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Abstract

This paper develops a model to analyze human capital investment and earnings patterns of target saving temporary migrants. The analysis will point out differences in investment- and earnings profiles which are due to differences in individual characteristics of migrant workers. The model predicts that earnings profiles of temporary migrants vary considerably due to differences in their saving targets, their ability level, their skill level upon arrival, their consumption pattern and their intentions after return to their home countries. The model provides a theoretical basis for the estimation of earnings profiles of temporary migrants.

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Contents

1 Introduction

The economic situation of migrant workers in the labor markets of the host countries became an issue of growing interest in the economic literature in recent years. A variety of studies empirically investigated the adjustment of earnings of immigrants to those of native workers.[1] The general finding for countries like Australia, Canada and the United States was that migrant workers do surprisingly well in the labor markets of the host countries. Being lower upon arrival, migrants earnings gradually adjust to those of native workers and, as found in some studies, even overcome those of natives.[2] The first finding is explained in terms of the human capital framework: migrants have a high incentive to invest into human capital specific to the labor market of the host country. They consequently accumulate human capital faster than native workers, resulting in relatively steeper earnings profiles. The cross-over of earnings of migrants with those of natives is explained with a higher innate ability and work motivation of migrants if compared with native workers. However, the generally favorable situation of permanent migrants in labor markets of Australia, Canada and the United States can not be generalized for all types of migration. Analyzing earnings profiles of temporary immigrants to West Germany, Dustmann (1990) finds that there is virtually no wage catch-up of migrants in the German labor market as was found for other countries. He explains his findings with the temporary character of the type of migration considered, having a flattening impact on earnings profiles.

The results of any empirical analysis on migrants earnings position seem to depend on the type of migration considered. Explanations of empirical findings need a more thorough theoretical foundation. A variety of questions arise that can only be answered in a theoretical framework. For instance, Chiswick's (1978) explains his findings of a wage cross-over with high incentives of migrants to invest in country specific human capital and higher ability levels. Do these two factors independently influence the migrants earnings path or are there interactions between the level of a migrant's ability and his incentive to invest into human capital? And is the hypothesis theoretically justified that a low transferability of skills has a steepening effect on migrant's earnings profiles? Furthermore, the literature does not define what really creates an incentive to invest into human capital. The incentive to invest into human capital should relate to the value of any further unit of human capital. A rise in those variables that posi-

[1]see, e.g. (Borjas (1985), (1987), (1989), Beggs and Chapman (1989), Chiswick (1978), Chiswick and Miller (1985), Carliner (1980), Long (1980) and Meng (1987).

[2]Chiswick (1978) reports that earnings of migrants in the American labor market exceed those of native workers after 10-15 years. Meng (1987) calculated that the earnings gap between natives and immigrants in the Canadian labor market closes after 14 years.

tively influence this value would accordingly provide a positive investment incentive. If measurable, an identification of these variables would allow for some statements about investment incentives of a given migrant population.

Turning to temporary migration, there is a variety of additional factors that should be considered if analyzing the migrant's earnings position. First of all, it has to be defined why workers do only temporarily migrate. Which factors determine the migrant's duration of stay and how does this influence his optimal investment into human capital? Different from existing models of human capital investment over an individual's life cycle,[3] the optimal decision of a temporary migrant on how much to invest into his human capital during his stay in the host country depends crucially on a variety of parameters that either do not have to be considered in life cycle models, like the value a worker attaches to the stock of human capital acquired when leaving the labor market, or may be assumed to be constant among individuals, like the total duration of the worker in the labor market considered.

This paper will present a model to analyze the human capital investment and the path of earnings of temporary migrants who are "target savers": migrants who only intend to stay in the host country as long as it is necessary to accumulate a certain stock of savings and then return to their home countries.[4] The main concern of the

[3]see, e.g., Ben-Porath (1967), von Weizsäcker (1967), Haley (1973), Heckman (1976), Blinder and Weiss (1976) and Rosen (1976).

[4]There is ample evidence that migration from Southern- to Northern European countries over the last decades consists largely of target saving temporary migrants. Glytsos (1988) characterizes these migrants as *staying relatively short periods of time in the receiving country, accumulating considerable amounts of money, remitting part of it during their stay abroad and returning home with the rest.* He reports that, from the one million Greeks emigrating to West Germany between 1960 and 1984, 85% returned gradually home. Remittances over this period amounted to about $ 4 billion. Based on a representative sample from 1972, the "Bundesanstalt für Arbeit" found out that guest workers to West Germany transferred between 30% and 45% of their disposable annual income to their home countries. Furthermore, a part of migrant households accumulated a considerable stock of savings in Germany. Depending on the nationality, only 15% - 25% had firmly decided to stay in West Germany (see "Monatsberichte der Deutschen Bundesbank", April 1974). Dustmann (1990), using information from the "German Socio-Economic Panel", calculated that 68% of the guestworker population in West-Germany in 1984 intended to return to their home countries. Kumcu (1989) reports, using a survey conducted by the "Central Bank of the Republic of Turkey", that the marginal propensity to save of turkish households in West-Germany ranks between 0.21 and 0.48. Macmillan (1982) reports similar numbers concerning the saving behavior for migrants in other European countries. In an excellent and comprehensive survey on migration of Thai workers to countries of the Middle East Pitayanon (1986) reports that remittances of migrant workers are considerable and to a large proportion invested into savings. The temporary character of migration is implied by a contract system that allows the worker to stay only for a restricted period.

analysis will be to identify parameters that are responsible for differences in migrants earnings position and to investigate their impact on earnings profiles. The results will be illustrated by simulating the system. The analysis provides a systematic theoretical analysis of factors that may have an impact on the earnings situation of temporary migrants. The model has a variety of implications for empirical work.

In particular, section 2 outlines the assumptions and the basic model and describes the optimization problem of the migrant. Section 3 considers only the period of positive investment into human capital production and analyzes the impact of differences in individual characteristics on investment- and earnings profiles. Section 4 investigates the occurrence and length of corner solutions, i.e., intervals with zero or full investment into human capital. Section 5 summarizes the main results and points out the consequences for empirical analysis.

2 A Model of Human Capital Investment of Target Saving Migrants

2.1 The Target Saving Migrant

Why does temporary migration occur at all? Why should a migrant want to return to his home country after having worked for some years in the host country? According to Hicks (1932), the decision to migrate is simply induced by a higher rate of return on a unit of human capital stock in the host country (*net economic advantages*). Consequently, once having migrated, why should the migrant deliberately return to his home country? An answer would be that the consumption of an equal bundle of goods will yield different levels of utility, according to whether consumption takes place in the host- or in the source country.[5] Although the value of the migrant's stock of human capital may be higher in the host country, he may rather enjoy to consume in the home- than in the host country. More technically, if the marginal utility of consuming a given bundle of goods is higher in the home- than in the host country, and if, on the other side, the rental rate on a given stock of human capital is higher in the host- than in the home country, then migration is likely to be temporary. The argument is simple: in an intertemporal context, each unit of time the migrant offers to the labor market of the host country will increase his lifetime wealth by more than if this unit of time is offered to the labor market of the home country. It therefore increases his

[5]The utility gained by consuming a given bundle of goods may depend on the environment where consumption takes place, including friends and family.

lifetime consumption and lifetime utility. On the other side, each unit of time spend in the host country will enable the migrant to consume during this time in his home country. Since life is finite and the marginal utility of consuming a given flow of goods is higher in the source country, this will have a decreasing impact on lifetime utility. It is now intuitively obvious that there should be an optimal length of stay t^* in the host country.[6] Since marginal utility is lower, the migrant will consume relatively less in the home- than in the host country and, accordingly, accumulate a certain stock of savings. Before he migrates, he will have to optimally determine the size of savings to be accumulated, the length of stay and his consumption pattern.[7]

However, at the time of decision making, the migrant may not be fully informed about the labor market situation in the host country. Let the migrant assume, when solving his optimization problem, that he will not increase his stock of human capital once being in the host country. This seems not to be an unrealistic assumption: friends or returners may have informed him about the earnings he may expect, given his level of skills. Since he is not well informed about the foreign labor market, he may not be able to anticipate any possibility of an improvement of his earnings position by human capital investment and rather rely on his relatively certain information. He now determines the length of stay simultaneously with his saving target and his consumption pattern. Upon arrival in the host country, he acquires full information about labor market conditions. He then reoptimizes, being restricted concerning his saving target, because, e.g. prior precommitments, but being flexible concerning the duration of stay. Given wages and prices, the migrant can now influence the length of stay by investments into human capital specific to the labor market requirements of the host country. He will do so by solving a new optimization problem, with the objective to minimize the time necessary to achieve a given saving target.

In what follows, this sub-optimization problem of the migrant will be developed and analyzed in detail.

[6]In this framework, a permanent migrant is either characterized by a higher or equal marginal utility of a given bundle of goods in the host- than in the source country or by a corner solution of his optimization problem: the optimal time to be spent in the home country happens to be at least equal to his lifetime.

[7]For a thorough treatment of the migrant's optimization problem determining the optimal length of stay, the stock of savings to be accumulated and the consumption rate in a simple theoretical framework, see Djajic and Milbourne (1988).

2.2 The Basic Model

In the following analysis it will be assumed that at each point in time the migrant can choose between two activities: the production of human capital and the production of earnings. At any t, he will therefore allocate his time to either one or both of these purposes.[8] The larger the stock of human capital, the larger is the migrant's earnings potential, i.e. the earnings he would realize per unit of time rented to the market. Furthermore, an increase in the stock of human capital will, besides increasing the earnings potential per unit of time offered to the market, increase the productivity of time in the production of further human capital. Accordingly, the level of human capital positively influences the efficiency to produce further human capital.[9] Leisure time is not explicitly considered in this analysis. Assuming that in each period (or at each point in time) the fixed amount of time allocated to either one or both activities is smaller than the total amount of time available, leisure could be considered to be a part of the "rest time" of the individual (leisure time is "exogenous").

