DEPARTMENT OF ECONOMICS

The end of subsistence farming: Growth dynamics and investments in human and environmental capital in rural Ethiopia

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Abstract

In settings characterized by weak human capital and agricultural land degradation, investments in human capital formation and land conservation can be key candidates for triggering sustained economic growth. In this study, based on insights from growth literature and models of economic transformation, we develop a framework to examine the dynamic interactions between income, human and natural capital in rural Ethiopia. In addition, the trade-offs and complementarities of economic and environmental policies in terms of their impact on growth, investments in human capital formation and land conservation are assessed. The study underscores the centrality of interconnectedness and reciprocal influences between growth and investments in human and natural capital in understanding the long-run implications of policy reforms. Development interventions that are crucial for achieving broad-based and sustainable improvements in household income, human and natural capital are identified, which have wider implications for settings sharing similar socioeconomic characteristics.

Key words: Ethiopian, Growth, human capital, natural capital, land degradation, sustainable development

1. Introduction

Agricultural land degradation in the form of soil erosion and soil fertility mining have been recognized as major type of land degradation, especially in developing countries due to over-cultivation and limited or absence of investment in land improvements (Lufumpa 2005; Hurni, 1988; Bekele and Holden, 1999; Nkonya *et al*., 2008). Empirical evidence (e.g. Chandran, 2004) estimated that land degradation reduces the annual agricultural gross domestic product of Africa by about 3 percent, and the problem is severe, especially in sub-Saharan Africa (SSA) where the present value of expected agricultural production loss due to land degradation is as high as 18 percent (Bojö, 1996; Scherr,2000).[2] As a consequence, average cereal yields have not shown any significant improvement and per capita food production has declined since the 1980s (Hanjra *et al*., 2009; Muchena *et al*., 2005).

Low human capital development has also contributed to the problem. Despite efforts to expand education, the literacy rate is still very low in Africa. In particular, SSA is a home for the majority of illiterate adults (UNESCO, 2007). In the absence of education and training, farmers find it difficult to move beyond longstanding traditional farming practices.

In agrarian economies, livelihood improvements and poverty reduction rest mainly on boosting agricultural productivity (Timmer, 1997; Ravallion and Chen, 2004), which itself depends, among others, on investments in human and natural capital (e.g. agricultural land and soil conservation. Since off-farm employment is limited, revenue from crop sale is the major means of financing almost all sorts of expenditures, suggesting the centrality of the reciprocal effect of farm income on investments in human capital formation and land conservation. This suggests that agriculture's importance to livelihood improvement goes far beyond its direct impact on farmers' incomes (DIFD,2005).

This paper positions itself in this context and we take one of the villages in rural Ethiopia as a case study, a country ravaged by severe land degradation, poverty, weak human capital and food insecurity. It is argued that sustainable livelihood improvements requires a careful analysis of the potential complementarities and trade-offs between economic, social and environmental objectives. This underscores the need for joint appraisals of growth, investment in human capital and land conservation. The critical interactions of these issues do not appear to have received much attention in the literature. While the growth dynamics have often been researched in depth at an aggregate level, the social contexts and environmental conditions which shape the

[2] For a review of the costs of land degradation, see Yesuf *et al*., (2005) and Nkonya *et al* (2008)

growth process and influence lives of communities are not sufficiently understood. Interconnectedness and reciprocal influences between growth and investments in human and natural capital are central to understanding the long-run implications of development interventions, especially at micro or village level where the real impacts of policies can be felt. Specifically, the study addresses the following questions: (i) What are the quantitative trade-offs between sustainable economic growth and the use of natural resources? (ii) How do investments in human and environmental capital affect the long-term growth rate? (iii) How do economic and environmental policies affect the long-run growth path? The study also seeks to determine the most promising exit paths that expedite structural transformation in rural Ethiopia.

The rest of the paper is organized as follows. While Section 2 provides an overview of related literature, Section 3 deals with conceptual framework and model formulation. In Sections 4 and 5, we examine, respectively, income, and consumption and saving dynamics. Model calibration and policy simulations are presented in section 6. Section 7 concludes.

2 Conceptual background and a review of relevant literature

Figure 1 presents a simple conceptual framework how socioeconomic factors in general and human and natural capital in particular impact on household income, and how the latter, in turn, influences investments in the two forms of capital. We use this framework to organize our review of the relevant literature and to develop the theoretical as well as empirical models. There are two pathways of improving household income: investments in human and natural capital, especially land conservation.

In rural settings, agricultural productivity and hence farm income can be enhanced if human and environmental capital are improved simultaneously. It is argued that since land is the main factor for agricultural production in rural settings, land degradation hurts the productivity of land as the quality of land diminishes over time. Land degradation can be mitigated by investing resources such as labour in land conservation activities. There are different channels through which increased land care affects long term growth. Notice that if more resources are allotted to land care activities, the less are available for other activities such as schooling, and this can negatively affect the long-term growth. Similarly, human capital can be improved through continuous investment in education. The more resources are channelled to schooling, the less will be available for land conservation. The central thrust of this paper is sustained growth is possible since physical limits to growth are usually more than offset by the accumulation of human and natural capital through allocation of resources to growth generating activities. Thus sustainable pathways out of the cycle of subsistence livelihood thereby triggering rural transformation are likely to be strongly connected to improvements in human and natural capital.

2.1 Income growth and human capital

Since the pioneering contributions of Schultz (1961), Becker (1964), and Welch (1970), the linkage between growth and human capital accumulation has received a lot of attention from policy makers, academia and donors alike. Following the new growth theory in the 1980s (Lucas, 1988, 1993; Romer, 1986, 1990) has been a key factor for differences in growth among countries. In the growth literature, two channels have been identified how human capital influences growth. It directly enters into the production activity as a factor of production, and hence accumulation of human capital can contribute to the growth of output or income (Easterlin, 1981). It also helps to facilitate, adopt and diffuse new technologies, and hence generates output or income growth (Freir-Seren, 2001; Aghion and Howitt, 1998; Hall and Jones, 1999). At microeconomic level, for instance, education raises agricultural productivity by improving the utilization of existing farm inputs thereby increasing household income (Appleton and Balihuta, 1996; Hanjra *et al*., 2009). Overall, human capital formation can influence growth by increasing the income of households and improving the productivity of other factors of production (Fatchamps and Quisumbing, 1999).

On the empirical front, the impact of human capital on growth is inconclusive both at aggregate and microeconomic level. A number of empirical studies at an aggregate level, especially in cross-country studies (Mankiw, Romer, and Weil, 1992; Barro and Sala-i-Martin, 1995; Islam, 1995; Oketch, 2005; Murthy and Chien, 1997; Appiah and McMahon, 2002; Barro, 2000; Gyimah-Brempong *et al*., 2006; and Grier, 2005) provide a strong support for the claim about the positive role of human capital, especially education in enhancing and sustaining economic growth. In other studies such as Kyriacaou (1991), Benhabib and Spiegel (1994), Nonneman and Vanhoudt (1996), Lau *et al*. (1991), Dasgupta and Weale (1992) and Pritchett (1995) the variable measuring human capital does not enter significantly in explaining growth.

The microeconomic evidence on the role of human capital, especially in raising agriculture productivity and hence household income, is also far from conclusive. While a number of studies (e.g. Fatchamps and Quisumbing, 1999; Battese and Coelli, 1995) report no significant relationship between human capital and crop and livestock productivity, other studies (e.g. Kurosaki and Fafchamps, 2002; Kurosaki and Khan, 2004; Yamazaki and Resosudarmo, 2007; Arega and Manyong, 2007**;** Lockheed *et al*., 1980) demonstrate a positive and significant effect of human capital on farm productivity.

Three observations can be made regarding the linkage between growth and human capital accumulation. First, the use of different proxies for human capital (e.g. average educational attainment, share of education expenditure, etc) can be a source of the contradicting empirical findings on the linkage. Second, differences in socioeconomic set up (e.g. advanced versus backward economies, modernized versus traditional, etc) can also be another source for the divergent empirical evidence. Third, the vast literature on growth does not take into account the reverse impact of growth on human capital accumulation. In other words, the extent of human capital accumulation depends on the level of income achieved in the economy, i.e. *ceteris paribus*, economies (or households) that have higher income tend to accumulate large human stock while poor countries lack the resources to invest in human capital development (Romer, 1990; Hall and Jones, 1999). Such conceptualization of the linkage is useful in understanding the contribution of human capital to growth by taking the influence of growth on human capital accumulation. At microeconomic level, for instance, the effect of growth on human capital formation is diverse and mixed, especially in agrarian economies where household income crucially depends on the size and quality of agricultural land (see, for instance, Bhalotra and Heady, 2003; Woldehanna *et al*., 2005; Cockburn and Dostie, 2007; Admassie, 2003).

Therefore, it is not clear, theoretically or empirically, to what extent household income, which depends chiefly on the quality and size of agricultural land, has an effect on investment in human capital or the reverse, especially in rural settings.

2.2 Income growth and investment in natural capital

In agrarian economies, growth is largely determined by the performance of the agricultural sector. Intensive use of land for agricultural production and some unsustainable farming practices (e.g. absence of fallowing, crop rotation, etc) have contributed to a high degree of land degradation (Kruseman and van Keulen, 2001; Barbier, 2001; Bekele *et al*., 2005).[3] In an effort to improve the quality of agricultural land, farm households have taken efforts to mitigate the problem through investment in land improvement technologies.

In the literature on technology adoption or dis-adoption, especially in developing countries, there is a proliferation of empirical evidence regarding the determinants of land-related investments (Bekele *et al*., 2005 and Anley *et al*. (2007) for Ethiopia; Nkonya *et al*., 2004 for Uganda; Place *et al*., 2002 for Kenya; Mekuria and Waddington, 2002 for Zimbabwe; de la Briere, 2001 for Dominican Republic; Bravo-Ureta *et al*., 2006 for El Salvador), and the results are both varied and diverse. Similarly, the empirical

[3] An estimated 50% of all crop land is reported to face serious soil degradation and erosion (Demeke and Hunde, 2004; FAO, 1986).

record regarding the effect on agricultural productivity and household income of investment in land conservation is also abundant under different socioeconomic settings. For instance, studies for Uganda (Nkonya *et al*., 2004 and Pender *et al*., 2004); for Rwanda (Byiringiro and Reardon, 1996) for Philippines (Shively, 1998); for Lesotho (Kaliba and Rabele, 2004); and for Ghana (Diao *et al*., 2007) uncover the positive effect of land-related investments on agricultural productivity and household income. In Ethiopia, studies on land and soil conservation (Pender and Gebremedhin, 2007; Gebremedhin *et al*., 1998; Benin, 2006; Holden *et al*., 2001; Bekele, 2003) show a similar story: land conservation improves agricultural productivity.[4] The central message of the diverse empirical findings indicates that in natural resource-dependent economies, sustainable economic growth depends on the level and quality of natural resources, and the condition of natural resources such as agricultural land depends, in turn, on the level of investment necessary to maintain the quality of the resources.

