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Role of Human Capital Accumulation in the Adoption of Sustainable Technology: An Overlapping Generations Model with Natural Resource Degradation

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ABSTRACT

We develop an economic model to derive the conditions under which individuals will invest in human capital and move on to adopt sustainable technology instead of natural resource-intensive technology. For this purpose, we extend the overlapping generation model developed by Ikefuji & Horii as our analytical framework. Unlike Ikefuji & Horii who developed an overlapping generation model (OLG) in the context of local pollution, the authors adopted it in the context of renewable natural resources. To do this, we have introduced the production sector that relies on natural resource-intensive technology. This research extends beyond the Ikefuji & Horii model by assuming that an individual derives utility by investing in his child's education apart from utility derived from consumption when young and adult. Human capital accumulation enables individuals to participate in human capital-intensive production, which produces output through sustainable production technology. As the main result of our theoretical analysis, we find that more educated individual is less dependent on the natural resource endowment for earning their income. We also find that sustainable consumption growth requires that individuals assign a certain positive weight to investment in their child's education. A long-run steady-state equilibrium level of human capital accumulation is higher and higher than the weight assigned by the parents to the child's education. In this overlapping generation's economy, sustainable consumption growth requires that individuals assign a certain weight or give some importance to human capital accumulation. This follows from the fact that the long-run steady-state value of the income earned by an individual depends positively on the expenditure on education.

INTRODUCTION

The human capital theory by Olaniyan & Okemakinde (2008) has emphasized how education raises efficiency as well as productivity of laborers by augmenting the cognitive skills of human ability. They argue that the productivity level of better-educated individuals is higher, a fact that will facilitate technological progress. According to Wells 1972, educated people are more willing to adopt innovative technology than less educated ones. Human capital accumulation via education facilitates the adoption and development of sustainable technologies that can reduce the extent of resource degradation. Human capital is a composite of skills accumulatedby workers through learning by doing or education (Becker 1964).

The pessimistic Malthusian view that natural resource scarcity would put an end to economic growth was countered by neoclassical economics in the 1970s. In a neoclassical growth framework, natural resources are an indispensable input in production, and the consequences are in contrast with the pessimistic Malthusian predictions. However, the application of the neoclassical growth theory to resource depletion problems dismisses the possibility that natural resource scarcity can significantly constrain economic growth (Nordhaus 1992). Despite the natural resource scarcity, economies may grow if there is continuous exogenous technical progress (Dasgupta & Heal 1974, Solow 1974, Stiglitz 1974). According to this theory, technical change and substitution among production inputs that permit the replacement of depleted resources by human-made capital (people, factories, machines, etc.) or by more abundant substitutes can effectively disassociate economic growth from natural resource depletion. According to Stiglitz (1974), increasing returns to scale, technical progress, and substitution of scarce inputs by abundant inputs are some of the ways to counteract the negative effects on economic growth of natural resource scarcity.

Gylfason (2001) argued that neglecting the role of human capital can result in poor economic performance and natural resource degradation in countries rich in natural resources. This happensbecause they assumed that natural resources and education could be substituted for each other. Hence, human capital accumulation can sustain growth and development as well as mitigate natural resource degradation (Bravo-Ortega & De Gregorio 2005, Gylfason et al. 1999, Papyrakis & Gerlagh 2004).

Human capital plays a critical role in promoting sustainable growth in the presence of natural resources (Goderis & Malone 2011). In such cases, human capital is assumed to embody technological progress in workers, while natural resource stock remains a purely quantitative input.

Hence, a comprehensive analysis must be carried out to evaluate the role played by human capital in sustaining economic growth or in the adoption of more sustainable technology. Moreover, we will explore whether the investment in human capital accumulation could lead to the adoption of sustainable production technology. Since sustainable technologies are less reliant on natural resources and use human capital intensively, they have smaller impacts on natural resource degradation than technologies that use natural resources intensively. Many empirical studies support such kind of specifications. The increase in the net enrolment ratio of primary schools leads to a decrease in the annual deforestation rate (Ikefuji & Horrii 2007). The increase in human capital by way of an increase in the education level of the individual greatly encourages the use of sustainable farming practices. It reduces the likelihood of felling trees (Swinton & Quitroz 2003). Higher literacy rates improve the quality of the environment, especially in low-income countries (Torras & Boyce 1998). As the health of the individual is negatively affected by environmental degradation, improvement in environmentalquality is posited to have a positive effect on human capital accumulation (Chakrobarty & Gupta 2014). Drawing on this body of literature, this study develops and solves an analytical model of a stylized economy to examine the role of human capital in natural resource management and the adoption of sustainable technology of production.

To analyze the role of human capital accumulation in the adoption of sustainable technology of production, we need a baseline analytical model to start with. For this purpose, we extend the model developed by Ikefuji & Horii (2014) for our analytical framework. They derive the conditions under which the economy could adopt sustainable technology that helps in escaping the‘poverty-environment trap.’

This research extends beyond Ikefuji & Horii (2014) to examine the role of human capital by assuming that an individual derives utility by investing in his child's education apart from utility from consumption when young and adult. Unlike Ikefuji & Horii (2014), who developed an overlapping generation model (OLG) in the context of local pollution, we have adapted it in the context of renewable natural resources. Our focus is entirely on the extractive use of resources for production purposes, and we neglect amenity services provided by the resources. To do this, we have introduced the production sector that relies on natural resource-intensive technology. In an OLG economy, Gerlagh & Keyzer (2001) have examined the possibility of a positive, balanced growth path with natural resources, which have amenity value but are not used as an essential input into the production sector. Unlike Gerlagh & Keyzer (2001), we have incorporated natural resources as an essential input in the natural resource-intensive production sector.

The livelihood of the 'asset less' poor is dependent on the exploitation of their surrounding localnatural resources, without the availability of any alternative livelihood earning opportunities (Barrett et al. 2001). Households having a greater number of uneducated members are more reliant on unskilled paid work to obtain most of their income (Banerjee & Duflo 2007). Underinvestment in human capital is a persistent problem for low-income households, particularly in fragile environments (Barbier 2010). Our analysis rests on this premise.

In our model, all individuals are assumed to live for a two-time period. In period t-1, she/he is young, and in period t, she/he becomes an adult. At the end of period t, an adult gets old and exits the system. We assume that participation in employment activity that does not exploit natural resources requires individuals to invest in human capital, and only through human capital accumulation can individuals participate in sustainable or human capital-intensive production activity. The young agent is endowed with a certain time or labor endowment, which, when combined with theeducational expenditure fully funded by their parents, leads to the accumulation/acquisition of human capital. We further assume that each young agent receives a transfer of income from their parents, which is utilized for consumption when young and to acquire ownership rights for natural resources from the current generation of adult agents. In this setting, the initial endowment of natural resource stock belongs to the adult agents of the first generation, and they sell the natural resourceto their successor generation to provide for adult age.

Further, individuals are not concerned about the welfare of future generations. As a result, in each period, only the working generation owns the natural resource stock. This framework is borrowed from Agnani et al. (2005).

In adult age, each individual can earn their livelihood by participating in two different production activities that rely on two distinct types of technologies. One is human capital-intensive (HCI) technology, which uses human capital and unskilled labor as production inputs. The other technology is called natural resource-intensive technology (NRI), which depends on unskilled labor and exploitation of a natural resource or agricultural land, or an easily accessible common property resource. The adult agent uses their total wage income and income received from selling their natural resource endowment for consumption, transfer to their child, and fund expenditure on their child's/young agent's education.

The framework stated above helps us characterize the conditions under which the household will be caught in the low human capital accumulation and natural resource degradation trap or the conditions that will help escape this trap through human capital accumulation viainvestment in human capital. Specifically, the scope of the study is extended to derive the conditions under which individuals will invest in human capital accumulation and adopt sustainable or human capital-intensive technology instead of natural resource-intensive technology, and by utilizing this framework, we will examine the likely desirable policies for sustainable economic growth.