The migrant's earnings capacity at time t is given by

$$E(t) = wH(t) \tag{1}$$

where w is the rental rate on one unit of services of human capital and $H(t)$ is the stock of human capital at t. $E(t)$ is the migrant's earnings potential, i.e. the value of the maximum amount of services the migrant can offer to the labor market. In order to increase future earnings, the migrant may invest part of his human capital stock at t into the production of further human capital. Assuming for simplicity that the only input factor into the production of human capital is human capital itself, the production relation is characterized by the following expression:

$$K(t) = F(H(t)s(t)) = \psi f(s(t)H(t)); \quad F'(.) > 0, \quad F''(.) < 0. \tag{2}$$

where $K(t)$ is the flow of produced human capital. $F(.)$ is the production function, assumed to be twice differentiable and strictly concave in it's argument $H(t)s(t)$ and $s(t)$ is the fraction of the human capital stock invested into the production of further

[8]Note that in a discrete model context, the migrant would have to decide for every period about the fraction of time to be allocated to either activity. In a continuous formulation, every such period reduces to one point in time. Therefore, time in a continuous formulation has a dual role: it drives the migrant along his duration cycle, and, at each point in time, it has to be allocated to specific activities.

[9]This assumption follows Ben-Porath (1967) and Heckman (1976).

human capital. ψ is an ability parameter. ψ may vary among individuals. For the following analysis, it will be assumed that $F'(x)_{x \to 0} \to c$, with c : finite. $s(t)$ is constrained by

$$0 \leq s(t) \leq 1 \tag{3}$$

If $s(t) = 1$, all human capital will be devoted to the production of further human capital. "Measured" or "actual" earnings at any t, $Y(t)$, are the difference between the migrant's earnings potential, $E(t) = wH(t)$, and the forgone earnings by allocating a fraction of time to investment activities:

$$Y(t) = (1 - s(t))\, E(t) \tag{4}$$

Consumption in the host country will enter the migrant's optimization problem as a constraint: since his objective is not to maximize utility during his stay in the host country, but to minimize the time necessary to realize his saving target, it will be assumed that he wants to sustain a level of consumption so as to maintain a utility level that is in a fixed relation to that he realized in the source country.[10] However, the size of the flow of consumption necessary to yield a constant flow of utility is not necessarily constant over the migrant's stay in the host country. Adopting the hypothesis that the utility gained from consuming a bundle of goods depends on the consumption pattern of the social reference group,[11] such consumption will only produce a constant utility if the migrant will not change his social environment.

However, temporary migration is usually caused by a higher general wage level and a more favorable labor market condition in the host country, as compared to the home country. The country of immigration is generally characterized by higher standards of living, as compared to the countries of emigration. If the migrant integrates to a certain extend into the foreign society, he may gradually change his social reference group. Living initially in an environment consisting of compatriots, the migrant may slowly explore the foreign life style and adopt foreign consumption patterns. The utility he gains from a given bundle of goods may accordingly decline. The integration process will be correlated with migrants' efforts to accumulate country-specific human capital.

[10]Note that this assumption does not imply that the migrant will realize the same overall utility as in the home country; consider a separable utility function $U(c, X) = U[u(c), v(X)]$, where c is consumption and X are all other utility-creating arguments like family, friends, environment etc. Only the first part $u(c)$ is of interest here.

[11]The notion that the level as well as the composition of consumption is strongly dependent on the consumption pattern of the social reference group was first brought up by Duesenberry (1949).

Integration is often equivalent to wage-effective human capital investment: learning the language, adoption of foreign habits and the foreign nationality may often be a necessary requirement to obtain certain job positions. To maintain the prior level of utility, the migrant may have to change the composition as well as the amount of goods consumed. Therefore, the investment into country-specific human capital will, on the one side, increase the migrant's earnings capacity but, on the other side, may require him to increase his expenditures on consumption.[12]

Let the prior fixed level of utility from consumption be given by $\bar{u}$. Assume that $\bar{u} = u[c(t) - \gamma_1 G(H(t))] = ln[c(t) - \gamma_1 G(H(t))]$. $G(H(t))$ is the *integration function*, transforming a given stock of wage-effective human capital into *integration potential*. The coefficient γ_1 indicates in how far this integration potential is *consumption effective*, i.e. the degree to which integration implies an increase of consumption necessary to maintain a given level of utility. Solving for $c(t)$, the flow of consumption of goods can be written as follows:

$$c(t) = \gamma_0 + \gamma_1 G(H(t)); \quad G'(.) > 0; \quad G(H(0)) = 0; \quad \gamma_0 = e^{\bar{u}} \tag{5}$$

Integration is *accelerating* if $G''(.) > 0$, *decelerating*, if $G''(.) < 0$, and *constant*, if $G''(.) = 0$. In the analysis below, only constant and decelerating integration will be considered. If $\gamma_1 = 0$, the integration potential has no consumption augmenting impact. This would be the case if e.g. migrants, though having an integration potential given by $G(H(t))$, are forced to live in special districts so that imitation effects or adoption of foreign consumption patterns are not probable to occur or if consumption patterns in the host country are very similar to those in the source country so that integration does not have a consumption augmenting effect. One could also think of γ_1 to depend on e.g. religious motives that prohibit the adoption of certain consumption patterns.

The stock of human capital is changing according to the following equation:

$$\dot{H}(t) = K(t) - \sigma H(t); \quad H(0) = H_0 \tag{6}$$

σ is the rate of depreciation of human capital and H_0 the stock of human capital that is wage effective at the time of immigration. The total savings at t, or, equivalently, the change in the stock of savings, may be written (in real terms):

[12]To simplify the analysis, prices and availability of goods are assumed to be equal in both countries and the price level for consumption will be set equal to 1. Note that, since prices are equal in both countries, any change in size or composition of the migrant's consumption bundle is not due to changes in relative prices, but caused by a change in the migrant's social reference group.

$$\dot{A}(t) = rA(t) + w(1 - s(t))\,H(t) - c(t); \quad A(0) = A_0 \tag{7}$$

r is the interest rate, assumed to be constant over time, and A_0 is the stock of initial capital or savings. The migrant's optimization problem is now to minimize the amount of time necessary to accumulate a given saving target $\bar{A}$. He therefore solves the following optimization problem:

$$\begin{aligned} max \int_0^T -1dt \\ s.t. \quad (6),(7) \text{ and} \\ A(T) \geq \bar{A} \\ T \in [0, t_1] \end{aligned} \tag{8}$$

T is the point of return. Since T is endogenous to the problem, with t_1 as an upper bound, the optimization problem is one of a free-time horizon with one end point restriction.[13] Since neither the objective function nor the differential equations (6), (7) explicitly depend on t, the system is autonomous. In this formulation, the migrant has in each t to optimally decide about $s(t)$, the fraction of the existing stock of human capital to be invested into the further production of human capital, so as to steer the system from an initial state A_0 to the desired state $\bar{A}$ in a minimum amount of time.[14] The Hamiltonian for this problem is:

$$\begin{aligned} \aleph(H(t), A(t), \lambda_1(t), \lambda_2(t), s(t)) = -p_0 + \lambda_1(t)[rA(t) + w(1 - s(t))H(t) - \\ (\gamma_0 + \gamma_1 G(H(t))] + \lambda_2(t)[F(H(t)s(t)) - \sigma H(t)] \end{aligned} \tag{9}$$

[13]$[t_0\ t_1]$ is the maximal duration of stay in the host country. t_1 is the point of return the migrant considered, before leaving his home country, as necessary to realize a given saving target in the "worst case", i.e. without any further investment into human capital.

[14]If the duration of stay in the host country is legally restricted to a certain period length (e.g. Thai migrants in countries of the Middle East), the migrant would maximize the final amount of savings $A(T)$ in the given time subject to (6) and (7). Though the optimal paths of all variables are only identical if the saving stock achieved in the time restricted problem happens to be equal to the saving target in the free-time horizon problem (or v.v.), most of the following analytical results are valid in both cases. This follows from the structure of the optimization problem: in both cases, neither control variables nor state variables do appear in the objective function.

$\lambda_1(t)$, $\lambda_2(t)$ and p_0 are costate variables, associated with equations (7), (6) and the objective function, respectively. In addition to the initial conditions and (6) and (7), first-order necessary conditions for an optimum are:

$$\dot{\lambda_1^*}(t) = -\frac{\delta\aleph}{\delta A} = -r\,\lambda_1^*(t) \tag{9-a}$$

$$\dot{\lambda_2^*}(t) = -\frac{\delta\aleph}{\delta H} = -\lambda_1^*(t)[w(1-s^*(t)) - \gamma_1\, G'(H^*(t))] - \lambda_2^*(t)[F'(.)s^*(t) - \sigma] \tag{9-b}$$

$$\begin{aligned} &-p_0 + \lambda_1^*(t)[rA^*(t) + w(1-s^*(t))H^*(t) - (\gamma_0 + \gamma_1 G(H^*(t))] \\ &+\lambda_2^*(t)[F(H^*(t)s^*(t)) - \sigma H^*(t)] \begin{cases} = 0 & : \quad T < t^1 \\ \geq 0 & : \quad T = t^1 \end{cases} \qquad \forall t, \quad 0 \leq t \leq T. \end{aligned} \tag{9-c}$$

$$\lambda_1^*(T) \geq 0; \qquad \lambda_1^*(T)[A^*(T) - \bar{A}] = 0; \qquad \lambda_2^*(T) = 0. \tag{9-d}$$

$$[p_0, \lambda_1^*(t), \lambda_2^*(t)] \neq [0,0,0] \quad \forall t; \qquad p_0 = 0 \quad \text{or} \quad p_0 = 1. \tag{9-e}$$

$$\frac{\delta\aleph}{\delta s} = -\lambda_1^*(t) w\, H^*(t) + \lambda_2^*(t)\, F'(.)\, H^*(t) \begin{cases} \geq 0 & : \quad s(t) = 1 \\ = 0 & : \quad s(t) \in (0,1) \\ \leq 0 & : \quad s(t) = 0 \end{cases} \tag{9-f}$$

The interpretation of the costate variables λ_1 and λ_2 is straightforward. They indicate the shadow value of an additional unit of capital or human capital, respectively, in the maximization process. For the problem under consideration, $-\lambda_1(t)$ and $-\lambda_2(t)$ indicate the decrease of the time necessary to stay in the host country if $A(t)$ or $H(t)$, respectively, will be increased by a marginal unit. Condition (9-c) results from the special structure of the problem: since the duration of stay is endogenous and $A(t)$ is end point restricted, T has to be determined such as to set the value of the Hamiltonian for the optimal control- and state trajectories for all t equal to 0 (if the upper bound t^1 is not binding) or ≥ 0 (if the upper bound t^1 is binding).[15] $-\lambda_1(T)$ is then the decrease in the duration of stay if the saving target will be relaxed by one unit:

[15]To simplify the analysis, it will be further on assumed that the upper bound, which is equal to the maximum amount of time the migrant considers as necessary to achieve the given saving target, will not become binding: $T < t_1$.