Overall, two observations are in order. First, although improved natural resource management via investment in natural resources is considered as a prerequisite for sustaining agricultural growth in agrarian economies, the literature on the reverse impact of improved income or growth on investment in natural resources such as land conservation is scanty. The absence of feedback effect may distort the contribution of land conservation to growth. Second, the role of human capital has often been assumed exogenous while it is influenced by investment in natural resources through income. Thus, such complex inter-linkages have received minimal attention in the current literature, and recognizing simultaneity effects help to analyze both the direct and indirect contribution of each of the elements considered. In what follows, based on insights from the literature, we develop a theoretical model in order to highlight these linkages.

[4] However, Holden et al. (2001) found insignificant impacts of soil conservation technologies on land productivity.

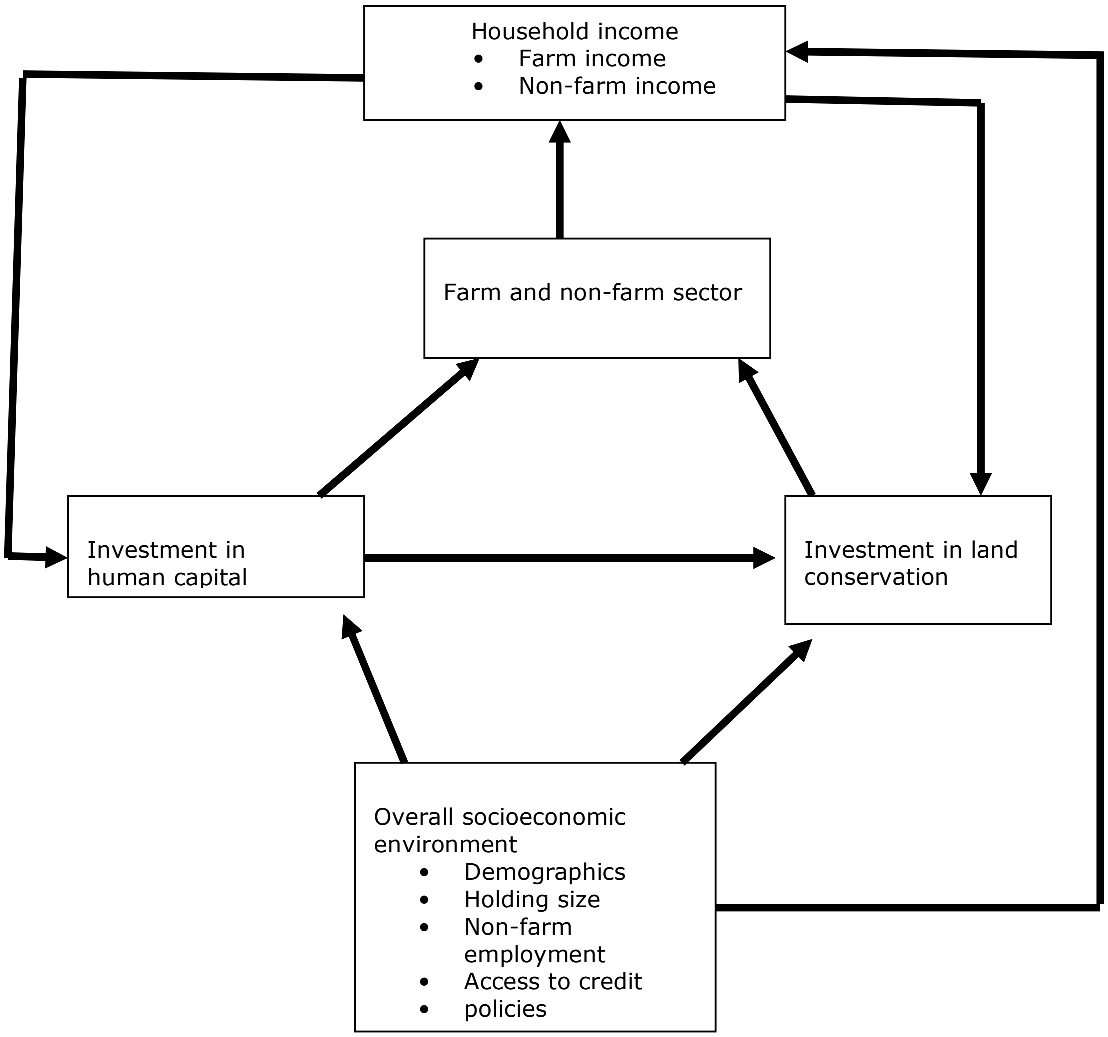

Figure 1: Linkages between income, human capital and land conservation

3 The model

We begin by developing a framework in which growth and investments in human and environmental capital are interrelated. This leads to several important, often overlooked, interrelated effects in terms of policy interventions.

3.1 Set up

Assume that the total endowment of a farm household consists of total labour net of leisure (L) which is assumed to be fixed, human capital stock (h) and natural capital, represented by total agricultural land (N). Let us denote the land quality indicator by r, and then $R \equiv rN$ is considered to be the effective agricultural land. It is assumed that only the combination of r and N matters for agricultural production. N is assumed to be fixed, and is normalized to one. Assume further that the household allocates the total labour net of leisure to farm production activities (l_a) and non-farm employment (l_f) such that:

$$L = l_a + l_f \tag{1.1}$$

3.2 The income generation function

The total income (Y) of the household consists of farm output (Y_a) and income from wage employment outside agriculture. Assume that farm output is produced using three factors of production: agricultural labour force (l_a), human capital (h) and effective agricultural land $(R \equiv r)$. Assuming no technological progress, farm income is generated by the agricultural production function of the form:

$$Y_a = F(l_a, h, r) \; with \; \frac{\partial F(.)}{\partial x} > 0 \; and \; \frac{\partial^2 F_x(.)}{\partial x^2} < 0, x = l_a, h, r \tag{1.2}$$

Assume that the income function exhibits constant returns to scale with respect to l_a, h and r together. In terms of quality-adjusted labour input (i.e. human capital augments agricultural labour force $(i.e. \, hl_a)$) the agricultural production function takes the form: $Y_a = F(hl_a, r)$. Non-farm income from wage employment (Y_f) is a product of the amount of labour engaged in the non-agricultural sector (l_f) and the wage rate (w), which is assumed to be fixed. The quantity of labour engaged outside agriculture is assumed to depend on the level of human capital as:

$$l_f = Q(h) \text{ with } ; \frac{\partial Q(.)}{\partial h} > 0 \; ; \frac{\partial^2 Q(.)}{\partial h^2} \le 0 \; ; 0 \le l_f \le L \text{ and } Q(\bar{h}) = 0 \tag{1.3}$$

where $\bar{h}$ is the minimum level of human capital. Equation (1.3) indicates that some level of education, beyond the minimum level, is required to secure employment outside agriculture.

Normalizing the output price to unity, the total income of the household is given by:

$$Y = Y_f + Y_a \Leftrightarrow Y = wQ(h) + F(l_a, h, r) \tag{1.4}$$

At every point in time, the total income of the household is allocated to consumption, C, and investments in human capital formation, I_h, and land conservation, I_r such that:[5]

$$C + I_h + I_r = Y \tag{1.5}$$

3.3 Investment in human capital formation

In the absence of investment in human capital formation, the level of human capital stock evolves according to:

$$\dot{h} = -\psi_h (h - \bar{h}) \tag{1.6}$$

where ψ_h is the depreciation rate of human capital. However, the skill deterioration does not take place indefinitely, and even in the absence of upgrading skills, there is a minimum level of human capital stock, $\bar{h}$, below which the level of human capital cannot fall (figure 2). This can be seen by solving equation (1.6) which can be expressed as: $h_t = \bar{h} + [h_0 - \bar{h}] e^{-\psi_h t}$ where h_0 is the initial level of human capital.[6]

[5] Notice that implicitly Y_a, l_a, h, r, l_f and C carry time subscripts, and the derivative of each variable with respect to time is denoted by: $\dot{x} = \frac{dx}{dt}$; $x = l_a, h, r, l_f, C$.

[6] In the absence of investment in human capital development, in the limit, h_t approaches the minimum threshold level, i.e. $\lim_{t\to\infty} h_t = \bar{h}$.

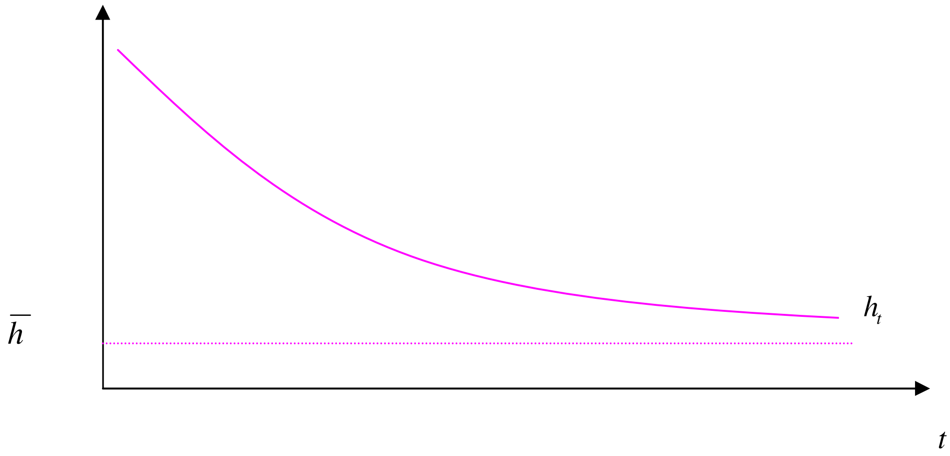

Figure 2: The dynamics of human capital accumulation

Notice that by investing the amount of goods, I_h, the human capital level can be improved.[7] Following the Solow (1956) and Swan (1956) tradition, assume that investment in human capital is determined by the size of saving rate, $s_h \in [0,1)$ such that:

$$I_h = s_h Y \tag{1.7}$$

The dynamics of human capital accumulation is thus given by:

$$\dot{h} = a_h s_h Y - \psi_h \left(h - \bar{h}\right) \tag{1.8}$$

where a_h is a scaling parameter.

