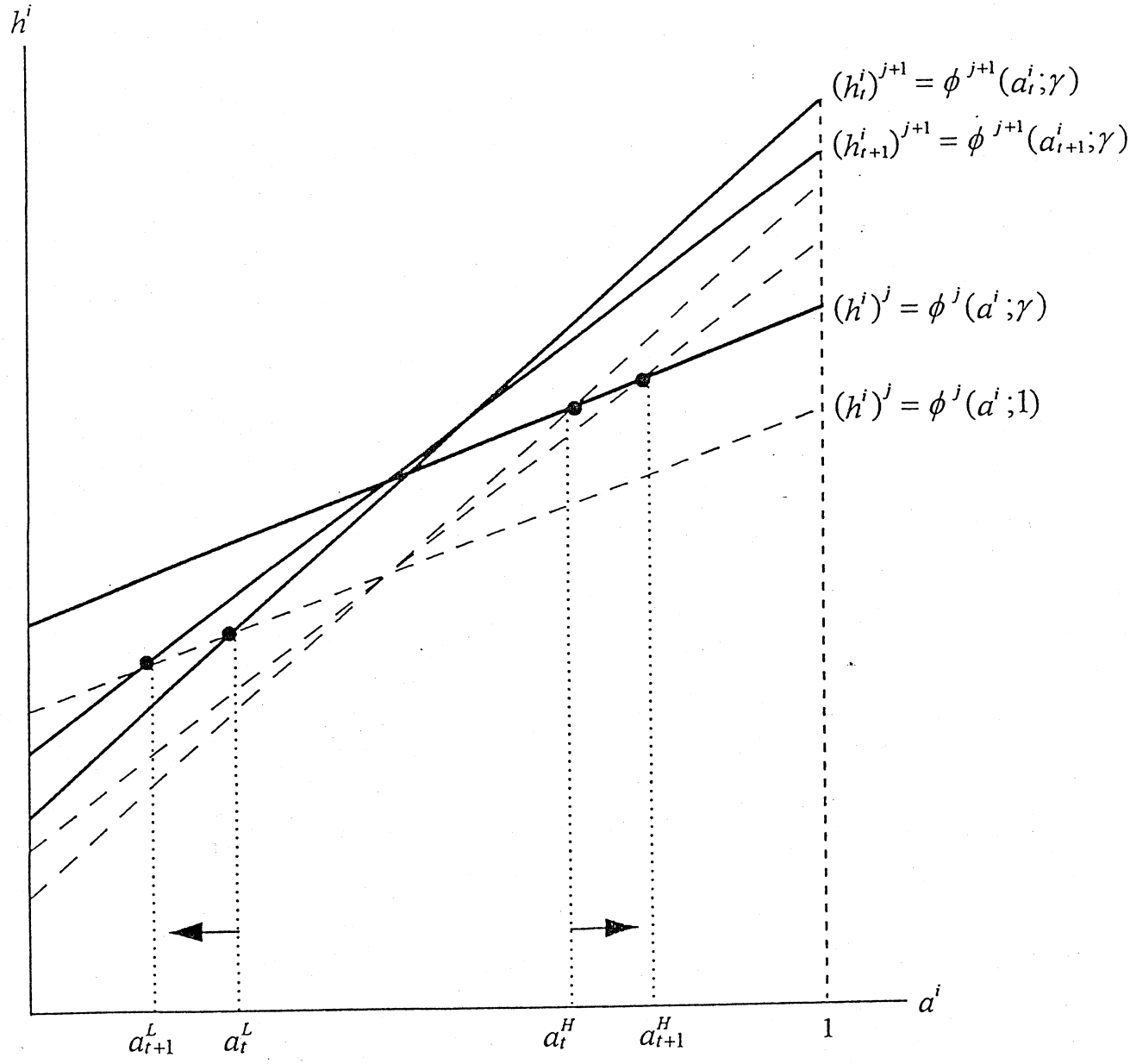
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Figure 4

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