As the key results of our theoretical analyses, we find that as the investment in a child's education by the parents increases, the total earned income of the individual increases, but the income earned from the natural resource stock endowment declines. A more educated individual is less dependent onnatural resources for earning their income. If the investment in education is zero, then the individual has no option but to rely completely on natural resource-intensive technology for earning their livelihood. We also find that as the investment in education increases, the output produced from sustainable technology rises, and the output produced from natural resource-intensive technology falls. However, as the extraction of natural resource stock increases, the aggregate output produced from sustainable technology decreases, and the aggregate output produced from natural resource-intensive technology increases. We also find that sustainable consumption growth requires that individuals assign acertain weight to investment in theirchild's education. A long-run steady-state equilibrium level of the human capital accumulation is higher, the larger the weight assigned by the parent to the child's education.

The steady-state value of income earned by an individual depends on the investment in education made by their parents. The long-run steady-state value of the income earned by an individual depends positively on the expenditure on education, the productivity of human capital-intensive technology, unskilled labor, the share of human capital in human capital-intensive output, and the productivity of human capital accumulation. The steady-state value of natural resource stock is higher when an individual assigns higher importance to education investment relative to consumption. The steady-state value of natural resource stock is higher, higher is the weight assigned by an adult agent on the investment in their child's education, higher is the productivityof human capital-intensive technology, higher is the share of human capital relative to the share of unskilled labor in human capital-intensive output lowers the price of natural resource-intensivesector output and lowers the productivity of natural resource-intensive technology.

In this overlapping generation's economy, sustainable consumption growth requires that individuals assign a certain positive weight or give some importance to human capital accumulation. This follows from the fact that the long-run steady-state value of the income earned by an individual depends positively on the expenditure on education. We now proceed with a description of the analytical framework.

THEORETICAL MODEL FRAMEWORK

In this section, we develop the theoretical/analytical model of human capital accumulation and natural resource degradation to explain the mechanisms that lead to the adoption of sustainable technology. We have considered an overlapping generation model (OLG), where each individual is alive for two time periods: t-1 and t. Individuals are born in period t-1 and are called young agents, and in period t, individuals become older and are called adult agents. We assume that thepopulation of each generation does not grow since each adult agent is presumed to bear a single child. Thus, the total population is stationary, and it is normalized to one.

During period t-1, young agents do not work, but they spend on consumption and buy the ownership right of a natural resource out of the transfer that they receive from their parents. When young, the individual benefits from their parent's spending on their education and builds on their human capital (through education acquisition). The young agents are endowed with a certain ability to learn, of which they devote a fraction towards learning or acquiring education, which, in turn, leads to human capital accumulation. This framework is borrowed from Ikefuji & Horii (2014). We, therefore, assume that there is no work undertaken during young age or childhood. We also assume that each adult agent in period t can earn their livelihood by participating in two different kinds of production activities that distinctly employ two different technologies: (i) production of output based on unskilled labor, such as exploitation of natural resources or agriculture land or easily accessible common property resources, (ii) production of output that depends on skilled labor, i.e., human capital. During period t, the adult agent uses their total wage income earned from unskilled labor and skilled labor or human capital that they supply to firms and income received from selling their natural resource endowment for consumption, transfer to their child, and to fund their child's/young's agent education for human capital accumulation which will benefit to their children as they become adults in the next period of their life.

Individual Preferences, Budget Constraints, and Labor Allocation

We assume that all the agents are identical and have rational expectations except for their age or cohort. Every period consists of individuals of two cohorts: young and adult agents. There is no population growth, and we normalize the number of agents of each generation or cohort to one. Every generation consists of L_{t-1} young agents or families who live for two periods. Since the population is homogenous and normalized to unity such that, $C_{t-1}^{Y} = c_{t-1}^{Y}, C_{t}^{A} = c_{t}^{A}$, and aggregate consumption in each period is simply $C_t = C_{t-1}^{Y} + C_{t}^{A}$, $V_t = v_t$ and $L_{t-1} = l_{t-1} = l$, it also holds for other variables. More formally, individuals born in period t-1 care about consumption when young, C_{t-1}^{Y}, consumption when adult, C_{t}^{A} and the amount spent or invested in a child's education in period t, V_t. We, therefore, assume that the parents enjoy giving a transfer to their children for education acquisition, as in Glomm & Ravikumar (1992). However, this bequest motive is not analyzed explicitly by us. Accordingly, the utility of an individual is represented by the following additively separable utility function:

$$U_t = lnC_{t-1}^{Y} + \beta lnC_{t}^{A} + (1-\beta) lnV_t . \quad \ldots(1)$$

Here, $0 < \beta < 1$ is the parameter that measures the weight assigned by the young agent to the future level of consumption (C_{t}^{A}) as opposed to the investment that they make in their child's education (V_t).

Similarly, to Ikefuji & Horii (2014), the human capital accumulation (due to educationacquisition) by young agents in period t is defined by

$$H_t = \psi V_{t-1} L_{t-1} = \psi V_{t-1} l. \quad \ldots(2)$$

Here, $\psi > 0$ is the productivity parameter associated with human capital accumulation.

Each young born in period t-1 is endowed with a certain endowment of labor ($L_{t-1} = l$), which when combined with educational expenditure (V_{t-1}), is fully funded by their parent's oradult agents of period t-1 helps build their human capital (H_t), which becomes available to the young agents in the next period of a lifetime, that is, in adult age. In period t, the endowment of labor of the adult agents (L_t) remains the same as their endowment of labor when she/he was young (L_{t-1}), that is, $L_{t-1} = L_t$, which, in turn, is constant l. Investment in the young agent's human capital by the adult agent in period t-1 can raise the young agent's productivity. It is often predicted by humancapital theory that investment in education has a positive impact on cognitive and other skills. These, in turn, supplement the productivity of labor (Becker 1964, Schultz 1961). The adult agents of generation t-1 are endowed with a unit time endowment, which she/he devotes entirely to work and earns income (Y_{t-1}); a part of this income, that is, $\mathcal{E} Y_{t-1}$, is transferred to their child or young agent of period t-1.

We assume that the initial endowment of natural resource stock belongs to the adult agents of period t-1 and aggregate economy-wide endowment is distributed equally among all the adult agents of the time t-1. These adult agents sell their natural resources to their successors, that is, young agents of period t-1, to provide for their spending, which then sells the stock to the firms in period t. This framework is borrowed from Agnani et al. (2005). Further, weassume that individuals cannot borrow or lend as they lack access to a well-functioning credit market,and they do not work when young. In period t-1, each young agent receives a transfer of incomefrom his/her parents ($\mathcal{E} Y_{t-1}$) that they utilize for consumption when young (C^Y) and to acquire ownership right for natural resources from first-generation adult agents ($p_{t-1}N_{t-1}$). The budget constraint faced by young agents is given as follows:

$$C_{t-1}^{Y} + p_{t-1} N_{t-1} = \mathcal{E} Y_{t-1} \quad \ldots(3)$$

Where $\mathcal{E}$ is the exogenously assumed fraction of income earned by an adult agent of period t-1 that is transferred to young agents who are born in period t-1, N_{t-1} is the endowment of the natural resource that young agent purchases from adults of generation t-1, p_{t-1} is the price of the ownership right of one unit of the natural resource in terms of the consumption good.

Accordingly, in period t, each adult earns aggregate wage income (Y_t) from their unskilled laborstock (equal to $w_{l_t} l$), skilled labor stock, or human capital stock (amounting to $w_{h_t} H_t$) and receives income from selling natural resources to the next generation young agent ($p_t N_{t-1}$). Where w_{l_t} and w_{h_t} are wages of unskilled and skilled labor/human capital, and $w_{l_t} < w_{h_t}$. The individual will earn w_{l_t} if he does not receive education, that is, V_{t-1}=0. But if he receives an education, then he can earn wages from unskilled labor as well as skilled labor/human capital. The adult agent uses their total wage income and income received from selling their natural resource endowment for consumption (C^A), transfer to their child ($\mathcal{E} Y_t$), and to fund expenditure on investment in child's/young's education (V_t). Thus, the budget constraint during the second periodof an individual's life (when adult) can be written as:

$$C_t^A + V_t + \mathcal{E}Y_t = Y_t + p_t N_{t-1} \quad \ldots(4)$$

Where $\mathcal{E}$ is the fraction of wage income earned by each adult agent in period t that is transferred totheir young, Y_t is the total wage income earned by adults, p_t is the unit price at which natural resource stock is sold to firms by an adult agent in period t.