$-\lambda_1(T) = dT/d\bar{A}$. From the complementary slackness condition in (9-d) it follows that $\lambda_1(T) = 0$ if $A(T) - \bar{A} > 0$, i.e. if the endpoint constraint is not binding. Since the problem is a minimal time problem, the constraint will be binding $\forall t$ if $\bar{A} > A_0$. p_0 is the costate variable associated with the objective function. Let $\int_0^T -1dt = x(T) = T$. Then $\dot{x}(t) = -1$ and $\dot{p_0} = -\frac{\delta \aleph}{\delta x(t)} = 0$. Consequently, p_0 is constant. For the problem under consideration, $p_0 > 0$ and, hence, $p_0 = 1$ without loss of generality.

The problem of the migrant in each t will then be to decide which fraction of the existing stock of human capital $H(t)$ to invest into the further production of human capital and which fraction to allocate to earnings activities. In each t the migrant uses as decision rule whether the investment of a marginal unit of human capital into the production of further human capital will be of more value, given his constrained objective, than allocating this unit to earnings activities. He has furthermore to consider that each additional unit of human capital produced will increase his stock of human capital and, therefore, promote integration and accordingly consumption expenditures.

In what follows the optimal path of $s(t)$ will first be analyzed. As obvious from (9-f), three policies may be considered to be optimal for some interval over the total time horizon $[0, T]$: (a) $s^* = 1$, (b) $s^* = 0$, (c) $s^* \in (0, 1)$. Section 3 only considers the case (c), i.e. an interior solution. The sensitivity of the path of the variables of interest to changes in individual characteristics will be analyzed in detail. Section 4 will then analyze the occurrence and duration of corner solutions ((a) and (b)).

3 The Optimal Policy in the Case of an Interior Solution

The main concern of the analysis in this section is not to investigate the path of investment into human capital and the resulting paths of human capital stock and observed earnings for a "typical" migrant. The intention is rather to investigate how changes in characteristics that are likely to differ considerably among temporary migrants are responsible for changes in investment- and earnings patterns. Such differences in characteristics would be the level of ability, the level of skills upon arrival in the host country, the total length of stay, which, in turn depends on the migrant's saving target, and the value the stock of human capital acquired in the host country has for the migrant upon return to the source country. Profiles are further affected by the degree to which an integration potential, acquired by human capital investment, becomes consumption effective. The general dynamics of the system as developed in section (3.1) corresponds to the profiles of a representative temporary migrant and will serve as a basis for comparative dynamic analyses in later sections, investigating the impact of differences in several characteristics on migrants' investment- and earning's paths. In the following discussion it will be differentiated between *investment cycle* and *duration cycle*. The duration cycle is the total period a migrant stays in the host country, while the investment cycle signifies only the period of positive investment into human capital.

3.1 The Optimal Path

Let $\eta(t) = \lambda_2(t)/\lambda_1(t)$ be the relative shadow price of human capital in terms of real capital. η would correspond to the incentive of a migrant to invest into human capital. For $s(t) \geq 0, s(t) \neq 1$, and using (9-a), (9-b) and (9-f), the change of this shadow price over time is given by the following expression:

$$\dot{\eta}(t) = \gamma_1 G'(H(t)) - w + \eta(t)[\sigma + r] \tag{10}$$

This is a non-homogeneous differential equation. Using the transversality condition which implies that $\eta(T) = 0$, the solution is given by:

$$\eta(t) = e^{(\sigma+r)t} \int_t^T e^{-(\sigma+r)\tau}[w - \gamma_1 G'(H(\tau))]d\tau \tag{11}$$

The relative shadow price of a unit of human capital, $\eta(t)$, is the sum of all future net marginal contributions of this unit to the objective function. Let $[w - \gamma_1 G'(H(t))] = \bar{\gamma}(t)$ be the marginal contribution of an additional unit of human capital stock. Accordingly, in the case of a decelerating integration, $G''(.) < 0$ and $\delta\,\bar{\gamma}(t)/\delta\,H(t) > 0$. In the case of a constant integration $\delta\,\bar{\gamma}(t)/\delta\,H(t) = 0$. Since $\eta(T) = 0$, which follows from the transversality condition, $\dot{\eta}(t) \leq 0$ if $\eta(0) > 0$.[16]

To simplify the following analysis, the integration function will first be assumed to be a linear function in H: $G''(H(t)) = 0$ and $G'(H(t)) = \gamma_1$. It follows that $\bar{\gamma}(t) = \bar{\gamma} > 0$. Accordingly, (11) simplifies to the following expression:

$$\eta(t) = \frac{\bar{\gamma}}{(\sigma + r)} \left[1 - e^{(\sigma+r)(t-T)}\right] \tag{12}$$

It is obvious from (12) that the size of $\eta(t)$ depends directly on the total length of stay, T, and on the degree to which some integration potential may become consumption effective, as indicated by γ_1. As mentioned above, differences in γ_1 may be

[16]Note that, if the stock of human capital acquired in the host country is of further use to the migrant after return to the home country, $\lambda^2(T) \neq 0$ and, accordingly, $\eta(T) \neq 0$. This case will be considered in section 3.2.4.

due to different cultures, religions and integration possibilities of individual migrants. Variations in ability level ψ and the stock of initial human capital H_0 do not influence η directly.

In what follows, the paths of the stock of human capital H, total investment sH, measured earnings Y, and the fraction of human capital reinvested into the production s, will first be analyzed for a typical migrant, without differentiating among individual characteristics.

The path of optimal investment decisions is determined by the equilibrium condition (9-f). For the interior solution, this relation reduces to

$$F'(s(t)H(t))\,\eta(t) = w\,; \qquad s \in (0,1) \tag{13}$$

Since the production function is strictly concave and $\dot{\eta}(t) < 0$, it follows directly from (13) that the total investment into human capital sH must be strictly monotonically decreasing over time: $(\dot{sH}) < 0$. This can be easily seen by inverting (13):

$$s(t)H(t) = \Gamma\left(\frac{w}{\eta(t)}\right)\,; \qquad \Gamma' < 0 \tag{14}$$

It follows that $s(t)\dot{H}(t) = -\Gamma'\,(w/\eta(t)^2)\,\dot{\eta}(t) < 0$. The decrease in sH may be either due to a decrease in the fraction of human capital invested into further production, or to a decrease in the stock of human capital or to a decrease in both variables. However, for any positive investment, the stock of human capital will rather increase than decrease as long as the depreciation of human capital will not overcompensate the production of new human capital. Therefore, as long as the stock of human capital is increasing, the fraction of human capital invested into further production has to decrease: $\dot{s} < 0$. Since the total input into the production of new human capital is steadily decreasing, the stock of human capital has to decrease towards the end of the investment cycle, if the depreciation rate is positive. Depending on the size of the change in η, s may then either increase or decrease, but it will eventually go to zero. Analytically, the optimal change in the stock of human capital over time can be easily obtained from (6) and (14):

$$\dot{H}(t) = F(\Gamma(\frac{w}{\eta(t)})) - \sigma\,H(t) \tag{15}$$

As long as $F\left(\Gamma\left(\frac{w}{\eta(t)}\right)\right) > \sigma\,H(t)$, i.e. the production of human capital overcompensates the decay of the existing stock of human capital, the stock of human capital will increase. Since the first term in (15) is decreasing over time and the second term is increasing, the stock of human capital peaks at some t and decreases thereafter. For $\sigma = 0$, the stock of human capital will increase over the whole investment cycle. Since $\ddot{H}(t) < 0$, $H(t)$ is a strictly concave function in t.

Solving equation (15) results in the following expression:

$$H(t) = e^{-\sigma t} H(0) + \int_0^t e^{-\sigma(t-\tau)} F(\Gamma(\frac{w}{\eta(\tau)}))d\tau \tag{16}$$

The stock of human capital at time t is the sum of the integral of all depreciation weighted investments into human capital in previous periods and the depreciated initial stock of human capital. Dividing (14) by (16) gives the optimal fraction of human capital to be invested into reproduction, $s(t)$. Differentiation with respect to t yields

$$\dot{s}(t) = -\frac{\Gamma'(.)\frac{w}{\eta^2(t)}\dot{\eta}(t)}{H(t)} - \frac{\Gamma(.)\dot{H}(t)}{H(t)^2} \tag{17}$$

The first term in (17) is always negative. The second term will be negative or zero for $\dot{H}(t) \geq 0$. Consequently, if there is no decay of human capital ($\sigma = 0$), $s(t)$ will decrease over the whole investment cycle. However, if $\sigma \neq 0$, the second term may temporarily become positive at the end of the cycle. This follows from (15): if $\sigma > 0$, $\dot{H}(t)$ may eventually become negative at the end of the investment cycle. If σ is sufficiently large, the second term in (17) may overcompensate the first term, inducing, consequently, $s(t)$ to increase again for a short period. However, since $\eta(t)$ is a monotonically decreasing function with $\eta(T) = 0$, it follows from (9-f) that, for $w > 0$, $s(T)$ must be equal to zero. Accordingly, s will finally decline, even if there may be intervals at the end of the investment cycle with $\dot{s}(t) > 0$.