3.4 Investment in natural capital

Economic activities affect the quality of land positively through investment which improves it, and negatively through extraction or depletion in the process of agricultural production. Assume that all land is used for agricultural activity and that the natural regeneration capacity of land quality is nil. This implies that if no investment is made, the land quality evolves according to:[8]

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[7] Although there are several factors influencing such decision, the expected financial return from schooling, appear to be the main candidate in affecting schooling investment decisions.

[8] If land is not used for agricultural production and is left idle, then the change in land quality will be: $\dot{r} \geq 0$. The natural growth rate of a resource such as effective agricultural land is often approximated by a logistic functional form as: $f\left(rN\right) = \chi rN\left(1 - rN/\pi\right)$ where $f\left(rN\right)$ is the natural growth rate of the effective agricultural land quality and χ is the natural regeneration rate and π is the 'carrying capacity' of a resource stock which is the maximum resource stock that can be sustained in a given environment (see, for instance, Lopeze *et al*., 2007; Brander and Taylor, 1998). If $rN = \pi$, then $f\left(rN\right) = 0$

$$\dot{r} = -\psi_r \left(r - \bar{r}\right) \tag{1.9}$$

where ψ_r and $\bar{r}$ are, respectively, the land degradation rate and minimum level of land quality. The threshold level indicates a level of land quality below which agricultural production is impossible.

Let r_0 be the initial land quality which is given. Solving equation (1.9) yields: $r_t = \bar{r} + \left[r_0 - \bar{r}\right]e^{-\psi_r t}$ (see figure 3).[9] To simplify matters, suppose that the level of investment in land improvement is determined by the level of income such that a fixed fraction, $s_r \in \left[0,1\right)$, of total household income is allotted to investment in land conservation

$$I_r = s_r Y \tag{1.10}$$

Notice that the quality of land cannot improve indefinitely following investment in land conservation as it does not exceed the 'virgin state'. We assume that this state occurs when all labour is moved to the non-farm sector as there will be no farming activity. In such settings, the land quality converges to its maximum land quality $\left(r^{\max}\right)$. Investment in land quality occurs when $r < r^{\max}$ and $l_f < L$. The dynamics of land quality can be expressed as:

$$\dot{r} = a_r s_r Y - \psi_r \left(r - \bar{r}\right) \text{ with } \bar{r} \le r \le r^{\max} \tag{1.11}$$

where a_r is a scaling parameter.

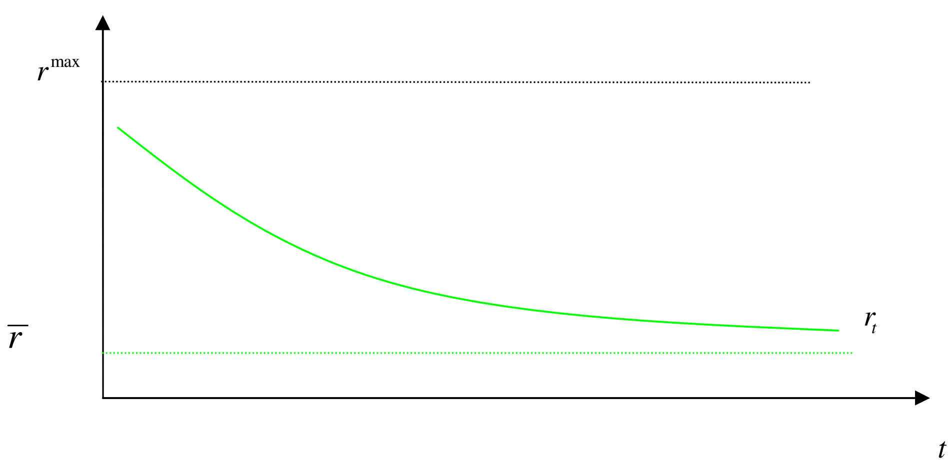

Figure 3: Trends in the effective agricultural land

[9] In the long-run r_t approaches its threshold level, i.e. $\lim_{t\to\infty} r_t = \bar{r}$.

3.5 Budget constraint

In the absence of borrowing or lending, the household budget constraint satisfies the condition that consumption does not exceed total income:

$$C \le wl_f + Y_a \tag{1.12}$$

Given the exogenous saving rates, total saving (S) equals total investment I, which consists of investment in human capital formation and land conservation, i.e.

$$I = S = \sum_i s_i Y \text{ with } i = h, r \text{ and } \sum_i s_i < 1 \quad i = h, r \tag{1.13}$$

4 Income dynamics

Given the production function, the non-farm employment functions, saving rates, and initial conditions, the dynamics of the system can be derived. As a general case, the growth of income can be expressed as:

$$\dot{Y} = w\dot{l}_f + \dot{l}_a F_{l_a}(.) + \dot{h}F_h(.) + \dot{r}F_r(.) \tag{1.14}$$

Let g_Y denote the growth rate of income, the dynamics of income growth can be expressed as follows:

$$g_Y = g_{l_f}\sigma_{l_f} + g_{l_a}\sigma_{l_a} + g_h\sigma_h + g_r\sigma_r \tag{1.15}$$

where $\begin{cases} g_x = \dfrac{\dot{x}}{x} \\ \sigma_x = \dfrac{xF_x(.)}{Y}, \quad (x = l_a, h, r) \\ \sigma_{l_f} = {}^{wl_f}\!/_{Y} \end{cases}$

Based on the general case, for the sake of brevity, two cases can be considered to examine the dynamics of the system. Total income is: (i) allocated entirely to consumption (i.e. no investment); or (iii) used for consumption or to cover two types of investment outlays, i.e. investments in human capital and land improvement.

Consider the above cases under two different environments: no wage employment opportunities (i.e. $l_f = 0$) or availability of wage employment outside agriculture (i.e. $l_f > 0$). For the sake of exposition, assume the following specific production and employment functions:

$Y_a = (l_a)^\alpha h^\beta r^\gamma$ with $\alpha + \beta + \gamma = 1$; $Q(h) = 0$; $Q(h) = bh$ *with* $b > 0$

4.1 Income dynamics under no non-farm employment

Since non-farm wage employment opportunities do not exist, agriculture is the main livelihood, and total household income depends on farm output (i.e. $Y = Y_a$). In such economic settings, agriculture bears the burden for employment creation, i.e. $l_a = L$ since $l_f = 0$.

4.1.1 The case of no investment in either form of capital $(s_h = s_r = 0)$

In the absence of investment in both forms of capital and given that $g_{l_a} = 0$, the dynamics of income growth is given by:

$$g_Y = -\psi_h \left(\frac{h - \bar{h}}{h} \right) \sigma_h - \psi_r \left(\frac{r - \bar{r}}{r} \right) \sigma_r \tag{1.16}$$

The 'drag on growth' is greater the higher is the share of income derived from land, σ_r, i.e. the negative effect of land quality deterioration will be more severe in settings where land is the main livelihood such as the study area than in areas where farm activity is a less important source of income. With a constant population and labour force, the growth rate of output is a decreasing function of the human capital depreciation and land degradation weighted by respective marginal contributions, the future generation will experience reduced income. A quick look at equation (1.16) confirms this. Notice that this situation is a typical feature of settings characterized by high discount rate or possibilities for economic growth are dependent heavily on natural resources with limited quantities of other forms of capital.

It will be interesting to see the steady state implications. In the long-run, h and r approach their respective minimum threshold levels (i.e. $h \to \bar{h}$ and $r \to \bar{r}$) such that $g_h = g_r = 0$. This implies that the steady state growth rate of income is zero, and this condition is depicted in figure 4. The steady state level of income, Y^*, is given by.[10]

$$Y_1^* = F\left(L, \bar{h}, \bar{r}\right) \tag{1.17}$$

[10] Given threshold levels of human capital and land quality such that $h_1^* = \bar{h}$ and $r_1^* = \bar{r}$ in the steady state, we have: $\lim_{t \to \infty} Y_t = Y_1^* = F\left(L, \bar{h}, \bar{r}\right)$.

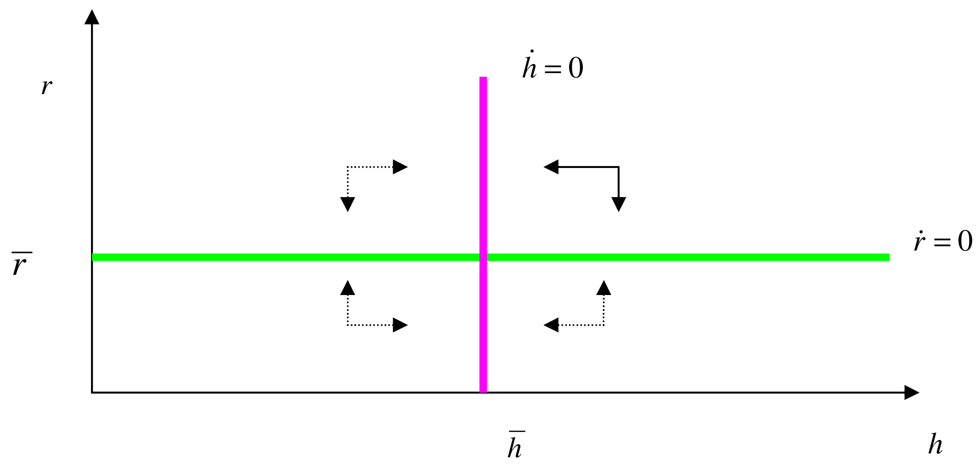

Figure 4: Phase diagram for the case of no investment

4.1.2 Investment in both human capital and land improvement

The simultaneous effect on income growth of investments in human capital formation and land improvement is given by the following expression:

$$g_Y = g_{l_a}\sigma_{l_a} + \left[\frac{a_h s_h Y}{h} - \psi_h\left(1 - \frac{\bar{h}}{h}\right)\right]\sigma_h + \left[\frac{a_r s_r Y}{r} - \psi_r\left(1 - \frac{\bar{r}}{r}\right)\right]\sigma_r \quad (1.18)$$