The total wage income earned by an adult in period t will be as follows:

$$Y_t = w_{h_t} H_t + w_{l_t} s_t l + w_{l_t}(1 - s_t)l = w_{h_t} H_t + w_{l_t} l \quad \ldots(5)$$

This can be explained as follows. The adult agent earns income by participating in two types of economic activities: (i) a production activity that depends on human capital-intensive technology, for which she/he earns a wage rate per unit of human capital, w_{h_t}, and wage rate per unit of unskilled labor, w_{l_t} and where s_t is the fraction of unskilled labor devoted to human capital intensive output production, and (ii) another production activity that relies on natural resources that can be exploited at zero economic cost for which they earn unskilled labor wage income (offraction, $(1-s_t)l$), where $(1-s_t)$ is the fraction of unskilled labor devoted to natural resource.

Intensive output production. The assumption of zero economic cost of extraction of natural resources offers mathematical tractability. A similar assumption is used by Agnani et al. (2005). Here l is labor input per unit of output as the population of each generation is normalized to one ($l_t = L_t = l$).

Production Structure and Firm's Behavior

As mentioned earlier, there exist N numbers of competitive firms producing a homogenous outputby using two different types of technologies. One type of technology is human capital-intensive, which produces output by using skilled labor/human capital and unskilled labor as inputs. There exist N^H firms in this sector. We assume a Cobb-Douglas form production function wherein inputscan be substituted for each other to produce the same output but cannot be substituted at a constantrate. This type of production function assumes constant returns to scale with respect to all the inputs for a given technology level. This production technology does not utilize natural resources, and in this sense, it is taken to be pollution-free or clean technology (Ikefuji & Horii 2014). Theaggregate output of all the N^H firms producing output from human capital-intensive technology can be written as:

$$Y_t^H = N^H A^H (H^\theta)(s_t l)^{1-\theta} \quad \ldots(6)$$

Where $A^H > 0$ is the constant measuring the productivity level of the human capital-intensive technology, s_t is the fraction of the adult's stock of unskilled labor (l) devoted to the productionof output through human capital-intensive technology.

The other available technology of production is natural resource-intensive, which uses unskilled labor to produce goods and relies more heavily on the extraction of natural resources, X_t. There exist N^R firms in this sector. The production function, in this case, is similar to the one given in Ikefuji & Horri's (2014) framework. Still, here, we have added the extracted natural resource stock, X_t, usedin production. The aggregate output of all the N^R firms produced from natural resource-intensive technology in per-worker terms is expressed as:

$$Y_t^R = N^R A^R (1 - s_t)\, l X_t \quad \ldots(7)$$

Where $A^R > 0$ is the constant that measures the productivity or technology level of the natural resource-intensive technology, $1-s_t$ is the fraction of unskilled labor of an adult agent devoted to production using natural resource-degrading technology, and X_t is the stock of natural resource used for production in this sector. The firm's exploitation of natural resources involves price p_t, and the utilization of natural resources as an input into the production depletes the stock of natural resources. Thus, the production technology in this sector is dirty.

Finally, the evolution of natural resource stock is determined by the amount of output produced from natural resource-intensive technology. This resource stock can regenerate or grow over time.

Natural Resource Dynamics

The natural resource stock in our model is renewable. It is used as an input in the production of natural resource-intensive output. In period t-1, the adult agents own the natural resource stock, which they sell to the young agents. These young agents are adults in period t, and they sell this stock to firms, which then decide on how much of that resource to extract and use as an input in the production of the natural resource-intensive output. The extraction of resources is costless, andthe decision on how much to extract is not modeled explicitly.

At the beginning of period t-1, the economy is initially endowed with a positive amount of the natural resource, N_{t-1}, which belongs to the adult agents of the first generation. In period t, the total stock of the natural resource, N_t, is determined by deducting resources used for current production, X_t, from available previous resource stock, N_t.

The equation governing the dynamics of natural resource stock is given by

$$N_t = (1+\delta)N_{t-1} - \eta\, X_t \qquad \ldots(8)$$

Where $0 < \delta < 1$ is the parameter referring to the natural regeneration capacity of resources and $\eta > 0$ measures the extent of natural resource degradation due to the extraction of natural resources forproduction in the natural-resource-intensive sector. With this apparatus, we now solve for the market equilibrium.

SOLVING FOR THE MARKET EQUILIBRIUM

The Firm's Optimization in the Two Production Sectors

Each firm in the human capital-intensive (HCI) sector produces the output by using human capital/skilled labor and unskilled labor by employing HCI technology that is given by the production function in equation (7). All firms in this sector share the same production technology.We assume that the human capital-intensive (HCI) sector is the numeraire, such that $p^H = 1$. In a perfectly competitive framework, the profit-maximizing firm chooses human capital/skilled labor (H_t) and unskilled labor ($s_t l$) while taking the human capital/skilled labor (H_t) and unskilled labor ($s_t l$) wage rates, w_{h_t}, and w_{l_t} as given, that is,

$$\max_{H_t s_t l} \pi^H = A^H(H_t^\theta)(s_t l)^{1-\theta} - w_h\, H_t - w_l\, s_t l$$

The first-order conditions of the representative firm's profit maximization problem are given, inper-worker terms, by:

$$w_{h_t} = \theta A^H H_t^{\theta-1}\,(s_t l)^{1-\theta}\ ; \qquad \ldots(9)$$

$$w_{l_t} = \frac{(1-\theta)A^H h_t^\theta}{(s_t l_t)^\theta} \qquad \ldots(10)$$

The above profit maximization conditions state that given the return to human capital/skilled and the unskilled labor wage rate, w_{h_t} and w_{l_t}, the demand for each type of labor is determined by equating these returns to the marginal productivity of human capital and unskilled labor respectively.

When output is produced from natural resource-intensive (NRI) technology, the representative firm hires unskilled labor ($(1\text{-}s_t)l$). It combines it with extracted natural resources (X_t) to maximize profit, taking relative prices of natural resource-intensive output (p^R), unskilled labor wage (w_{l_t}), and price of extracted natural resources used in production (p_t) as given. That is,

$$\max_{x_t, s_t l} \pi^R = p^R A^R (1-s_t) l X_t \ - w_{l_t}(1-s_t)l - p_t\ X_t$$

Here, the firm hires unskilled labor to be employed, $(1\text{-}s_t)\,l$, and natural resource stock to beused in the production of output, X_t, which lead to the following first-order conditions:

$$w_{l_t} = p^R A^R X_t\ ; \qquad \ldots(11)$$

$$p_t = p^R A^R (1-s_t) l \qquad \ldots(12)$$

This indicates that each firm hires unskilled labor and natural resources until their respective marginal products get equated to the factor return or price. By equating equation (10) with (11), we get that,

$$\frac{(1-\theta)A^H H_t^\theta}{(s_t l)^\theta} = p^R A^R X_t$$

$$s_t l = \left(\frac{(1-\theta)A^H}{p^R A^R X_t}\right)^{1/\theta} H_t\ ,$$

Where $H_t = \psi V_{t-1} l$

Equation (13) states that unskilled labor devoted to the production in the human capital-intensive (HCI) sector, $s_t l$, depends positively on the share of unskilled labor in aggregate output ($1\text{-}\,\theta$), the investment in the human capital of young agent made by the adult agent or parent, V_{t-1}, and the productivity of human capital-intensive technology relative to the productivity of natural resource-intensive technology, A^H/A^R, negatively on the price of natural resource-intensive output, p^R, and natural resource stock used in the production of natural resource-intensive output, X_t. Substituting thevalue of $s_t l$ from (13) into (9), we derive that

$$w_{h_t} = \theta(1-\theta)^{(1-\theta)/\theta} \frac{A^{H^{1/\theta}}}{(p^R A^R X_t)^{(1-\theta)/\theta}}\ . \qquad \ldots(14)$$

Lemma 1: For a given value of $(1-\theta)$, A^H, p^R and A^R, as X_t increases w_{l_t} increases, which in turn leads to decrease in w_{h_t}.