How will measured earnings develop over the duration cycle? Measured earnings $Y(t)$ are given by equation (5). They are the difference between the migrant's earnings potential $E(t)$ and the fraction of human capital stock invested into the production of further human capital, valued with the rental price of human capital, w. The change in measured earnings is given by the following expression:

$$\dot{Y}(t) = w(1 - s(t))\dot{H}(t) - wH(t)\dot{s}(t) \tag{18}$$

The interpretation of (18) is straightforward: $\dot{H}(t)$ is the total change in the stock of human capital. If $\dot{H}(t)$ is positive, potential earnings $E(t) = wH(t)$ will increase by the evaluated change in human capital stock. Since, however, a part of this stock is reinvested into further production of human capital, the increase in measured earnings is reduced by the evaluated fraction s that is invested into the production process. Additionally, measured earnings will change by the evaluated change in the fraction $\dot{s}$ of human capital invested into the production process. This change is given by the second term in (18). Accordingly, as long as $\dot{H}(t) > 0$, it follows that $\dot{s}(t) < 0$. Measured earnings will steadily increase. In the case of a zero depreciation rate ($\sigma = 0$), earnings will increase as long as $s(t) > 0$. As if $s(t) = \dot{s}(t) = 0$ (which may occur not only in $t = T$, but also for some interval $[T - \theta, T]$ at the end of the duration cycle, as will be shown in section (4.2)), $\dot{Y}(t) = 0$. In the case of a positive depreciation rate ($\sigma > 0$), $\dot{H}(t)$ will become zero at some t and negative thereafter. If $\dot{s}(t) < 0 \; \forall \; t$, earnings will even then continue to rise as long as $(1 - s)\dot{H} - \dot{s}H > 0$. Measured earnings peak if $(1 - s)\dot{H} - \dot{s}H = 0$ and decline thereafter. Note that, consequently, measured earnings peak at a later point in time than human capital and potential earnings.

The main objective of the target saving migrant is to accumulate a certain stock of savings, $\bar{A}$. The change in the stock of savings is given by $\dot{A}(t)$. $\dot{A}(t)$ represents the savings of the migrant worker at t. Savings in t are the difference between income in t and consumption expenditures in t. Accordingly, the stock of savings for any t is the difference between the potential wealth in t, $PW(t)$, and the accumulated full consumption until t, $FC(t)$:

$$A(t) = PW(t) - FC(t) \tag{19}$$

with

$$PW(t) = A_0 e^{rt} + \int_0^t w[1 - s(\tau)]\, H(\tau) e^{r(t-\tau)}\, d\tau \tag{19-a}$$

$$FC(t) = \int_0^t [\gamma_0 + \gamma_1\, G(H(\tau))]\, e^{r(t-\tau)}\, d\tau \tag{19-b}$$

(19) is the budget constraint of the migrant. The change in the stock of savings over time, evaluated at $t = T$, is given by

$$\dot{A}(T) = rA(T) + [w\, H(T) - \gamma_1\, G(H(T)) - \gamma_0] \tag{20-a}$$

It follows from (20-a) and the additional condition (9-c):

$$\dot{A}(T) = \frac{p_0}{\lambda_1(T)} = \frac{1}{\lambda_1(T)} \tag{20-b}$$

Accordingly, $\lambda_1(T)$ is the increase in T if the saving target is expanded by one unit. For $w\,H(t) > \gamma_1\,G((H(t)) + \gamma_0\;\forall\,t$, this change is definitely positive. Consequently, the time being in the country does positively depend on the size of the saving target. It is shown in Appendix (A.1.1) that the total time horizon T is a strictly concave function of the saving target: $T = g(\bar{A})$, $g'(.) > 0$, $g''(.) < 0$.

Relations (19) and (9-c) close the system: They describe the optimal time being in the country, T, as a function of the saving target $\bar{A}$. They further determine, utilizing (13) additionally, $\lambda_1(0)$ and $\lambda_2(0)$ as functions of the parameters of the system. Some qualitative results on the dependence of the shadow prices λ_1 and λ_2 on the saving target are given in Appendix (A.1.2).

To summarize, if there is no depreciation of human capital and if it is optimal at the beginning of the duration cycle to invest a positive fraction of human capital into further production ($s(0) > 0$), total investment sH and the fraction to be reinvested s will both monotonically decrease over the whole cycle, while the stock of human capital, H, will increase. If, however, there is a decay of human capital stock, the stock of human capital will peak at some t and decrease thereafter. Total investment sH will decrease over the whole cycle. However, the fraction to be reinvested, s, may again increase for a short interval at the end of the investment cycle, but will eventually decline. For a zero depreciation rate, measured earnings will increase as long as the investment into the production of human capital is positive. If $\sigma > 0$, measured earnings will decrease at the end of the duration cycle. They will, furthermore, peak at a later point than human capital. Finally, as outlined in the appendix, the optimal time being in the country is a strictly concave function of the saving target.

3.2 Optimal Investment and Differences in Individual Characteristics

Analyzing differences in investment- and earnings profiles among migrants as a consequence of differences in individual characteristics, one has first to determine in which way such differences in characteristics will enter the system. As mentioned above, the crucial relation for the dynamics of the system is equation (13). Technically, since the rental rate for a unit of human capital, w, is constant, different investment- and earnings profiles among migrants result either from differences in the state and the rate of growth of η or from differences of the functional form and the arguments of $F(.)$. Since η is the relative shadow price the migrant attaches to any further unit of human capital, it would correspond to what is called in the literature an "investment incentive".

Variables that directly influence η would accordingly provide a direct incentive to invest into human capital. η directly depends on two variables that may differ among individuals: the total horizon of stay, T, and the effect of integration on consumption expenditures, $\gamma(t)$. Furthermore, the value of the stock of human capital, acquired in the host country, upon return likewise affects η. The ability level ψ influences the system via the production relation. The stock of initial human capital, i.e. the skill level upon arrival H_0, has an impact on the system by changing the necessary input of s in order to guarantee that (12) will hold.

This section analyses in which manner a change in each of the above characteristics will influence the course of the variables of interest. It is obvious that, since the system is closed and interdependent, a change in one characteristic will induce a change in another characteristic: for instance, a higher ability level (entering the system via the production function) will allow the migrant to achieve the same saving target in a shorter amount of time T (entering the system via η). To get an idea about the effect of changes in characteristics, the analysis below will only consider a change in one characteristic in relation (13). In the example above, a change in the level of a ability would be analyzed for a fixed T, implying that saving targets differ. Results of the comparative dynamic analysis are illustrated by simulating the system for a Cobb-Douglas production technology.[17]

Section 3.2.1. investigates the effect of changes in the level of ability. Section 3.2.2. considers changes in the initial skill level, section 3.2.3. the impact of a change in the time horizon (resulting from a change in the saving target) and section 3.2.4 investigates in which way different purposes after return influence the optimal path of human capital investment. Finally, section 3.2.5. analyzes in which way properties of the integration function and changes of the parameter γ_1 influence the system.

3.2.1 Different Levels of Abilities

The empirical finding that earnings of foreign workers overtake those of natives after an adaptation period is explained by migrants having greater innate abilities than native workers (see, e.g., Borjas (1989), Chiswick (1978, 1986), and Meng (1987)). However, it is not clearly specified in the literature in which way ability should have an

[17]Note that, in the case of a Cobb-Douglas type of technology, $F'(x)_{x\to 0} \to \infty$. Accordingly, it follows from (9-f) that $s(t) > 0$ for $t \in [0, T)$. Therefore, a Cobb-Douglas technology excludes a period for which $s = 0$ (except in T), as will be discussed in section 4. However, because of its simple properties, such technology will be used to simulate the optimal path of variables in the case of an interior solution.

impact on the migrant's earnings profile. Does an increase in ability steepen earnings profiles by providing an investment incentive? The comparative dynamic results of this section will point out the impact of a change in ability on earnings- and investment profiles. Results are illustrated by simulating the system, using a Cobb-Douglas type of production technology.

In equation (3), ability was introduced as a shift parameter ψ of the production function of human capital. This parameter may differ among migrants. Rewriting the production relation as $F(s(t)H(t)) = \psi\, f(s(t)H(t))$, inversion of (12) and differentiation with respect to ψ results in the following expression:

$$\frac{\delta\, s(t)H(t)}{\delta\, \psi} = \frac{\delta\, \xi\left(\frac{w}{\eta(t)\,\psi}\right)}{\delta\, \psi} = -\xi'\,\frac{w}{\eta(t)\psi^2} \tag{21}$$

where $\xi(.)$ is the inverse function of $f'(.)$. Strict concavity of the production relation implies that the expression in (21) is positive, for $t < T$. Accordingly, for any positive investment ($0 < s < 1$), the total input into the production of human capital at a given t will be the higher the higher the ability level. Whether this difference will increase or decrease over the whole investment cycle depends on the sign and the magnitude of the second derivative of the function $\xi(.)$.[18] Since, however, the path of η is not affected by changes in ψ, the gap between the total investment of migrants with different ability levels will eventually decline and vanish for $t = T$. It is outlined in Appendix A.2.2 that the stock of human capital is higher for a higher abled migrant throughout the investment cycle. Furthermore, a higher ability will lead to steeper human capital profiles and a later peak point in human capital stock. The fraction of human capital reinvested into further production of human capital is initially higher for migrants with a higher level of abilities, but will gradually adjust to the level of those with lower abilities.