The growth rate of income depends positively on the growth rates of agricultural labour force, human capital and land conservation weighted by respective marginal contributions. We can also examine the dynamics of the system using a phase diagram (figure 5). Given any initial stocks of both forms of capital, the variables h and r converge to their respective steady state levels. The steady state levels of human capital, h^*, land quality, r^*, determine the steady state level of income, Y^* which is given by:

$$Y_4^* = F\left(L, h^*, r^*\right) \quad (1.19)$$

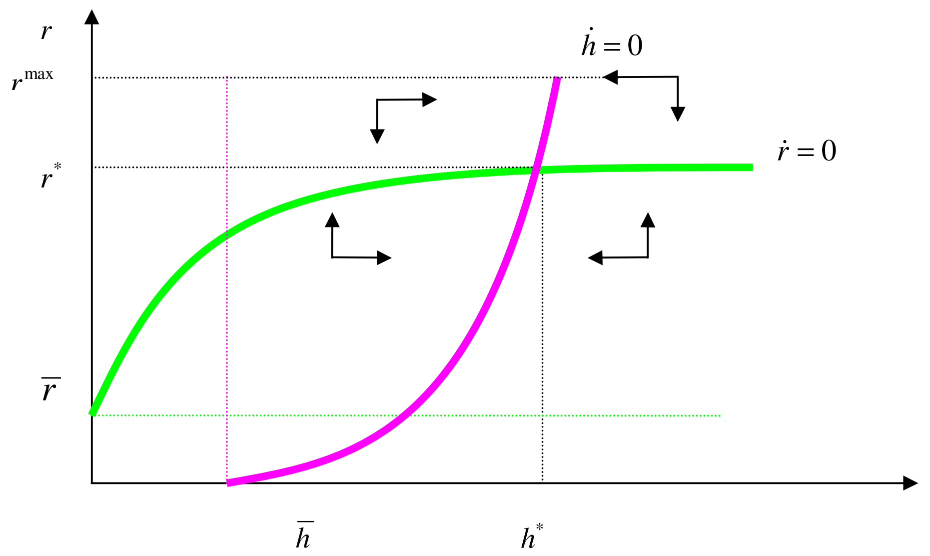

Figure 5: The phase diagram for the case of investments in human capital and land improvement

4.2 Income dynamics and non-farm employment

In an environment where non-farm wage employment opportunities exist, household income is not limited to farm income only since households can also generate wage income from non-farm employment (i.e. $Y = Y_a + Y_f$). The division of total labour force is given by $L = l_a + l_f$, and this implies that $\dot{l}_a = -\dot{l}_f$ and $\dot{l}_f = \dot{h}Q_h(h)$.

The change in income over time is given by:

$$\dot{Y} = \left(w - F_{l_a}(l_a, h, r)\right)\dot{l}_f + \dot{h}F_h(l_a, h, r) + \dot{r}F_r(l_a, h, r) \qquad (1.20)$$

We explore the long-run implications under different conditions.

(a) Case 1: $s_h = s_r = 0$

In the long-run, since both h and r approach their respective threshold levels (i.e. $\dot{h} \to \bar{h}$ and $\dot{r} \to \bar{r}$) and $l_f(\bar{h}) = 0$, the growth rate of income is zero. The long-run implications are similar to the no wage employment case considered previously.

(b) Case 4: $s_h > 0$ **and** $s_r > 0$

The dynamics of human capital accumulation and land conservation can be expressed as:

$$\frac{\dot{h}}{h} = \frac{a_h s_h\left[F(l_a, h, r) + wQ(h)\right]}{h} - \Psi_h\left(\frac{h - \bar{h}}{h}\right) \qquad (1.21)$$

$$\frac{\dot{r}}{r} = \frac{a_r s_r \left[F\left(l_a, h, r\right) + wQ\left(h\right)\right]}{r} - \Psi_r \left(\frac{r - \overline{r}}{r}\right) \qquad (1.22)$$

Notice that the phase curves for $\dot{h} = 0$ and $\dot{r} = 0$ are similar to the no wage employment case, except that both curves are now flatter. A close look at figures 5 and 6 shows that a simultaneous investment in human capital formation and land conservation yields greater steady state levels of both human capital and land quality than the same investment made under no non-farm employment environment. This, in turn, generates higher steady state income which can be expressed as:

$$Y_6^* = F\left(l_a^*, h^*, r^*\right) + wQ\left(h^*\right) \qquad (1.23)$$

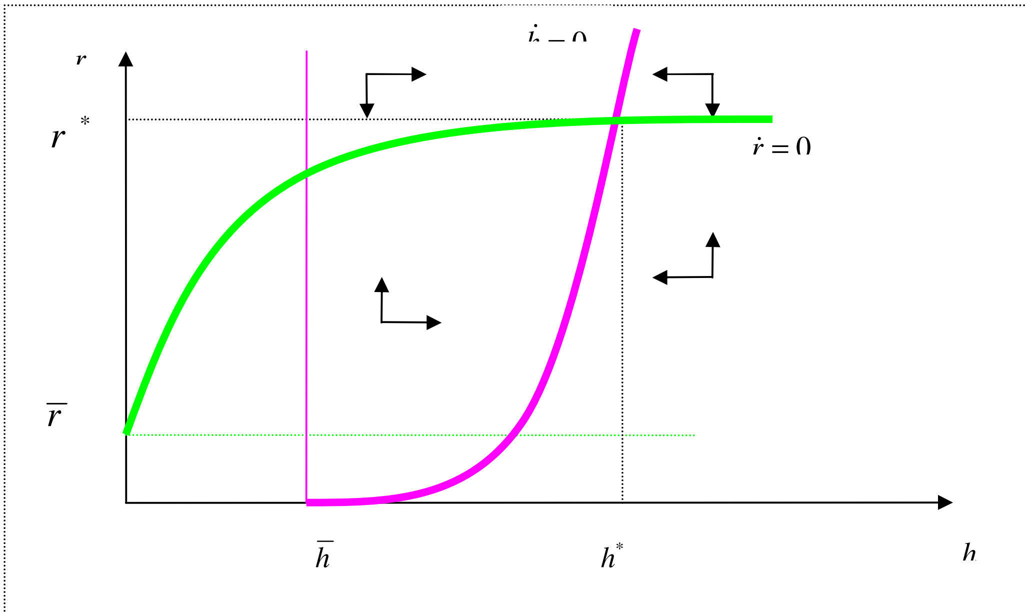

Figure 6: The long-run implications of investment in both forms of capital when non-farm wage employment opportunities exist

By and large, investment in human capital and land conservation is beneficial in terms of enhancing human capacity at the same time preserving the quality of natural capital. Employment creation in the non-farm sector has the effect of increasing household income and of inducing households to invest in human capital, which, in turn, improves both the quantity and quality of it, and it also lessens the pressure on farm land as educated people exit agriculture. The negative effect of land degradation on income will also be minimized as farm households depend less on farm land as the main source of livelihood. Eventually, the contributions of agricultural labour and land will decline as non-farm income assumes greater importance.

5 The dynamics of consumption and saving

If households do not invest in both forms of capital, then the dynamics of consumption is similar to income $(C = Y)$. However, if a fraction of the total income is devoted to finance investment in either human capital, land conservation or both, then the level of consumption depends on investment rates and income as:

$$C = (1 - s_r - s_h)Y \Leftrightarrow C = (1 - s_r - s_h)\left[wl_f + F(l_a, h, r)\right] \qquad (1.24)$$

Notice that since the ratio of consumption to income is constant, $\frac{C}{Y} = (1 - s_r - s_h)$, consumption grows by the same rate as income since the saving rates are fixed, i.e. $g_C = g_Y$. In what follows, we examine the effects of such investments and non-farm employment on steady state levels of consumption and savings.

4.1 Maximizing consumption when $l_f = 0$

Notice that when wage employment opportunities do not exist, consumption and investment depends on farm income, which is given by:

$$C = (1 - s_r - s_h)F(l_a, h, r) \textit{ with } l_a = L \qquad (1.25)$$

The steady state level of consumption, C^*, can be obtained by substituting the optimal levels of l_a, h and r into equation(1.25), i.e.

$$C^* = F(L, h^*, r^*) - sF(L, h^*, r^*) \Leftrightarrow C^* = F(L, h^*, r^*) - \left[\frac{\Psi_h}{a_h}(h^* - \bar{h}) + \frac{\Psi_r}{a_r}(r^* - \bar{r})\right] \qquad (1.26)$$

It should be noted that consumption improvements can be attained by changing the sectoral composition of saving or investment rates. In other words, the steady state level of consumption can be maximized by changing the investment rates between human and natural capital. The problem is to choose s_h and s_r so that equation (1.26) is maximized subject to $(s_h + s_r)F(L, h^*, r^*) = \frac{\Psi_h}{a_h}(h^* - \bar{h}) + \frac{\Psi_r}{a_r}(r^* - \bar{r})$.[11] The two optimality conditions are:

[11] Alternatively, the maximization problem can be formulated as choosing h and r that maximize $F(L, h^*, r^*) - \frac{\psi_h}{a_h}(h^* - \bar{h}) - \frac{\psi_r}{a_r}(r^* - \bar{r})$. The first-order conditions (FOCs) for a maximum are: $\frac{\partial C^*}{\partial h^*} = 0 \Leftrightarrow \frac{\partial F(L, h^*, r^*)}{\partial h^*} - \frac{\psi_h}{a_h} = 0$; $\frac{\partial C^*}{\partial r^*} = 0 \Leftrightarrow \frac{\partial F(L, h^*, r^*)}{\partial r^*} - \frac{\psi_r}{a_r} = 0$. The second-order

$$\frac{\partial C^*}{\partial s_h} = 0 \quad and \quad \frac{\partial C^*}{\partial s_r} = 0 \tag{1.27}$$

We consider, both individually and simultaneously, the conditions for the impact of investments in human capital and land improvement on steady state level of consumption.