Proof: Follows from the solution of w_{h_t} (See equation (14))

This lemma states that for a given level of share of unskilled labor in the human capital-intensive sector, $(1-\theta)$, productivity level of human capital intensive (HCI) technology (A^H), productivity level of natural resource-intensive (NRI) technology (A^R) and price of natural resource-intensive output (p^R), as the extraction of resources increases (X_t), the unskilled labor wage rate increases(w_{l_t}) (follows from (11)), since, from (11) we have, $w_{l_t} = p^R A^R X_t$. An increase in w_{l_t} reduces the wage rate for human capital (w_{h_t}) (follows from equation (14)). This happens because the increase in w_{l_t} will reduce the demand for unskilled labor in the human capital-intensive sector (follows from (10)), which, in turn, reduces the skilled labor/human capital wage rate (follows from (9)). This implies that as the unskilled wage rate increases, the profitability of output produced from natural resource-intensive technology will fall. Still, the profitability of output produced from human capital-intensive technology will increase.

From (12), we have

$$p_t = p^R A^R (1 - s_t) l$$

The above equation implies that the price of the extracted natural resource used in production (p_t)depends on the price of natural resource-intensive output (p^R), productivity level of natural resource-intensive (NRI) technology (A^R) and the unskilled labor used in natural resource-intensive output ($(1\text{-}s_t)l$).

We next turn to substituting $s_t l$ from equation (24) into the above equation. We get that

$$p_t = p^R A^R L_t - p^R A^R \left[\frac{(1-\theta)A^H}{p^R A^R X_t}\right]^{1/\theta} H_t$$

$$p_t = \frac{(p^R A^R X_t)^{1/\theta} l - ((1-\theta)A^H)^{1/\theta} H_t}{(p^R A^R)^{1-\theta/\theta}\ (X_t)^{1/\theta}}, \quad \text{...(15)}$$

Where $H_t = \psi V_{t-1} l$.

Lemma 2: For a given value of $(1 - \theta)$, A^H, p^R and A^R, as V_{t-1} increases p_t decreases and as X_t increases p_t increases.

Proof: Differentiating the equation (15) with respect to V_{t-1}, we get

$$\frac{\partial p_t}{\partial V_{t-1}} = -\frac{((1-\theta)A^H)^{\frac{1}{\theta}} \psi l_{t-1}}{(p^R A^R)^{\frac{1-\theta}{\theta}} (X_t)^{\frac{1}{\theta}}} < 0 \quad \text{...(16)}$$

Differentiating the equation (15) with respect to X_t, we get

$$\frac{\partial p_t}{\partial X_t} = \frac{1}{\theta} \frac{((1-\theta)A^H)^{\frac{1}{\theta}} \psi V_{t-1} l}{(p^R A^R)^{\frac{1-\theta}{\theta}} (X_t)^{\frac{(\theta^2-\theta+1)}{\theta^2}}} > 0 \quad \text{...(17)}$$

From equation (16), we can infer that the price that the firm will pay for the extracted natural resource and the price that adult agent will receive from selling their natural resource stock to firms (p_t) will decrease as the investment in the education of the young agent made by the parents (V_{t-1}) increases. The more educated individual will rely less on natural resource stock to earn their income; they can increase their income by working in a human capital-intensive sector. Similarly, from equation (17), we can say that p_t will increase as the natural resource stock extracted for production (X_t) will increase.

Consumers Optimization

The representative agent born at period t-1 maximizes their utility function with respect to young and adult agent consumption and expenditure to be made in their child's education, taking prices as given. The two-period utility maximization problem of the adult agent (in period t) can be written as:

$$\max_{C_{t-1}^Y, C_t^A, V_t} U_t = lnC_{t-1}^Y + \beta lnC_t^A + (1-\beta) lnV_t$$

Subject to budget constraints of time periods t-1 and t to be:

$$C_{t-1}^Y + p_{t-1} N_{t-1} = \mathcal{E} Y_{t-1}; \quad \text{...(19)}$$

$$C_t^A + V_t + \mathcal{E} Y_t = Y_t + p_t N_{t-1}; \quad \text{...(20)}$$

$$Y_t = w_{h_t} H_t + w_{l_t} s_t l + w_{l_t} (1 - s_t) l \quad \text{...(21)}$$

Given the transfer of income received by each young agent from their parents ($\mathcal{E} Y_{t-1}$ ($\mathcal{E}$ being exogenous here)) and the expenditure on education (V_{t-1}), the agent born in period t-1 chooses the expenditure to be done on their child's education (V_t), the natural resourceendowment to buy (N_{t-1}) from first generation adults agent or adult agents who coexists with theyoung agent born in period t-1.

Given the human capital/skilled labor equation in (2), $H_t = \psi V_{t-1} l$. and the budget constraint in (19) and (20), the langrage an expression for the above-stated problem, with the choice variables for optimization as V_t and N_{t-1}, can be written as:

$$\mathcal{L} = \ln(\mathcal{E} Y_{t-1} - p_{t-1} N_{t-1}) + \beta \ln((1-\mathcal{E}) Y_t + p_t N_{t-1} - V_t) + (1-\beta) lnV_t$$

Accordingly, the first-order conditions for the consumer's optimization problem take the form:

$$\frac{d\mathcal{L}}{dV_t} = \frac{\beta(-1)}{((1-\mathcal{E})Y_t + p_t N_{t-1} - V_t)} + \frac{(1-\beta)}{(V_t)} = 0; \quad \text{...(22)}$$

$$\frac{d\mathcal{L}}{dN_{t-1}} = \frac{-p_{t-1}}{(\mathcal{E} Y_{t-1} - p_{t-1} N_{t-1})} + \frac{\beta p_t}{((1-\mathcal{E})Y_t + p_t N_{t-1} - V_t)} = 0 \quad \text{...(23)}$$

By simplifying equation (22), one gets that,

$$V_t = (1-\beta)((1-\mathcal{E})Y_t + p_t N_{t-1}) \quad \text{...(24)}$$

Equation (24) shows that investment made by an adult agent in a child's education (V_t) depends positively on the weight given by her/him to the investment in the child's education ($1 - \beta$), the totalwage income that the adult agent will earn from their human capital and unskilled labor (Y_t) andpositively on the income that she/he received from selling natural resource stock to firm ($p_t N_{t-1}$).

By solving equation (23), we get that each consumer equates the marginal rate of substitution between current and future consumption to the marginal rate of investment in natural resources.

$$p_{t-1}((1-\mathcal{E})Y_t + p_t N_{t-1} - V_t) = \beta p_t(\mathcal{E}Y_{t-1} - p_{t-1}N_{t-1}) \quad \ldots(25)$$

Substituting the value of V_t from equation (24) into equation (25) yields:

$$p_{t-1}((1-\mathcal{E})Y_t + p_t N_{t-1} - (1-\beta)((1-\mathcal{E})Y_t + p_t N_{t-1})) = \beta p_t(\mathcal{E}Y_{t-1} - p_{t-1}N_{t-1})$$

By rearranging the above equation, we get the solution for the natural resource stock purchased bythe young to be:

$$\beta p_{t-1}((1-\mathcal{E})Y_t + p_t N_{t-1}) = \beta p_t(\mathcal{E}Y_{t-1} - p_{t-1}N_{t-1})$$

$$N_{t-1} = \frac{1}{2}\left[\frac{\mathcal{E}y_{t-1}}{p_{t-1}} - \frac{(1-\mathcal{E})Y_t}{p_t}\right] \quad \ldots(26)$$

Lemma 3: For a given exogenous value of $0 < \mathcal{E} < 1$, N_{t-1} depends positively on Y_{t-1} and p_t, and negatively on Y_t and p_t.

Proof: The proof of this lemma follows from equation (26)

From equation (26), it is plausible that the natural resource stock that the young agent will buy from the first-generation adult agent of period t-1 (N_{t-1}) depends positively on the transfer that the young agent will receive from their parents ($\mathcal{E}\, Y_{t-1}$), negatively on the price at which they will buy the natural resource stock (p_{t-1}), positively on the price that they will receive by selling the natural resource stock to next generation agents (p_t) and negatively on the total wage income that an adult will earn from their human capital/skilled labor and unskilled labor (Y_t).