Measured earnings are lower for the higher abled migrant at the beginning of the duration cycle and higher at the end of the duration cycle:

$$\frac{\delta\, Y(0)}{\delta\, \psi} < 0; \qquad \frac{\delta\, Y(T)}{\delta\, \psi} > 0 \tag{22}$$

Earnings profiles will accordingly cross over at some $t' > 0$. The optimal paths of investments, human capital stock and earnings are illustrated in figure 1-4. Figure 1 shows the profiles of total investment of migrants who differ only in their ability level (and, since T is assumed to be equal for both migrants, implicitly in $\bar{A}$). The dotted

[18]It is shown in Appendix (A.2.1) that the difference among profiles is decreasing if $\xi'' f' f'' < -1$.

line represents the investment path of the high ability migrant. His total investment is clearly higher than that of the migrant with lower abilities, but the difference declines over the investment cycle. Figure 2 illustrates the path of human capital and figure 3 the path of measured earnings. Note that for both migrants, measured earnings peak at a later point in time than the stock of human capital, as pointed out in the theoretical analysis. Furthermore, the high ability migrant reaches his peak point of human capital stock later than the low ability migrant. (see Appendix A.2). The earnings profile of the higher abled migrant is clearly steeper than that of the lower abled migrant. After being initially lower, earnings of the higher abled migrant "cross over" with those of the lower abled migrant and continue to increase more rapidly. Figure 4 illustrates the respective investment paths'. The fraction of human capital to be reinvested into the production process is higher for the higher abled migrant; however, profiles finally coincide.

To summarize , earnings profiles of high ability migrants are not only steeper than those of low ability migrants, but high ability migrants do also invest longer into human capital (this result is derived in Appendix A.2). Being initially lower, their earnings profiles will ultimately cross over with those of low ability migrants. Furthermore, ability does not provide an investment incentive. This follows directly from (12): $\delta\eta(t)/\delta\psi = 0$. Stronger investments and steeper earnings profiles are therefore not a consequence of incentives, but a consequence of lower marginal costs of producing human capital. The results support the hypothesis that higher ability of migrants would be an explanation for a cross-over of migrants' earnings with those of native workers.

3.2.2 Different Skill Levels upon Arrival

The initial stock of human capital that is specific to the labor market of the host country may vary considerably among migrants. The higher the divergence of labor market conditions between source- and host region, the lower will be the stock of initial human capital that is directly transferable to the needs of the foreign labor market. Accordingly, migrants from countries with labor markets that differ considerably from that of the immigration country will arrive with a low level of skills corresponding to the needs of the host country labor market. In the literature it is argued that, the larger the divergence between labor markets and, accordingly, the lower the migrant's level of skills applicable to the needs of the host country, the steeper would be the migrant's earnings profile (see, e.g., Chiswick 1978, 1986). It will be shown below that the initial level of skills, although changing the location of the migrants earnings profile, will affect its steepness only for a positive depreciation rate.

Differences in the level of skills upon arrival are captured in H_0. It follows directly from (14) that differences in H_0 do not affect the total investment into human capital:

$$\frac{\delta\, s(t)H(t)}{\delta\, H(0)} = 0 \tag{23}$$

Consequently, total investment into further human capital production will not vary among migrants with different initial skill levels. It follows from (14) and (15) that, for a zero depreciation rate ($\sigma = 0$), a higher stock of initial human capital results in a parallel upward shift of the human capital profile. However, if $\sigma > 0$, an increment in the initial skill level will shift the human capital profile upwards, but it will decrease the rate of growth of human capital:

$$\frac{\delta\, H(t)}{\delta\, H(0)} = e^{-\sigma\, t} > 0\ ; \qquad \frac{\delta\, \dot{H}(t)}{\delta\, H(0)} = -\sigma\, e^{-\sigma\, t} < 0 \tag{24}$$

If the depreciation rate is positive, profiles of human capital stock will peak at an earlier t' for migrants with a higher initial skill level: $(\delta\, t'/\delta\, H(0)) < 0$.[19] Figure 5 illustrates typical profiles of human capital stock for a positive depreciation rate. The dotted line represents the migrant with a higher initial stock of human capital.

The fraction reinvested into human capital production in $t = 0$, $s(0)$, must be lower the higher $H(0)$. This follows directly from (13). Since total investment into human capital is not affected by the initial stock of human capital, it follows immediately that the investment path is the flatter the higher $H(0)$. Investment paths' are illustrated in figure 6.

Measured earnings will follow the same pattern as the stock of human capital. For $\sigma = 0$, measured earnings will increase at a lower rate the higher the initial stock of human capital. This can be directly seen by rewriting (5):

$$Y(t) = w\, H(t) - s(t)H(t)\, w$$

Since $\delta[s(t)H(t)]/\delta H(0) = 0$, it follows that

$$\frac{\delta Y(t)}{\delta H(0)} = w\, e^{-\sigma\, t} \tag{25}$$

[19]The derivation of this result follows the same pattern as the respective result for different levels of ability, as outlined in Appendix A.2.2. Since $\dot{H}(t') = 0$, it follows that $\frac{\delta\, t'}{\delta\, H(0)} = -\frac{\sigma\, e^{-\sigma t'}}{F'\Gamma'\frac{w\dot{\eta}}{\eta^2}} < 0$.

For the non depreciation case, measured earnings profiles are parallel shifted by $wH(0)$. Earnings profiles are illustrated in figure 7, for $\sigma > 0$.

Accordingly, a change in the initial level of skills, although shifting the location, changes the slope of earnings profiles only by way of the depreciation rate. Since $\delta\eta(t)/\delta H_0 = 0$, a lower initial skill level does not provide any incentive effect, nor does it influence the marginal cost of producing human capital. In terms of an empirical analysis, skills upon arrival should mainly be explained by shifts in the intercept term. Slope coefficients should only change if the depreciation rate is large.

3.2.3 Differences in the Saving Target and the Length of Stay

The time the migrant intends to stay in the host country depends positively on his saving target $\bar{A}$ (see Appendix A.1.1). Depending on individual characteristics and situations, saving targets and, accordingly, durations of stay in the host country are likely to vary considerably among migrants.[20] The length of residence T directly influences the relative shadow price of a unit of human capital, η (see figure 8). Changes in T will therefore provide an investment incentive. It follows from (12) that a longer duration of stay has a positive impact on both, size and rate of change of η:

$$\frac{\delta\,\eta(t)}{\delta\,T} > 0\,; \qquad \frac{\delta\,\dot{\eta}(t)}{\delta T} > 0 \tag{26}$$

Differentiating (14) with respect to T, one can easily verify that total investment into human capital will likewise increase with a rise in T. Accordingly, migrants with the intention to stay longer in the host country should have a higher stock of human capital throughout their migration history. It follows from (15) and (16):

$$\frac{\delta\,H(t)}{\delta\,T} > 0\,; \qquad \frac{\delta\dot{H}(t)}{\delta\,T} = -F'\,\Gamma'\,\frac{w}{\eta(t)^2}\,\frac{\delta\,\eta(t)}{\delta\,T} - \sigma\,\frac{\delta\,H(t)}{\delta\,T} \tag{27}$$

The change in the growth of human capital is positive before the peak point $\dot{H} = 0$ is reached and negative thereafter. According to (27), and for $\sigma = 0$, the profile of human capital stock of a migrant with a longer intention to stay is steeper throughout the investment cycle.

[20]Qualitative results of the analysis apply as well if the time being in the country is restricted by e.g. immigration laws and the migrant wants to maximize the stock of savings during this period. A higher saving target would then correspond to a longer residence permit.

The fraction of human capital stock reinvested into further production is, for $t = 0$, the higher, the longer the horizon T. However, the evaluation of $\delta s(t)/\delta T$ for $0 < t < T$ is undetermined in sign.

$$\frac{\delta s(0)}{\delta T} > 0 \; ; \qquad \frac{\delta s(t)}{\delta T} = \frac{1}{H(t)} \left[\frac{\delta s(t)H(t)}{\delta T} - \frac{\delta H(t)}{\delta T} s(t) \right] \tag{28}$$

The first term in brackets of the second expression in (28) is the change in total input if T is changing. If $H(t)$ would not be affected by a change in T, this would exactly be the increase in $s(t)$ that is necessary to guarantee that the equilibrium condition (13) holds. However, since H is likewise affected by a change in T, the first term will be reduced by the change in the stock of human capital as a reaction in the change in T, multiplied with the fraction of human capital invested into further production. Since $(\delta H(0)/\delta T) = 0$, the second term is zero for $t = 0$, but will increase thereafter.

The change in measured earnings, induced by an increment in T, is given by the following expression:

$$\frac{\delta Y(t)}{\delta T} = w \left[\frac{\delta H(t)}{\delta T} [1 - s(t)] - \frac{\delta s(t)}{\delta T} H(t) \right] \tag{29}$$

The first term in (29) is the change in measured earnings, resulting from a change in human capital stock available for earnings activities. The second term is the cost increase which results from a higher investment effort as a consequence of an increase in T. It follows directly from (29) and $(\delta H(0)/\delta T) = 0$ that $(\delta Y(0)/\delta T) < 0$. Since $s(T) = 0$, $(\delta Y(T)/\delta T) > 0$. Accordingly, initial earnings are lower for those who intend to stay longer in the host country. Since their earnings paths are steeper, earnings are likely to cross over at some $t > 0$. Figure 9 illustrates the path of measured earnings for two identical migrants who differ only in their saving target and, therefore, T.