Case 1: $s_h > 0$ **and** $s_r = 0$

The steady state level of consumption can be obtained by substituting the optimal levels of l_a, h and r into equation (1.26) as:

$$C^* = (1 - s_h) F\left(L, h^*, \bar{r}\right) with\ s_h = s \tag{1.28}$$

Invoking the steady state conditions, we can rewrite (1.28) as:

$$C^* = F\left(L, h^*, \bar{r}\right) - \frac{\psi_h}{a_h}\left(h^* - \bar{h}\right) \tag{1.29}$$

Then the optimality condition is given by:

$$\frac{\partial C^*}{\partial s_h} = \frac{\partial C^*}{\partial h^*}\frac{\partial h^*}{\partial s_h} + \frac{\partial C^*}{\partial r^*}\frac{\partial r^*}{\partial s_h} = 0 \Leftrightarrow \left[\frac{\partial F\left(L, h^*, \bar{r}\right)}{\partial h^*} - \frac{\psi_h}{a_h}\right]\frac{\partial h^*}{\partial s_h} = 0 \text{ since } \frac{\partial C^*}{\partial r^*}\frac{\partial r^*}{\partial s_h} = 0 \tag{1.30}$$

The impact of saving rate on the steady state level of human capital can be shown to be positive. Since $\frac{\partial h^*}{\partial s_h} > 0$, the condition $\frac{\partial C^*}{\partial s_h} = 0$ holds if $\frac{\partial F\left(L, h^*, \bar{r}\right)}{\partial h^*} = \frac{\psi_h}{a_h}$. This condition states that consumption can be improved by increasing the saving rate until the net marginal contribution of human capital to total household income is zero. What is the

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conditions (SOCs) should be satisfied to ensure that consumption as obtained from FOCs is indeed at its optimum level. Hence the SOCs require:

$$\frac{\partial C^*}{\partial h^*} < 0 \Leftrightarrow \frac{\partial^2 F\left(L, h^*, r^*\right)}{\partial \left(h^*\right)^2} < 0 \text{ and } \frac{\partial C^*}{\partial r^*} < 0 \Leftrightarrow \frac{\partial^2 F\left(L, h^*, r^*\right)}{\partial \left(r^*\right)^2} < 0$$

$\frac{\partial C^*}{\partial h^*} < 0 \Leftrightarrow \frac{\partial^2 F\left(L, h^*, r^*\right)}{\partial \left(h^*\right)^2} < 0$. The necessary and sufficient conditions for maximum income and consumption in the steady state can be summarized as:

(a) the steady state exists; (b) the steady state is unique and stable as there is one and only one intersection between $\dot{h} = 0$ and $\dot{r} = 0$ curves; (c) (a) and (b) are sufficient for the existence of a unique solution to the system; and (d) since the SOCs are satisfied, there is no possibility of the solution to the FOCs being a minimum.

optimum saving rate, s_h^*, that corresponds to the steady state level of consumption? Suppose that the optimal saving rate allotted to human capital formation that maximizes steady state level of consumption is such that:[12]

$$s_h^* = \beta\left(\frac{h^* - \bar{h}}{h^*}\right) \tag{1.31}$$

Upon substituting (1.31) into the steady state conditions, and solving for the steady state level of human capital, $h^* = \left(\frac{a_h\beta}{\psi_h}\right)^{\frac{1}{1-\beta}} L^{\frac{\alpha}{1-\beta}}\bar{r}^{\frac{\gamma}{1-\beta}}$, the optimal saving rate is given by:

$$s_h^* = \beta\left(1 - \frac{\bar{h}}{(X_h)^{\frac{1}{1-\beta}} L^{\frac{\alpha}{1-\beta}}\bar{r}^{\frac{\gamma}{1-\beta}}}\right) \text{ with } X_h = \frac{a_h\beta}{\psi_h} \tag{1.32}$$

Accordingly, upon substitution, the steady state consumption level corresponding to the optimal saving rate can be expressed as:

$$C^* = (\alpha + \gamma)\left[(X_h)^{\beta} L^{\alpha}\bar{r}^{\gamma}\right]^{\frac{1}{1-\beta}} + \frac{\psi_h\bar{h}}{a_h} \tag{1.33}$$

Equation (1.33) shows that, given the constant returns to scale assumption, the optimal consumption level depends on marginal productivities of labour, human capital and land.

Case 2: $s_r > 0$ **and** $s_h = 0$

Making use of the steady state condition, we have: $s_r F\left(L, \bar{h}, r^*\right) = \frac{\psi_r}{a_r}\left(r^* - \bar{r}\right)$ with $s_r = s$ and upon substitution, we get:

$$C^* = F\left(L, \bar{h}, r^*\right) - \frac{\psi_r}{a_r}\left(r^* - r\right) \tag{1.34}$$

Employing the optimality condition yields the following expression:

$$\frac{\partial C^*}{\partial s_r} = \left[\frac{\partial F\left(L, \bar{h}, r^*\right)}{\partial r^*} - \frac{\psi_r}{a_r}\right]\frac{\partial r^*}{\partial s_r} = 0 \text{ since } \frac{\partial C^*}{\partial h^*}\frac{\partial h^*}{\partial s_r} = 0 \tag{1.35}$$

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[12] Based on the specific production function and in the absence of threshold level in human capital $\left(i.e., \bar{h} = 0\right)$), the optimal level of human capital is given by: $h^* = \left(\frac{a_h}{\psi_h}\right)^{\frac{1}{1-\beta}} L^{\frac{\alpha}{1-\beta}}\bar{r}^{\frac{\gamma}{1-\beta}}$, and the optimal saving rate is equal to β.

Since $\frac{\partial r^*}{\partial s_r^*}$ is positive, the condition $\frac{\partial C^*}{\partial s_r} = 0$ is satisfied if the net marginal contribution of land quality is zero, i.e. $\frac{a_r \partial F\left(L, \bar{h}, r^*\right)}{\partial r^*} - \psi_r = 0$. Let the optimal saving rate allotted to land improvement corresponding to the steady state level of consumption be expressed as:[13]

$$s_r^* = \gamma\left(\frac{r^* - \bar{r}}{r^*}\right) \tag{1.36}$$

Substituting (1.36) into the steady state conditions and solving for the steady state level of land quality yields: $r^* = \left(\frac{a_r \gamma}{\psi_r}\right)^{\frac{1}{1-\gamma}} L^{\frac{\alpha}{1-\gamma}} \bar{h}^{\frac{\beta}{1-\gamma}}$. The optimal saving rate is given by:

$$s_r^* = \gamma\left(1 - \frac{\bar{r}}{\left(X_r\right)^{\frac{1}{1-\gamma}} L^{\frac{\alpha}{1-\gamma}} \bar{h}^{\frac{\beta}{1-\gamma\beta}}}\right) \text{ with } X_r = \frac{a_r \gamma}{\psi_r} \tag{1.37}$$

Likewise, the steady state level of consumption corresponding to the optimal saving rate is given by:

$$C^* = (\alpha + \beta)\left[\left(X_r\right)^{\gamma} L^{\alpha} \bar{h}^{\beta}\right]^{\frac{1}{1-\gamma}} + \frac{\psi_r \bar{r}}{a_r} \tag{1.38}$$

A look at (1.38) reveals that the optimal consumption level depends on the marginal contributions of labour, human capital and land. Thus, investment in land improvement has a positive pay-offs in the long-run as it improves both consumption and the quality of agricultural land.

Case 3: $s_h > 0$ **and** $s_r > 0$

In this case, the steady state level of human capital and land quality are determined simultaneously. Using the steady state conditions, the optimal level of consumption is given by:

$$C^* = (1 - s) F\left(L, h^*, r^*\right) \Leftrightarrow C^* = F\left(L, h^*, r^*\right) - \left[\frac{\psi_h}{a_h}\left(h^* - \bar{h}\right) + \frac{\psi_r}{a_r}\left(r^* - \bar{r}\right)\right] \tag{1.39}$$

From equation (1.39), the effects of steady state levels of h and r on optimal consumption level can be obtained.

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[13] Without threshold level, the optimal saving rate that yields maximum consumption is simply the share of land in total output. In our Cobb-Douglas production function, the optimal saving rate is given by: $s_r^* = \gamma$.

$$\frac{\partial C^*}{\partial h^*} = \frac{\partial F\left(L, h^*, r^*\right)}{\partial h^*} - \frac{\psi_h}{a_h} \text{ and } \frac{\partial C^*}{\partial r^*} = \frac{\partial F\left(L, h^*, r^*\right)}{\partial r^*} - \frac{\psi_r}{a_r} \quad (1.40)$$

In a more expanded form, the optimality condition in the steady sate requires that:

$$\frac{\partial C^*}{\partial s_h} = \frac{\partial C^*}{\partial h^*}\frac{\partial h^*}{\partial s_h} + \frac{\partial C^*}{\partial r^*}\frac{\partial r^*}{\partial s_h} = 0 \text{ and } \frac{\partial C^*}{\partial r^*} = \frac{\partial F\left(L, h^*, r^*\right)}{\partial r^*} - \frac{\psi_r}{a_r} \quad \frac{\partial C^*}{\partial s_r} = \frac{\partial C^*}{\partial h^*}\frac{\partial h^*}{\partial s_r} + \frac{\partial C^*}{\partial r^*}\frac{\partial r^*}{\partial s_r} = 0 \quad (1.41)$$

Upon substitution and rearranging terms, the optimality condition can be expressed as:

$$\left[\frac{\partial F\left(L, h^*, r^*\right)}{\partial h^*} - \frac{\psi_h}{a_h}\right]\frac{\partial h^*}{\partial s_h} + \left[\frac{\partial F\left(L, h^*, r^*\right)}{\partial r^*} - \frac{\psi_r}{a_r}\right]\frac{\partial r^*}{\partial s_h} = 0 \quad (1.42)$$

$$\left[\frac{\partial F\left(L, h^*, r^*\right)}{\partial h^*} - \frac{\psi_h}{a_h}\right]\frac{\partial h^*}{\partial s_r} + \left[\frac{\partial F\left(L, h^*, r^*\right)}{\partial r^*} - \frac{\psi_r}{a_r}\right]\frac{\partial r^*}{\partial s_r} = 0 \quad (1.43)$$

Since $\frac{\partial h^*}{\partial s_h} > 0; \quad \frac{\partial r^*}{\partial s_h} > 0; \frac{\partial h^*}{\partial s_r} > 0; \text{and} \quad \frac{\partial r^*}{\partial s_r} > 0$, the optimality conditions as indicated in equations (1.42) and (1.43) requires that the term in brackets must be both equal to zero, i.e.

$$\frac{\partial F\left(L, h^*, r^*\right)}{\partial h^*} - \frac{\psi_h}{a_h} = 0 \quad \text{and} \quad \frac{\partial F\left(L, h^*, r^*\right)}{\partial r^*} - \frac{\psi_r}{a_r} = 0 \quad (1.44)$$

We make use of steady state conditions to solve simultaneously the steady state levels of human and natural capital which can be given as:

$$h^* = \left(X_h\right)^{\frac{1-\gamma}{\alpha}}\left(X_r\right)^{\frac{\gamma}{\alpha}} L \text{ and } r^* = \left(X_h\right)^{\frac{\beta}{\alpha}}\left(X_r\right)^{\frac{1-\beta}{\alpha}} L \quad (1.45)$$

Making use of the specific functional form and substituting the optimal levels of h and r into (1.39) to get the optimal consumption level:

$$C^* = \alpha\left[\left(X_h\right)^{\frac{\beta}{\alpha}}\left(X_r\right)^{\frac{\gamma}{\alpha}}\right]L + \frac{\psi_h \bar{h}}{a_h} + \frac{\psi_r \bar{r}}{a_r} \quad (1.46)$$

Clearly, simultaneous investment in both forms of capital has higher pay offs compared with individual investment injections.