From equation (21), we know that the aggregate income earned by an adult in the second period (that is, period *t* of life) is the sum of the income earned by supplying human capital in the human capital-intensive (HCI) production sector and wage income earned by supplying unskilled labor to the two sectors. Specifically,

$$Y_t = w_{h_t}H_t + w_{l_t}s_t l + w_{l_t}(1-s_t)l = w_{h_t}H_t + w_{l_t}l$$

Next, substituting the values of w_{h_t}, H_t, and w_{l_t} from equations (14), (2), and (11), respectively, we derive the following expression for aggregate income (Y_t) as a function of investment in young'seducation by the parent (V_{t-1}) and the unskilled labor wage rate (w_{l_t}).

$$Y_t = \theta(1-\theta)^{(1-\theta)/\theta} \frac{A^{H^{1/\theta}}}{(p^R A^R X_t)^{(1-\theta)/\theta}} \psi V_{t-1}l + p^R A^R X_t\, l$$

$$Y_t = \frac{\theta(1-\theta)^{(1-\theta)/\theta} A^{H^{1/\theta}} \psi V_{t-1} l + (p^R A^R X_t)^{1/\theta} l}{(p^R A^R x_t)^{(1-\theta)/\theta}}$$

Lemma 4: The above expression states that given the constants θ, A^H, ψ, p^R, and A^R, the income earned by an adult agent depends (Y_t) on the educational expenditure incurred by their parents (V_{t-1}) and the level of extraction of natural resource (X_t).

Proof: The proof of this lemma follows from equation (27).

This lemma states that the total wage income earned by adult agents (Y_t), that is, the sum of unskilled wage income and human capital/skilled wage income, depends positively on the educational expenditure incurred by their parents (V_{t-1}) and negatively on the extracted natural resource used in the production of NRI output (see equations (43) and (44)).

If $V_{t-1} = 0$, from equation (27), we get that,

$$Y_t = p^R A^R X_t\, l \quad \ldots(28)$$

Intuitively, this can be seen from equation (28). That is, if the parent of the young does not incur any expenditure on the education of their child ($V_{t-1} = 0$), then she/he does not receive any education and remains unskilled. In the next period, when this young agent becomes an adult, their income will now depend on the wage income earned from unskilled labor by working inthe natural resource-intensive sector ($p^R A^R X_t$), which in turn, depends on the extraction of the natural resource (X_t).

Combining the solution for Y_t with the cases where $V_{t-1} = 0$ and $V_{t-1} > 0$, given by equations (28) and (27), respectively, we get the total wage income earned by an adult to be:

$$Y_t = \begin{cases} p^R A^R X_t l, & V_{t-1} = 0; \\ \dfrac{\theta(1-\theta)^{(1-\theta)/\theta} A^{H^{1/\theta}} \psi V_{t-1} L_{t-1} + (p^R A^R X_t)^{1/\theta} l}{(p^R A^R X_t)^{(1-\theta)/\theta}}, & V_{t-1} > 0. \end{cases} \quad \ldots(29)$$

Thus,

Proposition 1: In this overlapping generation (OLG) economy, as the investment in the education of the child by the parent increases, the income earned by the adult in the next period also increases (see the case for $V_{t-1} > 0$ in equation (29)). If, however, there is no investment in the child's educationby the parent, then in the next period, the adult derives the entire income by working as unskilledlabor in the natural resource-intensive sector (this follows from equation (29) when $V_{t-1} = 0$).

Behavior of Outputs of the Two Sectors Along the Equilibrium Path

Given perfect competition in commodity and factor markets and constant returns to scale (CRS), the number of firms in the aggregate economy is immaterial. We exogenously assume it to N^H forthe firms using HCI technology and N^R for the firms using NRI technology. In this setup, choosing $N^H = N^R = 1$ will not change the results qualitatively. At the economy-wide level, the aggregate output produced by N^H firms from HCI technology (equation (6)) is given as:

$$N^H Y^H = N^H A^H ((H_t^{\theta})(s_t l)^{1-\theta}$$

Substituting the value of H_t from equation (2) and $s_t l$ from equation (13) into the above equation,we get,

$$N^H Y_t^H = N^H (A^H)^{\frac{1}{\theta}} \left(\frac{(1-\theta)}{P^R A^R X_t}\right)^{1-\theta/\theta} \psi V_{t-1} l \quad ...(30)$$

Differentiating the above equation with respect to V_{t-1}, we get that

$$\frac{\partial N^H Y_t^H}{\partial V_{t-1}} = N^H (A^H)^{\frac{1}{\theta}} \left(\frac{(1-\theta)}{P^R A^R X_t}\right)^{1-\theta/\theta} \psi l > 0$$

...(31)

Lemma 5: Equation (31) states that as the investment in education (V_{t-1}) increases, the aggregate output produced from HCI technology ($N^H Y_t^H$) rises for a given positive level of extracted natural resource stock (X_t). Similarly, from equation (30), one can infer that as the extracted natural resource stock (X_t) increases, the output produced from HCI technology falls.

The aggregate output produced by N^R firms from NRI technology is given as:

$$N^R Y_t^R = N^R A^R (1 - s_t) l X_t$$

Next, substituting the value of $s_t l$ from equation (13) into the above equation, we get:

$$N^R Y_t^R = N^R (A^R l X_t - \frac{\left((1-\theta)A^H\right)^{\frac{1}{\theta}} \psi V_{t-1} l^2)}{(P^R)^{\frac{1}{\theta}} (A^R X_t)^{\frac{1-\theta}{\theta}}}$$

...(32)

Differentiating the above equation with respect to V_{t-1}, we get the following expression:

Lemma 6: The above equation (33) states that as the investment in education (V_{t-1}) increases, theaggregate output produced from NRI technology ($N^R Y^R$) decreases. Similarly, from equation (32), we can say that as the extracted natural resource stock (X_t) increases, the output produced from NRI technology increases. Thus,

Proposition 2: As investment in education increases or $dV_{t-1} > 0$, the aggregate output produced from HCI technology ($N^H Y^H$) increases, and the aggregate output produced from NRI technology ($N^R Y^R$) decreases. Similarly, as the extraction of natural resource stock ($dX_t > 0$) increases, the aggregate output produced from HCI technology decreases, and the aggregate output produced from NRI technology increases (proof follows from Lemma 5 and Lemma 6).

Intuitively, whenever investment in the education of the young agent made by the parents (V_{t-1}) increases, the price that the firm will pay for the extracted natural resources (p_t) decreases (follows from Lemma 2). We also know that as the extraction of resources increases (X_t), the price that the firm will pay for the extracted natural resources (p_t) will increase (follows from Lemma 2), and the unskilled labor wage rate increases (w_{l_t}), which in turn, will decrease wage rate for human capital (w_{h_t}) (follows from Lemma 1). An increase in (p_t) will reduce the profitability of output production from natural resource-intensive (NRI) technology, Y_t^R. This will reduce the output produced by NRI technology. Similarly, a decrease in w_{h_t} will increase the profitability of output produced from human capital intensive (HCI) technology, Y^H. This will increase the output produced from HCI technology.

Next, let us see how the natural resource that young agents will buy from first-generation adult agents of period t-1 changes when investment in education increases. Substituting the value of Y_t from equation (27) and p_t from equation (15) into equation (26), we get,

$$N_{t-1} =$$

$$\frac{1}{2}\left[\frac{\varepsilon Y_{t-1}}{p_{t-1}} - \frac{(1-\varepsilon)\left[\frac{\theta(1-\theta)^{\frac{1-\theta}{\theta}} A^{H\frac{1}{\theta}} \psi V_{t-1} l + (p^R A^R X_t)^{\frac{1}{\theta}} l}{(p^R A^R X_t)^{\frac{1-\theta}{\theta}}}\right]}{\frac{(p^R A^R X_t)^{\frac{1}{\theta}} l - ((1-\theta)A^H)^{\frac{1}{\theta}} \psi V_{t-1} l}{(p^R A^R)^{\frac{1-\theta}{\theta}} (X_t)^{\frac{1}{\theta}}}}\right]$$

...(34)

Differentiating the above equation with respect to V_{t-1}, we

$$\frac{\partial N_{t-1}}{\partial V_{t-1}} = \frac{-(1-\varepsilon)\theta(1-\theta)^{\frac{1-\theta}{\theta}} A^{H\frac{1}{\theta}}\psi(p^R A^R X_t)^{\frac{1}{\theta}} - (1-\varepsilon)X_t(p^R A^R X_t)^{\frac{1}{\theta}}((1-\theta)A^H)^{\frac{1}{\theta}}\psi}{\left((p^R A^R X_t)^{\frac{1}{\theta}} l - ((1-\theta)A^H)^{\frac{1}{\theta}} V_{t-1} l\right)^2} \quad ...(35)$$

$$\frac{\partial N_{t-1}}{\partial V_{t-1}} < 0, \text{ as } 0 < \varepsilon, \theta < 1; p^R, A^R, X_t, A^R > 0 \text{ and } V_{t-1} > 0$$

Proposition 3: In this OLG economy, investment by the parents in young agent's education (V_{t-1}) will always lower the young's reliance on natural resource stock (N_{t-1}) (see equation (35) for proof). This follows from the fact that in equilibrium, a more educated adult will tend to be less dependent on natural resources for earning their income in the second period (t).