The analytical results indicate that the duration of stay of a migrant has a strong impact on his investment behavior and the steepness of his earning's profile. A longer duration of stay (and, accordingly, a higher saving target) provides an investment incentive by directly influencing the value of each unit of human capital acquired. If estimating earnings profiles empirically, an omission of this variable may accordingly lead to a considerable estimation bias.[21] This becomes obvious from fig. 9: If neglecting the impact of the duration of stay on earnings, and observing two otherwise identical

[21]Note that the appropriate variable in a non-deterministic world would be the *expected* total duration of stay.

migrants at t^*, one would accordingly impose the wrong restriction of identical earnings profiles on the estimation equation. An empirical test on the hypothesis that migrants who intend to stay longer in the host country should have steeper earnings profiles is provided by Dustmann (1990). The empirical findings support the results derived above.

3.2.4 Differences in Purposes after Return

Up to this point, it was assumed that the stock of human capital accumulated in the host country is of no further use for the migrant after return to his home country. This would be the case if, for instance, the migrant intends to retire after return and live on his savings accumulated in the host country. However, if the migrant has not only the intention to accumulate a certain stock of human capital, but, additionally, wishes to acquire certain skills that are of further use to him after return, the results of the analysis may change. For instance, the migrant worker may want to establish his own business in the home country for which he needs human capital that he can only acquire in the host country. Human capital acquired in the host country may as well help him to get better jobs upon return to the home country.[22]

In what follows, it will be pointed out in which way earnings profiles of migrants who intend to accumulate not only a stock of savings, but also some stock of human capital, differ from those of migrants who do not attach any value to the human capital acquired in the host country after return. Let $\eta^A(t)$ denote the relative shadow price of a unit of human capital for a migrant who wants to accumulate a certain stock of human capital. $\eta(t)$ is further defined as in (12). From the endpoint restriction on $H(T)$, i.e. $H(T) \geq \bar{H}$, where $\bar{H}$ is the level of human capital to be accumulated, it follows that $\lambda_2(T) \geq 0$ and $\lambda_2(T)(H(T) - \bar{H}) = 0$. After appropriately reformulating and solving the optimization problem, it follows:

$$\eta^A(t) = \eta(t) + e^{(\sigma+r)(t-T)}\eta^A(T) \tag{30}$$

It will further be assumed that the relative value of a unit of human capital in T is larger than zero: $\eta^A(T) > 0$.[23] Accordingly, it follows from (30) that $\eta^A(t) > \eta(t)\ \forall\, t$.

[22]The "training aspect" of temporary migration seems to be considered as an important positive effect by the countries of origin. Mehrländer (1980) reports that *employment abroad was expected to improve the training of the workers concerned, ultimately creating a larger reservoir of skilled labor in the countries of origin*(p.82).

[23]Note that this implies that the stock of human capital the migrant wishes to accumulate in the host country is larger than the stock of human capital he would acquire anyway (i.e. by solving the

The objective of the migrant to acquire a certain stock of human capital in the host country may therefore provide a positive incentive to invest into country specific human capital. Differentiation of (30) with respect to t reveals that the relative value of human capital decreases with a lower rate if $\eta^A(T) > 0$. This difference is the higher, the higher $\eta^A(T)$.

$$\dot{\eta}^A(t) = \dot{\eta}(t) + (\sigma + r)\, e^{(\sigma+r)(t-T)}\, \eta^A(T) \tag{31}$$

It is immediately obvious from (13), (30), (31) and the strict concavity of the production relation that total investment into human capital sH will be higher for a migrant who wishes to accumulate some stock of human capital.[24]

To analyze the effect of a change in the positive value of human capital stock in T on the path of human capital and measured earnings, one simply substitutes $\eta(t)$ by $\eta^A(t)$ and analyzes the change in the state and growth of the respective variables as a result of changes in $\eta^A(T)$. As outlined in Appendix (A.3), an increase in $\eta^A(T)$ will positively affect the stock of human capital $H(t)$ for all t and will have a steepening impact on profiles before and after the peak point of human capital stock. Furthermore, the initial fraction of human capital to be reinvested into further production in $t = 0$ is higher the higher $\eta^A(T)$. However, this difference will diminish over time.

Measured earnings change according to the following equation:

$$\frac{\delta\, Y(t)}{\delta\, \eta^A(T)} = w \left[\frac{\delta\, H(t)}{\delta\, \eta^A(T)} - \frac{\delta\, s(t)H(t)}{\delta\, \eta^A(T)} \right] \tag{32}$$

In $t = 0$, measured earnings of a migrant who wishes to accumulate some stock of human capital are below those of a migrant without such intentions. However, earnings may eventually cross over at some $t > 0$. Note that $(\delta Y(T)/\delta\eta^A(T))$ is not necessarily positive since $s(T)H(T) \geq 0$.

According to the above analysis, the migrant's intention to accumulate a certain stock of human capital in the host country is likely to provide an incentive to invest into human capital. Earnings profiles of such migrants are steeper, but it may take quite long until they cross over with those of comparable migrants without the intention to accumulate a certain stock of human capital until T. For the empirical analysis, the

formerly considered optimization problem that imposes no restriction on $H(T)$). If the constraint on $H(T)$ will not be binding, it follows from the complementary slackness condition that $\lambda_2(T) = 0$ and, consequently, the optimization problem would be equivalent to the one treated above: $\eta^A(t) = \eta(t)$.

[24]Note that, for $\eta^A(T) > 0$, $s(T)$ and $s(T)H(T)$ do not have to be equal to zero at the end of the investment cycle, as it is the case if $\eta(T) = 0$.

results indicate that migrants' intention to accumulate some stock of human capital has not only an impact on the size of the intercept, but also on slope coefficients.

The shadow value of human capital and the path of measured earnings are illustrated in figure 10 and figure 11. The dotted line represents the migrant with further intentions after return.

3.2.5 Differences in Consumption Patterns

Up to now the analysis merely considered a constant integration. Furthermore, no attention was paid to the size of γ_1, the parameter that indicates in how far a given integration potential becomes consumption effective. As pointed out above, the size of γ_1 may depend on the specific situation of the migrant in the host country. Legal restrictions and migration policy in the host country may cause γ_1 to be extremely small or even equal to zero. Cultural differences and religious motives may likewise restrict a given integration potential from becoming consumption effective, thereby reducing γ_1. Consequently, migrants from different countries and with different cultural backgrounds may differ considerably in the extend to which their acquired integration potential becomes consumption effective. If migrants of different origin are, additionally, treated differently in the host country, such differences will vary even more.

Furthermore, the integration function is not necessarily a constant function of the stock of human capital accumulated in the host country. Integration may well be decelerating. This would indicate that the human capital acquired for the foreign labor market at an early stage is more integration effective than more specific human capital acquired at later stages. This seems quite reasonable since early investments may comprise the adoption of working patterns, working rules and language, while later investments may be much more work specific and, therefore, less integration effective.

The following analysis will investigate the impact of a change in the parameter γ_1 on investment and earnings pattern for the case of a constant integration. Furthermore, constant integration will then be compared with decelerating integration.

A change in γ_1 has a direct and an indirect impact (via the integration function and the stock of human capital) on the relative shadow price of a unit of human capital, η:

$$\frac{\delta\,\eta(t)}{\delta\gamma_1} = \int_t^T e^{(\sigma+r)(t-T)} \left[-G'(H(\tau)) - \gamma_1 G''(H(\tau))\frac{\delta\,H(\tau)}{\delta\,\gamma_1}\right] d\tau \qquad (33)$$

In the case of a constant integration, the second term in (33) vanishes. Expression (33) is then definitely negative: The higher the extend to which a given integration potential becomes consumption effective, the lower the relative shadow price of a unit of human capital. An increase in γ_1 would therefore provide a negative incentive effect. However, if the integration process is decelerating, any additional unit of human capital will increase consumption expenditures by less than the former unit. An increase in the stock of human capital as a result of an increase in γ_1 will therefore raise the earnings potential by more than the integration potential. This effect is captured by the second term in (33). This indirect effect of a change in γ_1 should be considerably smaller than the direct effect. For $(\delta H/\delta \gamma_1) > 0$ (see below), it then follows that $G'(.) + \gamma_1 G''(.)(\delta H/\delta \gamma_1) > 0$. Accordingly, $(\delta \eta(t)/\delta \gamma_1) < 0$.

For the change in the total investment into human capital as a reaction of a change in γ_1, one obtains:

$$\frac{\delta s(t)H(t)}{\delta \gamma_1} = -\Gamma'(.) \frac{w}{\eta^2(t)} \frac{\delta \eta(t)}{\delta \gamma_1} \tag{34}$$

The expression in (34) is negative. Consequently, the higher γ_1, the lower is the total investment into human capital stock. Furthermore:

$$\frac{\delta H(t)}{\delta \gamma_1} = -\int_0^t e^{-\sigma(t-\tau)} F'\Gamma' \frac{w}{\eta^2(\tau)} \frac{\delta \eta(\tau)}{\delta \gamma_1} d\tau \tag{35-a}$$

$$\frac{\delta \dot{H}(t)}{\delta \gamma_1} = -F'\Gamma' \frac{w}{\eta^2} \frac{\delta \eta}{\delta \gamma_1} - \sigma \frac{\delta H(t)}{\delta \gamma_1} \tag{35-b}$$

It is obvious from (35-a) and (35-b) that, the larger γ_1, the lower the stock of human capital and the flatter profiles of human capital stock. The rate of change of human capital stock is lower before and after the peak point. One can easily show that, for small σ, the peak point t' of human capital stock will be the earlier the higher γ_1. The fraction to be reinvested into human capital in $t = 0$, $s(0)$, is the smaller the higher γ_1. However, this difference is decreasing over time. Measured earnings will change according to the following expression:

$$\frac{\delta Y(t)}{\delta \gamma_1} = w(1 - s(t)) \frac{\delta H(t)}{\delta \gamma_1} - wH(t) \frac{\delta s(t)}{\delta \gamma_1} \tag{36}$$