5.2 Consumption growth in the presence of wage employment

The impact of wage employment opportunities on consumption depends on the marginal returns to labour in agriculture and wage rate in the non-farm sector. In a more general form, the steady state level of consumption can be expressed as:

$$C^* = F\left(l_a^*, h^*, r^*\right) + wQ\left(h^*\right) - \left[\frac{\Psi_h}{a_h}\left(h^* - \bar{h}\right) + \frac{\Psi_r}{a_r}\left(r^* - \bar{r}\right)\right] \quad (1.47)$$

The impacts of human capital and land improvement on optimal consumption are, respectively, given by:

$$\frac{\partial C^*}{\partial h^*} = \frac{\partial F\left(l_a^*, h^*, r^*\right)}{\partial h^*} + \frac{\partial F\left(l_a^*, h^*, r^*\right)}{\partial l_a^*}\frac{\partial l_a^*}{\partial h^*} + wQ_h\left(h^*\right) - \frac{\Psi_h}{a_h} \quad (1.48)$$

$$\frac{\partial C^*}{\partial r^*} = \frac{\partial F\left(l_a^*, h^*, r^*\right)}{\partial r^*} - \frac{\Psi_r}{a_r} \quad (1.49)$$

Notice the link between l_a and l_f :

$$\frac{dl_f^*}{dh^*} = Q_h\left(h^*\right) \text{ and } dl_a^* = dL - dl_f^* \Leftrightarrow \frac{dl_a^*}{dh^*} = -Q_h\left(h^*\right) \quad (1.50)$$

A change in the level of human capital affects both agricultural labour force and labour employed in the non-farm sector. Since the optimal levels of h and r depend, among other things, on s_h and s_h, a change in the sectoral saving rates might lead to an improvement in consumption. Accordingly, the optimality conditions can be expressed as:

$$\left[\frac{\partial F\left(l_a^*, h^*, r^*\right)}{\partial h^*} - \frac{\Psi_h}{a_h}\right] + \left[w - \frac{\partial F\left(l_a^*, h^*, r^*\right)}{\partial l_a^*}\right]Q_h\left(h^*\right) = 0 \quad (1.51)$$

$$\frac{\partial F\left(l_a^*, h^*, r^*\right)}{\partial r^*} - \frac{\Psi_r}{a_r} = 0 \quad (1.52)$$

The impact of wage employment on optimal consumption depends on the difference between the marginal productivity of labour in agriculture and the wage rate in the non-farm sector. A look at equation (1.52) implies that there exists a threshold level of wage rate $(\bar{w})$ that lead to four different regimes.

(i) Regime I: $w < \bar{w} \quad \left(i.e. \quad w < \frac{\partial F\left(l_a^*, h^*, r^*\right)}{\partial l_a^*}\right)$

Since the marginal return to agricultural labour is greater than the wage rate outside agriculture, households will not willing to work in the non-agricultural sector, i.e. $l_f = 0$. Hence agriculture will bear the burden for income generation and employment creation. Since $l_f^* = 0$, the optimality condition and related results are similar to the no wage employment case considered previously.

(ii) Regime II: $w = \bar{w}$ $\left(i.e. \quad w = \frac{\partial F\left(l_a^*, h^*, r^*\right)}{\partial l_a^*} \right)$

If the wage rate outside agriculture and the marginal return to labour in agriculture are the same, then households will be indifferent to work between these two sectors, and hence $l_f \geq 0$.[14] Two cases can be considered. If the household does not engage in wage employment, then we have $l_f = 0$ and $l_a = L$, and the implications are similar to (i). On the other hand, if the household prefers to work in the non-farm sector, then we have $l_f > 0$ and $l_a = L - l_f$. We consider the general case where a portion λ, $\lambda \in [0,1]$, of labour force is engaged in wage employment, i.e. $l_f^* = \lambda b h^*$.

Suppose that the optimal saving rates are such that:

$$s_h^* = \frac{\beta}{1 + X_h b w}\left[\frac{h^* - \bar{h}}{h^*}\right] \textit{and } s_r^* = \frac{\gamma}{1 + X_h b w}\left[\frac{r^* - \bar{r}}{r^*}\right] \quad (1.53)$$

We make use of the steady state conditions to obtain the optimal levels of human and natural capital which can be expressed as:

$$h^* = \frac{\left(X_r\right)^{\frac{\gamma}{\alpha}} L}{\lambda b \left(X_r\right)^{\frac{\gamma}{\alpha}} + \left(X_h\right)^{\frac{\gamma-1}{\alpha}}} \textit{ and } r^* = \frac{\left(X_r\right)^{\frac{\alpha+\gamma}{\alpha}}\left(\frac{1}{X_h}\right) L}{\lambda b \left(X_r\right)^{\frac{\gamma}{\alpha}} + \left(X_h\right)^{\frac{\gamma-1}{\alpha}}} \quad (1.54)$$

With a bit of algebra, the corresponding optimal saving rates are:

$$s_h^* = \frac{\beta}{1 + X_h b w}\left[1 - \frac{\bar{h}\left[\lambda b \left(X_r\right)^{\frac{\gamma}{\alpha}} + \left(X_h\right)^{\frac{\gamma-1}{\alpha}}\right]}{\left(X_r\right)^{\frac{\gamma}{\alpha}}}\right] L \quad (1.55)$$

$$s_r^* = \frac{\gamma}{1 + X_h b w}\left[1 - \frac{\bar{r}\left[\lambda b \left(X_r\right)^{\frac{\gamma}{\alpha}} + \left(X_h\right)^{\frac{\gamma-1}{\alpha}}\right]}{\left(X_r\right)^{\frac{\alpha+\gamma}{\alpha}}\left(\frac{1}{X_h}\right)}\right] L \quad (1.56)$$

The optimal consumption level is thus given by:

[14] Although the choice of occupation depends on other factors such as access to roads, power supply, and other social infrastructure, we assume that the monetary return to labour is the key determinant of occupational choices.

$$C^{*}=\left(\frac{1+X_{h}b\lambda w}{X_{h}}\right)L\left\{\begin{array}{l}\dfrac{\beta}{1+X_{h}b\lambda w}\left[\dfrac{(X_{r})^{\frac{\gamma}{\alpha}}}{\lambda b(X_{r})^{\frac{\gamma}{\alpha}}+(X_{h})^{\frac{\gamma-1}{\alpha}}}-\bar{h}\right]- \\ \dfrac{\gamma}{1+X_{h}b\lambda w}\left[\dfrac{(X_{r})^{\frac{\alpha+2\gamma}{\alpha}}(X_{h})}{\lambda b(X_{r})^{\frac{\gamma}{\alpha}}+(X_{h})^{\frac{\gamma-1}{\alpha}}}-\dfrac{\bar{r}}{(X_{r})(X_{h})}\right]\end{array}\right\} \tag{1.57}$$

Notice that for $\bar{h}=\bar{r}=0$, it is possible to show that the optimal consumption level is given by the product of the wage rate and the total labour endowment, i.e. $C^{*}=wL$. Hence, any value of λ, $0\leq\lambda\leq1$, defines an optimal solution provided that $w=\bar{w}$.

(iii) Regime III: $w>\bar{w}\left(i.e.\quad w>\dfrac{\partial F(l_{a}^{*},h^{*},r^{*})}{\partial l_{a}^{*}}\right)$

Holding other factors constant, if the wage rate in the non-farm sector is higher than the marginal returns to agricultural labour, then households with certain education level are willing to work in the non-farm sector (i.e. $l_{f}>0$). In this type of economic setting, the relatively high wage rate for labour in the non-farm sector serves as an incentive to move labour from agriculture, and hence wage employment will have a positive impact on income growth. This is in a way similar to Lewis's (1954) model which argues that any surplus labour in agriculture can be transferred to the so-called modern sector regardless of the characteristics of workers.

Our model, however, differs from Lewis's model in that only educated labour force can be transferred to the non-farm sector. Even so, labour mobility is conditional on wage rate in the non-farm sector. In the extreme case, if the wage rate outside agriculture is sufficiently high so that nearly all labour is shifted to the non-farm sector (we call this Regime IV: $w=\tilde{w}$ where $\tilde{w}$ is the maximum wage rate compatible with complete structural transformation), then income and consumption growth depend chiefly on wage rate and the marginal productivity of labour in the non-farm sector. This represents a complete transformation of an economic setting where the non-farm sector bears the burden for employment creation and has become the main means of livelihood. To simplify the algebra, we can express the endogenous variables in terms of Z, and the optimal saving rates can thus be expressed as:

$$b\left(w-\alpha(Z)^{\frac{\beta}{\alpha}}(X_{r})^{\frac{\gamma}{\alpha}}\right)+\frac{\beta}{Z}-\frac{\psi_{h}}{a_{h}}=0;s_{r}^{*}=\frac{\psi_{h}-a_{h}s_{h}\beta\lambda bw}{\psi_{h}}\,with\;\;Z=\frac{a_{h}s_{h}}{\psi_{h}-a_{h}s_{h}\beta\lambda bw} \tag{1.58}$$

Notice that the optimal saving rate for natural capital depends on the saving rate for human capital formation. The latter is defined implicitly and no closed-form expression is possible for s_{h}^{*}. However, assuming that $\alpha=\beta$ which is the same as saying that human capital augments farm labour, it is possible to find an explicit expression for the system. Accordingly, from equation (1.58), the relevant solution for Z can be expressed in terms of the wage rate and other model parameters only as:

$$Z^* = \frac{-\psi_h + a_h bw + \sqrt{\psi_h^2 + (a_h bw - 2\psi_h) a_h bw + 4b(\beta a_h)^2 X_r}}{2a_h b X_r \beta} \qquad (1.59)$$

Upon substituting Z^* into each endogenous variable indicated in Table 1, the optimal or steady state levels of endogenous variables can be obtained which depend on the wage rate and other exogenous parameters alone.