Solving for Equilibrium Consumption, Resource Use, and Associated Price

Next, we will derive the solution for V_t, C_{t-1}^Y and C_t^A substituting the value of N_{t-1} from equation (26) into (24), we get V_t as:

$$V_t = \frac{(1-\beta)}{2}\left((1-\mathcal{E})Y_t + \frac{\mathcal{E}p_t Y_{t-1}}{p_{t-1}}\right) \quad ...(36)$$

Equation (36) states that investment incurred by an adult agent in their child's education dependspositively on the weight assigned by the adult agent to investment in their child's education$(1-\beta)$, positively on the transfer that the adult receives when young from their parents ($\mathcal{E} Y_{t-1}$), positively on the total wage income that the adult agent earns from their human capital/skilled labor and unskilled labor (Y_t), positively on the price that she/he receives from selling the natural resource in period t relative to the price at which she/he buys it from the adult agent in period t-1, $p_t/p_t - 1$. All of which are plausible directions of impact.

Next, the consumption of the young, C_{t-1}^Y, is solved by rearranging equation (19), which yields that

$$C^Y{}_{t-1} = \mathcal{E}Y_{t-1} - p_{t-1}N_{t-1}$$

Further, substituting N_{t-1} from equation (26) into the above, we get that,

$$C_{t-1}^Y = \frac{1}{2}\left(\mathcal{E}Y_{t-1} + \frac{p_{t-1}}{p_t}(1-\mathcal{E})Y_t\right) \quad ...(37)$$

Equation (37) implies that the consumption of the young agent in period t-1 depends positively on the transfer that she/he receives from the adult agents or their parents ($\mathcal{E} Y_{t-1}$), positively onthe total wage income that the adult agent will earn from their human capital/skilled labor and unskilled labor (Y_t), positively on the price at which they buy natural resource from an adult agent in period t-1 relative to the price that they receive from selling natural resource stock in period t $(\frac{p_{t-1}}{p_t})$.

Further, the consumption of the adult is derived by rearranging equation (20) and substituting N_{t-1} from (26) and V_t from (36) into equation (20), we get that

$$C_t = \frac{\beta}{2}\left((1-\mathcal{E})Y_t + \frac{\mathcal{E}p_t Y_{t-1}}{p_{t-1}}\right) \quad ...(38)$$

Equation (38) states that the consumption by an adult in period t depends positively on the weight assigned by a young agent to the future level of consumption as opposed to the investment in theirchild's education (β), positively on the transfer she/he receives from their parents when young ($\mathcal{E} Y_{t-1}$), the total wage income that adult agent will earn from their human capital and unskilledlabor (Y_t), and the price that she/he receives from selling the natural resource in period t relative to the price at which they buy it from the adult agent in period t-1, $\frac{p_t}{p_{t-1}}$.

Further, from equation (15), we have

$$p_t = p^R A^R l - \frac{((1-\theta)A^H)^{\frac{1}{\theta}}\psi V_{t-1} l}{(p^R A^R)^{\frac{1-\theta}{\theta}}(X_t)^{\frac{1}{\theta}}} \quad ...(39)$$

From equation (39), we can say that whenever $V_{t-1} > 0$, in the above equation $p_t > 0$ when the following holds.

$$X_t > \frac{(1-\theta)A^H(\psi V_{t-1})^{\theta}}{(p^R A^R)} = \bar{X} \quad ...(40)$$

Where $\overline{X}$ is the threshold level of resource extraction that depends positively on the educational expenditure incurred by his/her parents, V_{t-1}. Further, from equation (39), we can say that,

$$p_t = 0 \quad \text{when } X_t = \frac{(1-\theta)A^H(\psi V_{t-1})^{\theta}}{(p^R A^R)} = \bar{X} \quad ...(41)$$

From equation (41), one can infer that the natural resource stock extracted, X_t, for production of natural resource-intensive output, Yt^R, depends positively on the price that the firm will receive from natural resource-intensive production, p^R, positively on the productivity of technology, A^R, as well as the investment in the education of the young agent made by the parents, V_{t-1}.

Combining the above two cases (that is, when $p_t = 0$ and $p_t > 0$), the solution for the price of the resource, p_t, turns out to be:

$$p_t = \begin{cases} 0, & X_t = \bar{X} \\ p^R A^R l - \frac{((1-\theta)A^H)^{\frac{1}{\theta}}\psi V_{t-1} l}{(p^R A^R)^{\frac{1-\theta}{\theta}}(X_t)^{\frac{1}{\theta}}}, & X_t > \bar{X} \end{cases} \quad ...(42)$$

The above equation states that the extracted resource stock (X_t) used in the production of the NRI sector increases whenever the extracted resource stock, X_t, increases beyond a certain threshold level $\overline{X}$, The price of the extracted resource stock remains at 0 if $X_t \leq \bar{X}$, where $\bar{X}$ is given by equation (41). We rule out the case where $p_t = 0$, as young will always want a positive price when they sell natural resource to firms where natural resource is assumed to be an essential input in the production of the NRI sector. The extracted resource stock depends on the investment in the education of the young agent made by the parents (V_{t-1}) (see equations 40 and 41). When $X_t > \overline{X}$ As the investment made by parents in the education of young agents increases, the price of natural resource stock decreases (see Lemma 2). Whenever $V_{t-1} = 0$, the $p_t = p^R A^R l$ (from (39)) and $V_{t-1} > 0$, the p_t is given by equation (39). From Lemma 2, we can say that as the extracted resource stock used in the production of the NRI output increases, the price of extracted resources increases. Hence, the profitability of production from NRI technology decreases due to an increase in the price of the extracted natural resource. Whenever $X_t > \overline{X}$ The increase in the price of extracted resources due to the increase in extraction (see equation (17)) will be more than offset by the decrease in the price of extracted resources due to the increase in investment in young agent education made by their parent(see equation (16)). We can say that higher educational attainment by an individual means she/he entails a lower dependence on natural resources to increase their income. The more educated the individual, the more options available to her/him to earn their livelihood by sustainable means.

Proposition 4: When the extraction of natural resources exceeds a certain minimum threshold level ($X_t > \overline{X}$), such that $p_t > 0$, the price that an individual receives from selling its natural resource stock to a firm gets lowered (42) as the investment in education made by the young agent (V_{t-1}) increases (16). This implies that the more educated the individual is, the less dependent on natural resources for earning his/her income (proof follows from Lemma 2).

Next, we analyze the effect of investment in the education of an agent by their parents (V_{t-1}) as well as the level of extracted natural resource (X_t) on the aggregate income of the adult agent (Y_t).