The first term in (36) is the impact on measured earnings of the change in γ_1 by changing the stock of human capital. For $t > 0$, this effect is clearly negative. The second term is the change in earnings due to a change in the fraction of human capital allocated to further investment into human capital. Since $(\delta s/\delta \gamma_1) < 0$, this effect on earnings is positive. It follows that $(\delta Y(0)/\delta \gamma_1) > 0$ (since $(\delta H(0)/\delta \gamma_1) = 0$) and

$(\delta Y(T)/\delta\gamma_1) < 0$. Accordingly, migrants who, due to either cultural and religious or legal restrictions, to a larger extent integrate into the foreign society in such a way that their integration potential becomes consumption effective, have higher measured earnings in the beginning of their duration cycle. This is due to a lower investment into human capital. At the end of the duration cycle, however, their earnings are lower. Earnings will cross over with those of migrants with a lower γ_1 at some $t > 0$.[25] Earnings paths are illustrated in figure 12. The results indicate that migrants who are not heavily restricted to integrate into the foreign society, neither by legal restrictions nor by cultural constraints, should have earnings profiles that are flatter than those of migrants who do not integrate so easily. The analysis supports empirical findings that migrants, who are culturally more different, have steeper earnings profiles (see, e.g., Chiswick (1978), Chiswick and Miller (1985), and Meng (1987)). However, the reason would not be that those migrants have a lower stock of readily transferable initial human capital upon arrival (see section 3.2.2), but rather that easy integration provides a disincentive effect for human capital investment and increases demand for consumption.[26] If estimating earnings equations, one should accordingly differentiate between variables that represent the level of skills of a migrant, explaining differences in the intercept term, and variables that measure the degree to which a migrant may adopt foreign consumption patterns, explaining differences in slope parameters.

The properties of the integration function will likewise influence the relative shadow price of human capital and, consequently, investment as well as human capital stock and earnings. Keeping γ_1 constant, the size of $\eta(t)$ depends on the second derivative of the integration function. The smaller $G''(.)$, the higher is $\eta(t)$ for any $t < T$. For illustration, consider the extreme case: if comparing a constant and a decelerating integration process, it follows from (10) and (11):

$$\Delta\eta(t) = \eta^D(t) - \eta^C(t) = \int_0^t e^{(\sigma+r)(t-\tau)} \left[\int_0^\tau \dot{\gamma}(s)ds\right] d\tau > 0, \text{ with } \dot{\gamma}(t) = [-\gamma_1 G''(.)\dot{H}(t)] \tag{37}$$

η^C, η^D are the relative shadow prices in the case of constant and decelerating integration, respectively. For $\sigma = 0$, $\Delta\eta(t)$ is a strictly monotonically decreasing function in t, with max $\Delta\eta = \Delta\eta(0)$ and min $\Delta\eta = \Delta\eta(T) = 0$. Since $\Delta\eta$ is the larger the smaller $G''(.)$, it follows that total investment will positively depend on the size of $-G''(.)$.

[25]Since the second term in (36) is very small, compared with the first term, the crossover point should be at an early stage.

[26]Note that an increase in w, the rental rate on human capital, would have an opposite effect, providing a positive investment incentive and thus generating earnings profiles that are steeper but starting out with lower earnings in $t = 0$.

Accordingly, human capital stock will increase faster, if integration is decelerating, as will measured earnings.

4 Full and Zero Investment

The analysis above is solely concerned with the optimal path of relevant variables if $s \in (0,1)$. However, it might well be the case that it is optimal for the migrant to invest all or none of his human capital into further production. The condition for a boundary solution to be optimal follows directly from (9-f):

$$F'(s(t)H(t))\,\eta(t) \begin{cases} \geq w & : \quad s(t) = 1 \\ \leq w & : \quad s(t) = 0 \end{cases} \tag{38}$$

The interpretation of (38) is straightforward: If the marginal benefit of all human capital, if invested into further production, is higher or equal to the marginal costs w that arise by drawing off the last unit from earnings investment, then $s(t) = 1$. Investment will be zero if marginal costs are higher or equal to the value of the marginal product of the first unit to be invested.

For the following analysis, recall the following property of the production relation:

$$F'(sH)_{sH \to 0} = \psi f'(sH)_{sH \to 0} \to c$$

Accordingly, the marginal product of the first or last infinitesimally small fraction of human capital invested into further production is finite and goes in the limit to c.[27]

The following analysis will investigate whether and in which order the policies of full and zero investment could be considered by the migrant to be optimal over some interval of his duration cycle. The dependence of the length of boundary policies on characteristics of the migrant will further be pointed out.

4.1 Full Investment

The first question to be answered is whether it is optimal for the migrant to invest over some interval his entire stock of human capital into the production of further

[27]Note that this condition is not fulfilled for a Cobb Douglas technology, which was used for simulation purposes, with $F'(x)_{x \to 0} \to \infty$, where $s(t) = 0$ will only occur if $\eta(t) = 0$. For any positive rental rate w, $s(t)$ will always be chosen small enough to fulfill (13), for $t < T$.

human capital, i.e. whether there exists a period for which $s(t) = 1$ forms an optimal investment policy. As obvious from (4), measured earnings would in this case be equal to zero. The shadow value of a unit of human capital for $s(t) = 1$ follows from the first order condition of the maximization problem and is given by the following expression:

$$\eta(t) = -\bar{\gamma}\left[\int_t^T e^{\int_\tau^T [(\sigma+r)-F'(.)]ds} d\tau\right] \tag{39}$$

It follows that $\eta(0) < 0$, $\eta(T) = 0$ and $\dot{\eta}(t) > 0$. Consequently, if $s(t) = 1$, $\eta(t)$ will always be smaller or equal to zero. This is in contradiction to the equilibrium condition (38): if $s(t) = 1$, $F'(.)\,\eta(t) \geq w$. If $w > 0$ and $F'(.) > 0$, $\eta(t) \leq 0$ will always contradict the equilibrium condition. Accordingly, there will be no period of full investment into the production of human capital over the whole duration cycle of the temporary migrant.[28]

4.2 Zero investment

From the equilibrium condition (38) follows that $s(t) = 0$ if $F'(.)\eta(t) < w$. Since $\dot{\eta}(t) \leq 0$, it follows that, whenever the evaluated marginal product of the first unit invested into the accumulation of human capital is smaller than the value of this unit if allocated to earnings activities, it would be optimal not to invest over the whole duration cycle. The size of the relative shadow price at 0, $\eta(0)$, depends crucially on the time the migrant intents to stay in the country, as can easily be seen from (12). The larger is T, the larger will be $\eta(0)$, keeping everything else constant.

It follows from (12) and (38) that the minimum length of stay necessary to induce the migrant to invest into the production of human capital is given by the following expression:

$$\tilde{T} = -\left[\frac{1}{\sigma+r}\right] ln\left(1 - \frac{w(\sigma+r)}{\bar{\gamma}F'(s(0)H(0))}\right) \tag{40}$$

Accordingly, if the migrant intends to stay less than $\tilde{T}$, it would be optimal for him not to undertake any investment into his human capital over his whole duration cycle. The critical $\tilde{T}$, below which no investment is worthwhile, depends on the migrant's

[28]The intuitive argument goes as follows: if $s = 1$, any unit of further human capital would rather increase than decrease the time being in the host country since further savings would not be accumulated, but savings would rather be used up. Since λ_2 indicates the decrease of time being in the country if the stock of human capital increases by one unit, the sign of λ_2 should change, which would then result in the contradiction outlined above.

individual characteristics as on global variables like w and r. For $\frac{w(\sigma+r)}{\bar{\gamma}F'(H(0)s(0))} < 1$, simple comparative statics reveal:

$$\frac{\delta \tilde{T}}{\delta \psi} < 0\,; \qquad \frac{\delta \tilde{T}}{\delta H(0)} > 0\,; \qquad \frac{\delta \tilde{T}}{\delta \gamma_1} > 0\,; \qquad \frac{\delta \tilde{T}}{\delta w} > 0\,; \tag{41}$$

Accordingly, the critical time a migrant has to stay in the host country to make any investment worthwhile is shorter the higher the migrant's level of initial skills, the higher the degree to which some integration potential becomes consumption effective and the higher the rental rate on a unit of human capital. Consequently, a migrant who is not likely to invest into human capital would be characterized as one with average or low abilities, but highly skilled, who is not restricted or constraint to adopt foreign consumption patterns and who intents to stay a relatively short time in the host country.

Assume now that T is large enough, so that the migrant will undertake some investment into his human capital. It then follows from (12) that the relative shadow price of human capital is decreasing over time, with $\eta(T) = 0$.[29] Consequently, since $\eta(t)$ is a continuous function, it follows from (38) that there must exist a period $[T-\theta, T]$, $\theta > 0$, without any investment, if the rental price for human capital, w, is positive. This period is characterized by the following inequality:

$$F'(s(\tau)H(\tau))\left[\frac{\bar{\gamma}}{(\sigma+r)}\left[1 - e^{(\sigma+r)(\tau-T)}\right]\right] < w; \quad \tau \in [T-\theta, T] \tag{42}$$

The size of θ depends on the parameters of the problem and the technology of human capital production as well as on the stock of human capital at $(T-\theta)$, $H(T-\theta)$. If human capital production is very inefficient, or if the rental price for human capital w is very high, θ may be quite large. In Appendix (A.2.5) it is shown that the length of the investment cycle depends positively on the level of ability. If $\theta \geq T$, no investment into human capital will take place over the whole duration cycle. This case is then equivalent to the one discussed above.