Figure 10 summarizes succinctly the various regimes. When the wage rate is below the threshold level, consumption depends on farm income alone (Regime I). On the other hand, when the wage rate outside agriculture is set above the threshold level, but not too high enough to shift the entire work force out of farming, then consumption depends on both farm and wage income (Regime III). The interesting result is that if the wage rate is raised by a significant magnitude, this will move the entire work force to the non-farm sector (figure 11). At this wage rate, the entire labour force will be engaged in the non-farm sector since working in the agricultural sector involves high opportunity cost. In this case, optimal consumption depends mainly on non-farm income (Regime IV).

Table 1: Endogenous variables in terms of Z

$h^* = \frac{\Omega_1 L}{1 + b\Omega_1}$	$r^* = \frac{\Omega_1 L}{1 + b\Omega_2}$	(1.60)
$Y_f^* = \frac{b\Omega_1 wL}{1 + b\Omega_2}$	$Y_a = \frac{\Omega_3 L}{1 + b\Omega_1}$	(1.61)
$l_f = \frac{b\Omega_1 L}{1 + b\Omega_1}$	$l_a^* = \frac{L}{1 + b\Omega_1}$	(1.62)
$s_h^* = \frac{\psi_h Z^* L}{a_h(1 + bwZ^*)}\left[1 - \frac{\bar{h}(\Omega_4)}{\Omega_4 L}\right]$	$s_r^* = \frac{\gamma L}{(1 + bwZ^*)}\left[1 - \frac{\bar{r}(1 + b\Omega_1)}{\Omega_1 L}\right]$	(1.63)
$C^* = \left(1 - \frac{\psi_h Z^*}{a_h(1 + bwZ^*)}\left[1 - \frac{\bar{h}(\Omega_4)}{\Omega_4 L}\right] - \frac{\gamma}{(1 + bwZ^*)}\left[1 - \frac{\bar{r}(1 + b\Omega_2)}{\Omega_4 L}\right]\right)\frac{\Omega_1 L\left(\frac{1}{Z^*} + bw\right)L}{1 + b\Omega_1}$		(1.64)

Note: $\Omega_1 = Z^{*\frac{1-\gamma}{\beta}}(X_r)^{\frac{\gamma}{\beta}}$; $\Omega_2 = Z(X_r)^{\frac{1-\beta}{\beta}}$; $\Omega_3 = Z^{*\frac{\alpha}{\beta}}(X_r)^{\frac{\gamma}{\beta}}$; $\Omega_4 = Z^{*\frac{1-\gamma}{\beta\alpha}}(X_r)^{\frac{\gamma}{\beta}}$

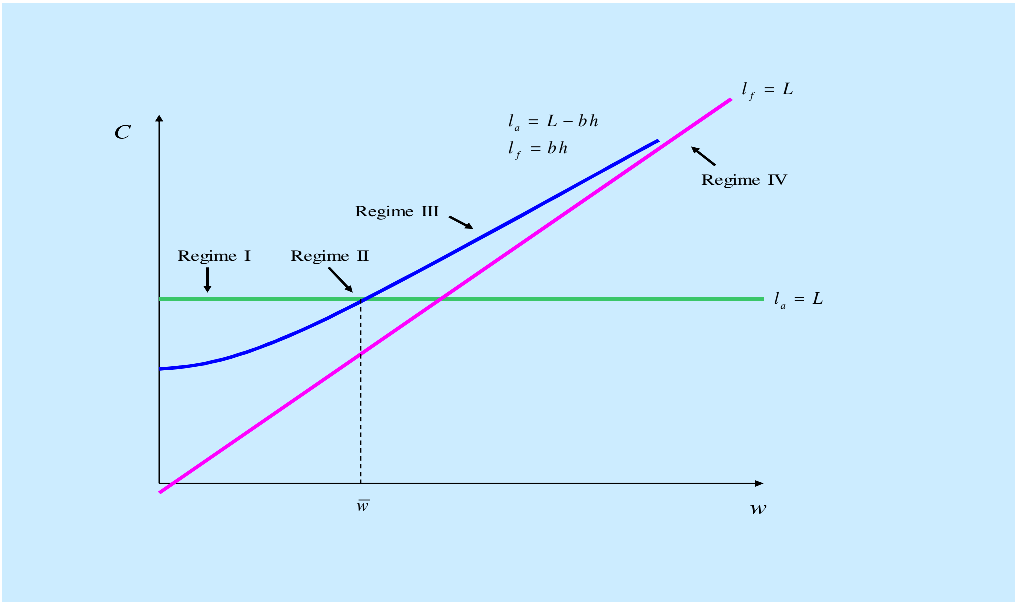

Figure 10: The optimal consumption levels under different regimes with respect to the wage rate

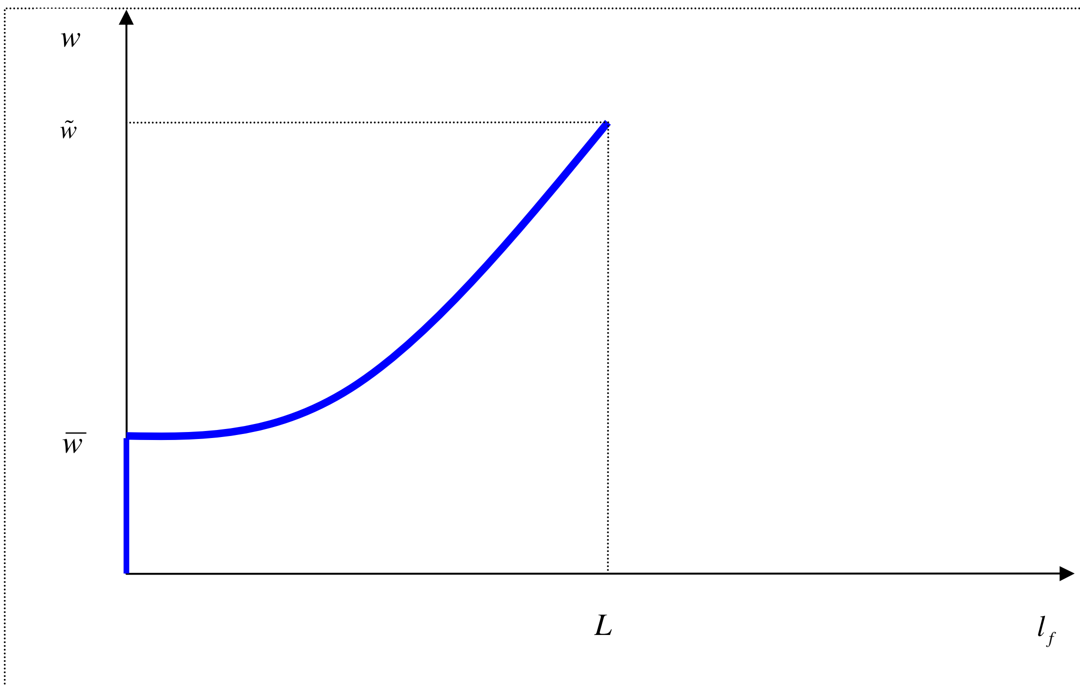

Figure 11: Impact of human capital on non-farm employment

6 Model calibration and policy simulations

Based on insights from the theoretical model, we examine the ability of the model to explain structural transformation of a village economy in rural Ethiopia. For specific values of model parameters, the impact of wage rate on endogenous variables such as income, consumption, and investment is examined. Unlike the common practice of relying on outside sources for model calibration, the values of key model parameters such as share parameters (i.e. α, β and γ) are taken from the village social accounting matrix estimated for the study setting, with $\alpha = \beta = 0.38$ and $\gamma = 0.24$ (see Ferede (2008) for details of the village SAM). Assume equal depreciation rates for human and natural capital, i.e. $\psi_h = \psi_r = 0.10$, and $a_h = a_r = 1$; $b = 0.10$. In addition, the total labour endowment (L) and the minimum threshold levels are normalized to one $\left(L = \bar{h} = \bar{r} = 1\right)$. The simulation results are presented for both zero and positive values for the minimum threshold levels of human and natural capital (Table 2). The key results can be summarized as follows:

(a) The development of the non-farm sector changes the structure of the household income, and as the wage rate increases the share of farm income declines while non-farm income accounts for a greater proportion of total household income, an indication of structural transformation (figure 14). This structural transformation is brought about by the expansion of non-farm employment and a surge in non-farm wage rate. Particularly two actions are important for structural transformation that promote inter-sectoral resource flows from agriculture to non-farm sector of the economy. Two of the most important transfer mechanisms are investment in human and natural capital by households. Facilitating the development of non-farm sector that expands employment and income is an essential complement to improving both agricultural production and agricultural land.

(b)The optimal level of human capital formation increases with the wage rate, i.e. the relatively high wage rate outside agriculture induces households to invest in human capital formation. Although the optimal saving rate for human capital formation declines as the wage rate raises, the total investment in human capital increases through time (figure 15). Thus a high wage rate in the non-farm sector triggers investment in human capital development, and forms a key for improved household income.

(c) Similarly, the optimum level of land quality improves following an increase in the wage rate. However, both the saving rate and total investment in land improvement declines as non-farm income assumes greater importance in total household income. As farming activity becomes a less important source of livelihood, the dependence of households on land diminishes, and accordingly, households allocate less income to land quality improvement. Notice that at a certain level of human capital, given the wage rate, there is a possibility that the entire labour force can be employed in the non-farm sector, and investment in land conservation will be zero (i.e. $s_r = 0$), i.e. no further investment in land improvement.[15] This happens when the wage rate outside agriculture is sufficiently higher than the marginal productivity of labour in agriculture. When the

[15] Although this seems a theoretical possibility, it can be applicable to settings where farming is less promising, and a development of non-farm sector could absorb a significant proportion of labour force.

wage rate is high enough, the opportunity cost of working in farming activity becomes so high that households choose to allocate their time working for a wage employment ($w = \tilde{w}$). Since there will be nearly no farming activity that degrades the land, the farm land will get rest, and the land quality will be maintained at a higher level. Notice that $r^{\max}$ occurs as $l_f \to L$ which implies $h^* \cong \frac{L}{b}$, i.e. the land quality is maintained at higher level.

(d) Consumption increases with the change in the structure of the economy (figure 16), and it reaches maximum when there is a complete transformation of the economy, i.e. $l_f \to L$ and land quality is at its maximum. Notice that at $r^{\max}$, consumption depends chiefly on non-farm income, i.e.

$$C^* = \left(1 - s_h^*\right) Y^* \Leftrightarrow C^* = \left(1 - \frac{\Psi_h}{a_h b \tilde{w}}\right) \tilde{w} L \text{ with } s_h^* = \frac{\Psi_h}{a_h b \tilde{w}} \quad (1.65)$$

This indicates that consumption can be increased from its current level if the non-farm sector is developed. Hence economic growth accompanied by structural change enhances the welfare of households.