For this, we differentiate equation (27) with respect to V_{t-1}, to get:

$$\frac{\partial Y_t}{\partial V_{t-1}} = \frac{\theta(1-\theta)^{(1-\theta)/\theta} A^{H^{1/\theta}} \psi l}{(p^R A^R X_t)^{(1-\theta)/\theta}} > 0 \quad ...(43)$$

$$\frac{\partial Y_t}{\partial X_t} = \frac{1}{\theta}\frac{(p^R A^R)^{1/\theta}(X_t)^{1-\theta/\theta} l}{(p^R A^R X_t)^{(1-\theta)/\theta}} - \frac{(1-\theta)}{\theta}\left(\frac{\theta(1-\theta)^{\frac{1-\theta}{\theta}} A^{H^{\frac{1}{\theta}}} \psi v_{t-1} l_{t-1} + (p^R A^R X_t)^{\frac{1}{\theta}} l}{(p^R A^R)^{\frac{1-\theta}{\theta}}(X_t)^{\frac{1}{\theta}}}\right)$$

$$\frac{\partial Y_t}{\partial X_t} = \frac{1}{\theta}(p^R A^R l) - \left(\frac{(1-\theta)^{\frac{1}{\theta}} A^{H^{\frac{1}{\theta}}} \psi V_{t-1} l}{(p^R A^R)^{\frac{1-\theta}{\theta}}(X_t)^{\frac{1}{\theta}}} + \frac{(1-\theta) p^R A^R l}{\theta}\right)$$

$$\frac{\partial Y_t}{\partial X_t} = (p^R A^R l) - \left(\frac{(1-\theta)^{\frac{1}{\theta}} A^{H^{\frac{1}{\theta}}} \psi V_{t-1} l}{(p^R A^R)^{\frac{1-\theta}{\theta}}(X_t)^{\frac{1}{\theta}}}\right)$$

This follows from equation (39), which states that

$$\frac{\partial Y_t}{\partial X_t} = p_t \quad ...(44)$$

Equation (44) shows that the increase in the income of an adult due to an increase in extracted resources depends positively on the price the adult agent receives by selling the natural resource stock to the firm in the NRI technology sector. However, according to (16), the price that an individual receives from selling natural resources to the firm falls as the investment in a young agent's education by their parent rises. The proposition that follows from above is as follows.

Proposition 5: As the investment in education by parents, V_{t-1}, increases, the aggregate earned income of the adult increases, according to (43), but the income earned from natural resource stock declines, according to (44). This is because, from equation (16), we get that the price that the adult receives from selling natural resource stock declines when V_{t-1} increases.

Intuitively, as the investment made by an adult agent in their child's education increases, V_{t-1}, increases the accumulation of human capital increases (as from (2), $H_t = \psi V_{t-1} l$). This, in turn, implies that young agent of period t-1 can earn wage income by working in the HCI sector from boththeir skilled labor/human capital as well as unskilled labor components. The young agents will supply unskilled labor ($s_t l$) and human capital (H_t) to the HCI sector. From equation (45), we know that whenever $V_{t-1} > 0$, $s_t l > 0$, and by assumption, we know that $w_{h_t} > w_{l_t}$. Hence, an individual's aggregate wage income will always be higher whenever an investment in their human capital is made by their parent. Moreover, the increase in total wage income (Y_t) due to the extraction of resources (X_t) is equal to the price that they will receive from selling the natural resource stock to the firm (which is p_t) (see equation (44)), which in turn, declines whenever the investment in human capital (V_{t-1}) increases (see equation (16)). The more educated individual prefers to work in the HCI sector, due to which the extraction of resources and its price decreases.

Next, from equation (13), we have

$$s_t l = \left(\frac{(1-\theta)A^H}{p^R A^R X_t} \right)^{1/\theta} H_t \qquad \text{...(45)}$$

Where $H_t = \psi V_{t-1} l$. That is, the demand for unskilled labor in the HCI technology sector (that is $s_t l$) depends positively on the share of unskilled labor in this sector (1-θ) and technological productivity of the HCI sector relative to the NRI sector (A^H/A^R), negatively on the wage rate of unskilled labor ($p^R A^R X_t = w_{L_t}$ (from expression in (11)) and investment in education made by parents (V_{t-1}). The unskilled wage income depends on the extracted resource stock (X_t); when X_t increases, the unskilled wage income in the NRI sector also increases. When $V_{t-1} = 0$, $s_t l = 0$, and the adult relies only on NRI technology for earning income (that is $p^R A^R X_t l = w_{l_t} l$), she/he will earn unskilled wages by working in the NRI sector (see equation (29)). However, when $V_{t-1} > 0$, $s_t l > 0$, in comparison, the individual will earn a higher income than the case where $V_{t-1} = 0$, which will be through sustainable means of production [again from equation (29)]. Thus, we have,

Proposition 6: The diversification of the income-earning source of the individual from complete reliance on the NRI sector ($s_t l = 0$) to partial reliance requires a certain positive amount of investment in the education of the young agent by the parent (this can be seen in equation (27)). From equation (28), it can be seen that when $V_{t-1} = 0$, $Y_t = w_{l_t} l$, the adult agent will earn their income only from unskilled labor (l). When $V_{t-1} > 0$, $s_t l > 0$ from (45), $Y_t = w_{h_t} H_t + w_{l_t} l$, individual will earn income from both skilled labor/human capital and unskilled labor [see equation (21)].

Having derived the equilibrium solutions for young agent consumption (C^Y_{t-1}), adult agent consumption (C^A_t), expenditure to be made by adult agents in their child's education (V_t), natural resource endowment to buy from the adult agent (N_{t-1}), unskilled labor wage (w_{l_t}) and human capital wage income (w_{h_t}). As is commonly done in models of growth economics, we areinterested in characterizing the steady-state values of the variables. We now characterize the long-run steady-state equilibrium for this stylized overlapping generations (OLG) economy.

STATIONARY EQUILIBRIUM

We focus on balanced growth paths, i.e., paths that are characterized by constant growth rates of all variables. The reason for this choice is that balanced growth paths are the only kind of path that can generate long-run growth in the economy. We analyze those paths defined as follows:

Steady states are time-invariant sequences defined by $Y_{t-1} = Y_t = \bar{Y}$, $V_{t-1} = V_t = \bar{V}$, $C^Y_{t-1}\ C^A_t = \bar{C}$, $N_{t-1} = N_t = \bar{N}$ and $p_{t-1} = p_t = \bar{p}$.

Substituting $Y_{t-1} = Y_t = \bar{Y}$ and $p_{t-1} = p_t = \bar{p}$ in equation (36), we will get the steady-state value of investment in education as given as follows. We have,

$$\bar{V} = \frac{(1-\beta)}{2}\left((1-\mathcal{E})\bar{Y} + \frac{\mathcal{E}\bar{P}\bar{Y}}{\bar{P}} \right) = \frac{(1-\beta)}{2}\bar{Y} \qquad \text{...(46)}$$

Equation (46) represents the steady-state value of an investment in the education of the young agent. $\overline{(V)}$ depends on the weight put by the adult agent on the investment in the child's education $(1-\beta)$ and half of the steady-state value of total wage income earned by the adult agent.

Next, we will solve for $\bar{Y}$ from equation (27), substituting, $Y_t = \bar{Y}, V_{t-1} = \bar{V}, X_t = \bar{X}, l_{t-1} = l_t = \bar{l}$ in the above equation (27), we get the steady-state value of income earned by the individual to be:

$$\bar{Y} = \frac{\theta(1-\theta)^{(1-\theta)/\theta} {A^H}^{1/\theta} \psi \bar{V} \bar{l}}{(P^R A^R \bar{X})^{(1-\theta)/\theta}} + P^R A^R \bar{X} \bar{l}$$

Substituting the value $\overline{X}$ of from equation (41) into the above equation and using $V_t - 1 = \overline{(V)}$ we get that,

$$X_t = \frac{(1-\theta)A^H(\psi\bar{V})^\theta}{(P^R A^R)} = \bar{X}$$

$$\bar{Y} = \frac{\theta(1-\theta)^{(1-\theta)/\theta} A^{H^{1/\theta}} \psi \bar{V} \bar{l}}{(P^R A^R \frac{(1-\theta)A^H(\psi\bar{V})^\theta}{(P^R A^R)})^{(1-\theta)/\theta}} +$$

$$P^R A^R \frac{(1-\theta)A^H(\psi\bar{V})^\theta}{(P^R A^R)} \bar{l}$$

$$\bar{Y} = \theta A^H(\psi\bar{V})^\theta \bar{l} + (1-\theta)A^H(\psi\bar{V})^\theta \bar{l}$$

$$\bar{Y} = A^H(\psi\bar{V})^\theta \bar{l} \quad ...(47)$$

Equation (47) indicates that the long-run steady-state value of the income earned by an individual depends positively on the steady-state level of expenditure on education $(\overline{V})$, the productivity of human capital-intensive technology (A^H), steady-state unskilled labor ($\bar{l}$), the share of human capital in human capital-intensive output production (θ) and the productivity of the human capital accumulation (ψ).