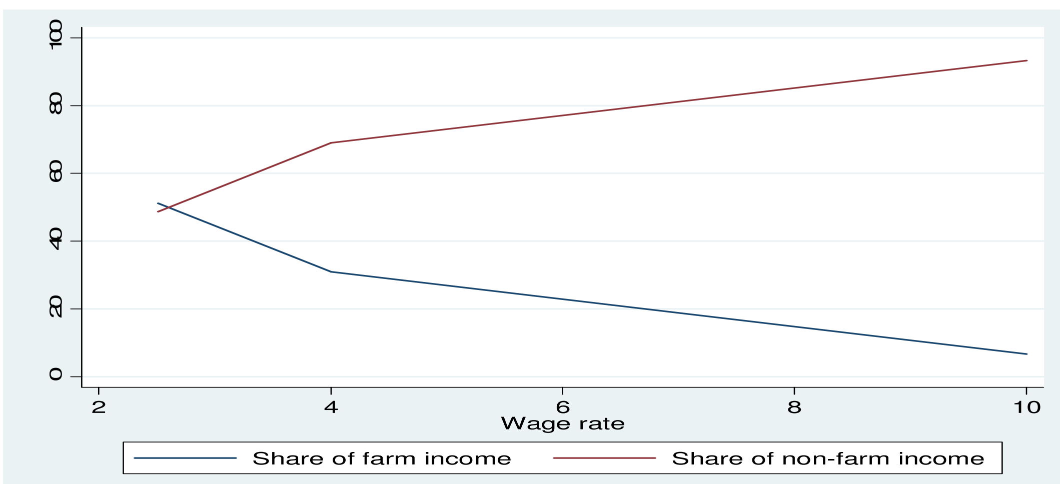

Figure 14: Impact of non-farm wage rate on the composition of household income

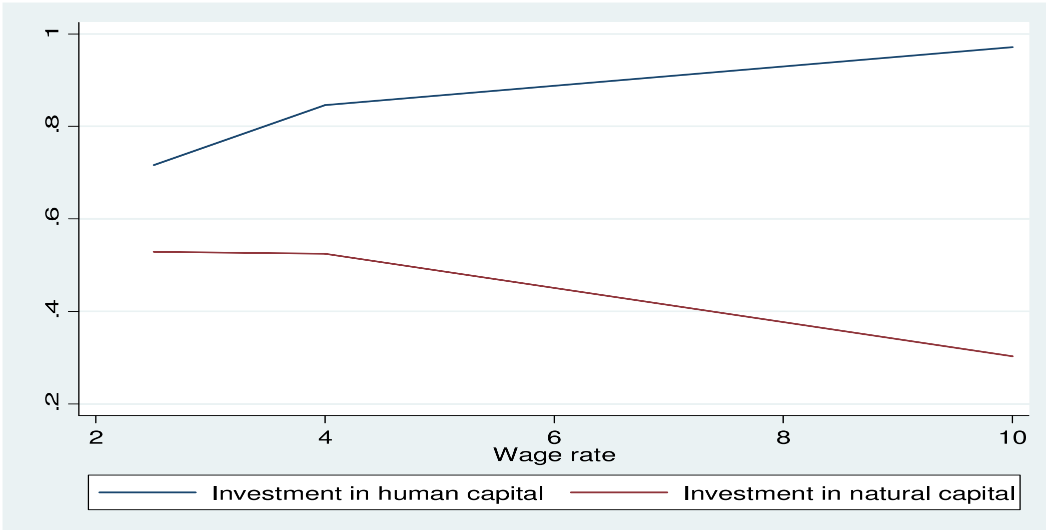

Figure 15: Impact of non-farm wage rate on investment in human and natural capital

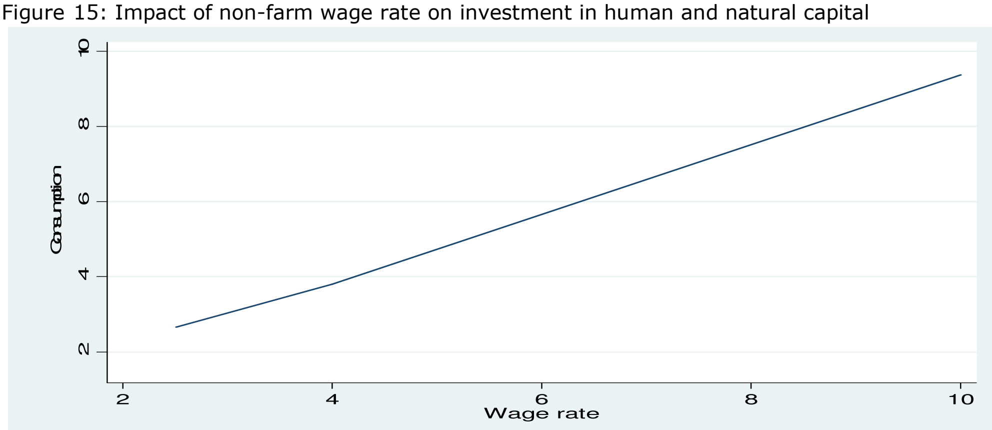

Figure 16: Impact of non-farm wage rate on consumption

Table 2: Simulation results for the impact of a change in wage rate on consumption, human and natural capital

Endogenous variables	$\bar{h} = \bar{r} = 0$				$\bar{h} = \bar{r} = 1$			
	$w = 0$	$w = \bar{w}$ ($w = 2.51$)	$w = 4$	$w = 10$	$w = 0$	$w = \bar{w}$ ($w = 2.51$)	$w = 4$	$w = 10$
h^*	3.495	7.151	8.438	9.716	3.495	7.151	8.438	9.716
r^*	3.100	9.709	16.24	49.949	3.100	9.709	16.24	49.949
l_a^*	0.651	0.285	0.156	2.838×10^{2}	0.651	0.285	0.156	2.838×10^{2}
l_f^*	0.350	0.715	0.844	0.971	0.350	0.715	0.844	0.972
Y_a^*	1.988	1.882	1.514	0.6923	1.988	1.882	1.514	0.692
Y_f^*	0.000	1.795	3.375	9.716	0.000	1.795	3.375	9.716
C^*	1.161	2.510	3.682	9.271	1.415	2.659	3.805	9.374
s_h^*	0.176	0.195	0.173	9.335×10^{-2}	0.126	0.167	0.152	8.374×10^{-2}
s_r^*	0.24	0.123	7.430×10^{-2}	1.596×10^{-2}	0.163	0.110	6.974×10^{-2}	1.564×10^{-2}
I_h^*	0.350	0.717	0.846	0.972	0.25	0.615	0.744	0.872
I_r^*	0.279	0.530	0.524	0.303	0.323	0.405	0.341	0.163
Gross investment	0.629	1.247	1.370	1.275	0.573	1.02	1.085	1.035

Source: Simulation results

7 Conclusion and policy implications

This study develops an integrated framework for assessing the interaction between income dynamics, human and natural capital in rural Ethiopia, a country trapped by a cycle of drought and famine, low per capita income, undeveloped human capital, and severe land degradation.

The study indicate that the sources of income growth are improved investments in human capital and in land improvement ventures. It has been shown that investments in both types of capital interact each other to influence income both directly and indirectly. Investment in land conservation, for example, has two effects on rural livelihoods: it directly increases farm productivity which yields higher farm income, and the latter stimulates investment in human capital formation, and provides of evidence of a potential 'win-win-win' outcome, benefiting both income growth and improvement in human capital formation at the same time preserving the quality of agricultural land, in which the second effect (on human capital) has received little attention in the literature. This suggests that in rural settings already suffering high rates of agricultural land degradation, failure to invest in land improvement technologies has been shown to lead to agricultural land degradation (i.e. in the form of nutrient mining and erosion) which, in turn, has the effect of reducing farm productivity and investment in human capital formation. Since most of the land suitable for agriculture is already employed in production in the study setting, meeting current and future food requirements hinges on rapid increases in agricultural productivity through investment in land improvement technologies.

The findings of the study have important policy implications from the point of view of sustaining the growth process and achieving structural transformation.

(1) In the absence of investment in land conservation, heavy dependence on land reduces the growth rate of income or consumption. Therefore, in settings characterized by strong-orientation towards land as the main source of livelihood, investment in land improvement figures out an important pathway to enhance income growth and to reverse land degradation.

(2) Although human capital has been fundamental for sustained growth as documented in growth literature (e.g. Romer, 1986; Lucas, 1988), its effect in stimulating income and consumption growth and preserving natural resources depends crucially on the possible outcomes regarding job offer outside agriculture. It appears that a mere employment creation outside agriculture is not sufficient to induce labour mobility, and the wage rate in the non-agricultural sector should be greater than that of the marginal productivity of labour in agriculture. The relative marginal return to labour between agriculture and non-agriculture is the key driving factor for labour mobility between sectors. Therefore,

employment and higher returns outside agriculture are the key pathways to expedite growth and increase rural incomes.[16]

(3) Policies which do not pay due attention to employment creation and environmental protection are doomed to have weak human capital formation and environmental decline which will dampen economic growth in the long-run. When the effects of agricultural land degradation are experienced via reduced economic activity, and influence other sectors of the economy such as education, a broader development policy which focuses on human capital formation and land improvement is required to bring structural transformation and move the economy in a sustainable manner.

Overall, the problems of low agricultural growth, weak human capital and agricultural land degradation can be properly addressed through a synchronized and targeted intervention in the different sectors of the economy, and no single intervention may be sufficient in itself. In particular, development interventions that promote both investments in human capital formation and land conservation as well as creation of productive employment in the non-agricultural sector would be crucial for sustainable economic transformation. There exist opportunities to exploit complementarities and synergies of promoting education and use of conservation measures such as investment in land improvement so as to improve the livelihood of the farm households in a traditional farming system. Failure to address even one of the critical constraints could neutralize the contribution of any other intervention. This linkage can be described by ancient proverb (Salleh, 1992:3), but adapted to the study setting:

"If you plan for:
a year, sow *teff*;
ten years, plant trees; and
a hundred years, educate people".

[16] A mere job creation without a corresponding creation of adequate income will just produce "working poor". Similarly, there may be high economic growth, but without resultant employment expansion, a phenomenon is known as "jobless" growth, which is a typical feature of many African countries (ECA, 2005).

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