Substituting the value of $\bar{Y}$ from equation (47) into equation (46), we get

$$\bar{V} = \frac{(1-\beta)}{2}^{\frac{1}{(1-\theta)}} (A^H \bar{l})^{\frac{1}{(1-\theta)}} (\psi)^{\frac{\theta}{1-\theta}} \quad ...(48)$$

Substituting $V_{t-1} = \bar{V}$, from (47) and $l_{t-1} = \bar{l}$, in equation (2), we get human capital accumulation by the young agent as:

$$\bar{H} = \frac{(1-\beta)}{2}^{\frac{1}{(1-\theta)}} (A^H \bar{l})^{\frac{1}{(1-\theta)}} (\psi)^{\frac{1}{1-\theta}} (\bar{l})^{\frac{(2-\theta)}{(1-\theta)}} \quad ...(49)$$

Equation (49) indicates that investment in human capital depends on the positive productivity of human capital-intensive technology (A^H), and unskilled labor. $\bar{l}$, share of human capital relative to the share of unskilled labor in HCI output production ($\theta/1-\theta$) and the productivity of the human capital accumulation (ψ), the weight given by adult agent to investment in child's education ($1-\beta$). From this, the following proposition follows.

Proposition 7: Given $A^H, \bar{l}, \theta/1-\theta$ and ψ, a long-run steady-state equilibrium level of the human capital accumulation are higher, higher is the weight put by the parent on the child's education [the proof for this result follows from equation (49)].

Substituting the value of $N_{t-1} = N_t = \bar{N}$ and $X_t = \bar{X}$ in equation (8), we get

$$\bar{N} = \frac{\eta}{\delta} \bar{X}$$

Substituting the value of $\overline{X}$ from (41) in the above equation, we get

$$\bar{N} = \frac{\eta}{\delta} \frac{(1-\theta)A^H(\psi\bar{V})^\theta}{(P^R A^R)}$$

Substituting the value $\bar{V}$ of from equation (48) in the above equation, we get

$$\bar{N} = \frac{\eta}{\delta} \frac{(1-\theta)A^H \left(\psi \frac{(1-\beta)}{2}^{\frac{1}{(1-\theta)}} (A^H \bar{l})^{\frac{1}{(1-\theta)}} (\psi)^{\frac{\theta}{1-\theta}}\right)^\theta}{(P^R A^R)}$$

$$\bar{N} = \frac{\eta}{\delta} \frac{(1-\theta)(A^H)^{\frac{1}{(1-\theta)}} (\psi)^{\frac{\theta}{1-\theta}} \frac{(1-\beta)}{2}^{\frac{\theta}{(1-\theta)}} (\bar{l})^{\frac{\theta}{(1-\theta)}}}{(P^R A^R)} \quad ...(50)$$

Equation (50) indicates that the higher the steady-state value of natural resource stock, the higher the weight assigned by an adult agent on the investment in their child's education ($1-\beta$), higher isthe productivity of human capital-intensive technology (A^H), higher is the share of human capital relative to the share of unskilled labor in human capital-intensive output production ($\theta/1-\theta$), the lowerthe price of NRI output (p^R), and lower is the productivity of NRI technology (A^R).

Proposition 8: Given $A^H, \frac{\theta}{1-\theta}$, and P^R, the steady-state value of natural resource stock is higher, higher is the weight given by adult agents to investment in a child's education ($1-\beta$) (the formal proof follows from equation (50)).

Substituting the value of $Y_{t-1} = Y_t = \bar{Y}$ and $p_{t-1} = p_t = \bar{p}$ In equation (37), we get that,

$$C_{t-1}^Y = \frac{1}{2}\left(\mathcal{E}\bar{Y} + \frac{\bar{P}}{\bar{P}}(1-\mathcal{E})\bar{Y}\right) = \frac{1}{2}\bar{Y} \quad ....(51)$$

Substituting the value of $Y_{t-1} = Y_t = \bar{Y}$ and $p_{t-1} = p_t = \bar{p}$ In equation (38), we get

$$C_t^A = \frac{\beta}{2}\left((1-\mathcal{E})\bar{Y} + \frac{\mathcal{E}\bar{P}\bar{Y}}{\bar{P}}\right)$$

$$= \frac{\beta}{2}\bar{Y} \quad ...(52)$$

$$\frac{C_{t-1}^{Y} - C_{t}^{A}}{C_{t-1}^{Y}} = \frac{\frac{1}{2}\bar{Y} - \frac{\beta}{2}\bar{Y}}{\frac{1}{2}\bar{Y}} = (1-\beta) \quad ...(53)$$

Equation (53) indicates that the consumption growth rate depends on the weight given by adult agents to investment in education $(1 - \beta)$.

Proposition 9: In this OLG economy, the continuous growth in consumption requires that individuals must assign a certain weight or give some importance to human capital accumulation ($\beta > 0$) (the proof follows from equation (53)). This completes the characterization of our stylized OLG economy.

CONCLUSION

In this chapter, we have developed a theoretical model to analyze the role of human capital accumulation in the adoption of natural resource technology of production. For this purpose, we extend the model developed by Ikefuji & Horii as our analytical framework. This research goes beyond the Ikefuji & Horii work by assuming that an individual derives utility by making an investment in their child's education. We have considered an overlapping generation model, where each individual is alive for two time periods, t-1 and t. She/he is born in period t-1 and is called the young agent; in period t, the individual becomes an adult and exists in the system. During a young age, an individual born in period t-1 does not work but only consumes and buys ownership rights of the natural resource out of the transfer that she/he receives from their parents. When young, the individual also benefit from the parent's education spending and builds their human capital that becomes available to him during working age in period t. We assume that an individual does not work when he is young. During the t-1 period, young agents are endowed with a certain ability to learn, which they devote entirely to learning, which, in turn, leads to human capital accumulation. During period t, an adult agent receives income from unskilled labor and human capital that they sell to the firm. Adult agent in period t also devotes an exogenous part of their income as transfer to their children for the latter's investment in education that would enable the young agent in human capital accumulation. This helps us characterize the conditions under which individuals will invest in human capital accumulation and adopt sustainable technology of production instead of natural resource-intensive technology of production.

As the main results of theoretical analyses, we find that as the investment in a child's education by the parent increases, the total earned income of the individual increases, but the income earned from the natural resource stock endowment declines. A more educated individual is less dependent onnatural resources for earning their income. If the investment in education is zero, then the individual has no option but to rely completely on natural resource-intensive technology for earning their livelihood. We also find that as the investment in education increases, the output produced from sustainable technology rises, and the output produced from natural resource-intensive technology falls. Similarly, as the extraction of natural resource stock increases, the aggregate output produced from sustainable technology decreases, and the aggregate output produced from natural resource-intensive technology increases. We further find that sustainable consumption growth requires that individuals assign a certain positive weight to investmentin their child's education. A long-run steady-state equilibrium level of human capital accumulation is higher; higher is the weight put by the parent on the child's education.

The steady-state value of income earned by an individual depends on the investment in education made by their parents. The long-run steady-state value of the income earned by an individual depends positively on the expenditure on education, the productivity of human capital-intensive technology, unskilled labor, the share of human capital in HCI output production, and the productivityof human capital accumulation. The steady-state value of natural resource stock is higher whenanindividual gives higher importance to education investment relative to consumption. The steady-state value of natural resource stock is higher, higher is the weight assigned by an adult agent on the investment in their child's education, higher is the productivity of human capital-intensive technology, higher is the share of human capital relative to the share of unskilled labor in HCI output production, lower is the price of NRI output, and lower is the productivity of NRI technology. In this overlapping generation economy, sustainable consumption growth requires that individuals assign a certain weight or give some importance to human capital accumulation. This follows from the fact that the long-run steady-state value of the income earned by an individual depends positively on the expenditure on education.

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