The above considerations assumed a linear integration function: each additional unit of human capital stock will increase consumption expenditures necessary to maintain a constant level of utility in a linear way. However, integration may as well be decelerating. In this case, $G''(.) < 0$. Accordingly, each additional unit of human capital acquired will, although raising the migrant's earnings capacity by w, increase his integration potential by less than the former unit. It follows that $\dot{\gamma}(t) = [-\gamma_1 G''(.)\dot{H}(t)] \geq 0$

[29]This is, of course, not the case if the stock of human capital accumulated is of further use to the migrant upon return, as analyzed in section 3.2.4.

for $\dot{H}(t) \geq 0$. By differentiating (10) with respect to t it can easily be shown that, if integration is decelerating, η decreases faster than in the case of a constant integration:

$$\ddot{\eta}(t) = -\dot{\gamma}(t) + \dot{\eta}(t)[\sigma + r] \tag{43}$$

Note that $\dot{\gamma} = 0$ if the integration is constant. It follows from (37) that $\Delta\eta(t)$, the difference between the shadow price in the case of constant and decelerating integration, is decreasing over time and vanishes for $t = T$. Accordingly, the length of a period over which η falls below a certain threshold $\bar{\eta}$ must be longer if integration is constant.

A period of zero investment $[T - \epsilon, T]$ will then be described by the following inequality:

$$F'(s(t)H(t)) \int_t^T e^{(\delta+r)(t-\tau)} \gamma(\tau) d\tau < w \; ; \qquad t \in [T - \epsilon, T] \tag{44}$$

If the integration is constant, $\epsilon = \theta$. If the integration is decelerating, $(\theta - \epsilon) = \alpha$, with $\alpha > 0$. The smaller $G''(.)$, the larger will be α. In other words: The length of the investment cycle depends positively on the size of $G''(.)$ and is largest for $G''(.) = 0$.

5 Summary and Conclusion

This paper analyzes human capital investment and earnings pattern of temporary migrants who are target savers. The main purpose is to investigate in a human capital framework the impact of those characteristics, which are likely to differ considerably among temporary migrants, on the migrant worker's earnings situation. The results are contrasted with the hypotheses in the literature which are used to explain empirical findings of earnings pattern of migrant workers. The analysis provides a variety of implications for empirical studies. The model could provide a theoretical basis for empirical work if estimating earnings pattern of temporary migrants.

The main findings could be summarized as follows:

(1) Defining changes in the relative shadow price of a further unit of human capital in the migrant's optimization problem as *investment incentives*, the time the migrant intents to stay in the host country, being an increasing function of his saving target, provides a positive investment incentive. The longer a migrant wants to stay in the host country, the steeper will be his earnings profile. If estimating earnings profiles of temporary migrants who are likely to vary considerably in their total duration in the host country, this variable should be crucial to explain differences in migrants'

earnings profiles. Furthermore, for migrants who only want to stay a short period in the host country it may be optimal not to invest at all into human capital. The critical time of stay necessary to make any investment worthwhile is relative longer for migrants with average or low ability levels, who are highly skilled and easily adopt foreign consumption patterns, and who emigrate to a high wage country.

(2) The intention to acquire some stock of human capital provides a positive incentive effect. If the migrant not only wants to accumulate some stock of savings, but additionally some stock of human capital which is of further use to him after return to his home country, he is likely to have a steeper earnings path, although his initial earnings position is lower. For empirical research, if estimating earnings equations for a population of temporary migrants, the value a migrant attaches to the stock of human capital acquired in the host country at the point of return may accordingly have an effect on the intercept as well as on slope coefficients.

(3) The more easily a migrant adopts foreign consumption patterns and integrates into the society of the host country, the lower should be his incentive to invest into human capital. Migrants who do not easily integrate and who, additionally, are constraint by cultural or religious motives or by legal restrictions to adopt foreign consumption patterns, should have relatively steeper earnings profiles. This would support empirical findings, indicating that earnings profiles of migrants coming from countries with considerably different cultural environments are relatively steep. However, the steepness of earnings profiles would then not be explained by the low transferability of the stock of human capital upon arrival, as it is often hypothesized.

A higher rental rate on human capital provides a positive incentive effect.

(4) The stock of human capital upon arrival, though shifting the location of the migrant's earnings profile, affects the steepness only by way of the depreciation rate. If the depreciation of human capital is equal to zero, a change in the initial stock of human capital shifts the earnings profile parallely. The consequence for empirical research would be that skill levels, although explaining differences in the intercept term, do not explain differences in slope parameters. The level of skills has no incentive effect.

(5) A higher level of ability does not provide a direct incentive to invest into human capital, but it lowers the marginal cost of human capital production. High ability migrants have steeper earnings profiles and longer investment cycles than those with low abilities.

The main conclusion would be that the earnings position of a temporary migrant strongly depends on variables that do not have to be considered if analyzing earnings of native workers or permanent migrants. For an empirical analysis, this means that reliable estimates of earnings equations of temporary migrants require a more detailed database than would be necessary when analyzing earnings paths of native workers or permanent migrants.

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A Appendix

A.1 The Impact of the Saving Target on the System

The Dependence of $\bar{A}$ on T

Assume, for simplicity, the case of constant integration, with $G(H(t)) = \gamma_1 H(t)$. For $A^*(t)$, $H^*(t)$ and $s^*(t)$ satisfying the necessary conditions (6), (7) and (9), relation (19) implicitly determines T for a given saving target $\bar{A}$. It follows by the implicit function rule:

$$\frac{\delta T}{\delta \bar{A}} = \frac{1}{r\bar{A} + H^*(T)(w - \gamma_1) - \gamma_0} > 0 \tag{45}$$

and, furthermore:

$$\frac{d[\frac{dT}{d\bar{A}}]}{d\bar{A}} = \frac{\delta^2 T}{\delta \bar{A}^2} = -\frac{r}{[H^*(T)(w - \gamma_1) + r\bar{A} - \gamma_0]^2} < 0 \tag{46}$$

Consequently, the minimal time necessary to stay in the country is a strictly concave function of the saving target $\bar{A}$: $T = g(\bar{A})$, $g' > 0$, $g'' < 0$.

The Dependence of λ_1^0, λ_2^0 on $\bar{A}$

λ_1^0 and λ_2^0 are the shadow values for a unit of capital and human capital, respectively, in $t = 0$. They both depend in size on the saving target $\bar{A}$. Some qualitative results will be given below.

Since $s^*(T) = \lambda_2^*(T) = 0$, it follows from (9-c) and (**??**):

$$\dot{A}^*(T) = \frac{e^{rT}}{\lambda_0} = rA^*(T) + (w - \gamma_1)H^*(T) - \gamma_0, \quad \text{with } A^*(T) = \bar{A} \tag{47}$$

Consequently:

$$\ddot{A}^*(T) = r\dot{A}^*(T) + \dot{H}^*(T)(w - \gamma_1) = \dot{A}^*(T)\left[r - \frac{1}{\lambda_1^0}\frac{d\lambda_1^0}{dT}\right] \tag{48}$$

It follows from (48):

$$\frac{d\lambda_1^0}{dT} = -\frac{\dot{H}^*(T)}{\dot{A}^*(T)}(w - \gamma_1)\lambda_1^0 \tag{49}$$

Since $\dot{H}^*(T) = -\sigma H^*(T)$, (49) is equal to zero for $\sigma = 0$. In the case of a positive depreciation rate ($\sigma > 0$), $(d\lambda_1^0/dT) \geq 0$, since $\dot{A}(t) = rA(t) + (w - \gamma_1)H(t) - \gamma_0 > 0\ \forall\, t$. It follows from (12) and (49):

$$\frac{d\lambda_2^0}{dT} = \frac{\bar{\gamma}}{[\sigma + r]}\left[1 - e^{-T(\sigma+r)}\right]\frac{d\lambda_1^0}{dT} + \bar{\gamma}\lambda_1^0 e^{-T(\sigma+r)} \quad (50)$$

Consequently, $(d\lambda_2^0/dT) > 0$ for $\sigma \geq 0$. However, the increase in the shadow value of a unit of human capital as a consequence of a change in T in $t = 0$ is the higher the higher the rate of depreciation. It follows:

$$\frac{d\lambda_2^0}{dT}_{\sigma>0} > \frac{d\lambda_2^0}{dT}_{\sigma=0} \quad (51)$$

Combining the above results with (45) yield:

$$\left.\begin{matrix} \frac{d\lambda_1^0}{d\bar{A}} = 0 \\ \frac{d\lambda_2^0}{d\bar{A}} > 0 \end{matrix}\right\} \text{for } \sigma = 0 \quad \left.\begin{matrix} \frac{d\lambda_1^0}{d\bar{A}} > 0 \\ \frac{d\lambda_2^0}{d\bar{A}} > 0 \end{matrix}\right\} \text{for } \sigma > 0 \quad (52)$$

Consequently, the size of the saving target will not affect the shadow value of a unit of human capital stock for any t (since $\lambda_1(t) = e^{-rt}\lambda^0$) if $\sigma = 0$. It will, however, positively affect $\lambda_1(t)$ for $\sigma > 0$. For any $\sigma > 0$, the shadow value of a unit of human capital in $t = 0$ will increase as a consequence of a change in the saving target. This impact on λ_2^0 depends positively on the depreciation rate of human capital.

A.2 Differences in Ability

Profiles of Total Investment

From (21), it follows directly for $(\delta\, s\dot{H}/\delta\,\psi)$:

$$\frac{\delta\, s\dot{H}}{\delta\,\psi} = \frac{\dot{\eta} f'}{\psi\eta}[\xi'' f' + \xi'] \quad (53)$$

The first term in (53) is negative. Accordingly, the difference in profiles of migrants with different levels of abilities is decreasing over time if the second term is positive. Since the derivative of an inverse function is the reciprocal of the derivative of the original function, $\xi' = (1/f'') < 0$. It follows that the gap between total investment profiles will narrow over the investment cycle if $\xi'' f' f'' < -1$.

Profiles of Human Capital Stock

It follows from (15) and $F(s(t)H(t)) = \psi f(s(t)H(t))$:

$$\frac{\delta\, H(t)}{\delta\,\psi} = \int_0^t e^{\sigma(\tau-t)}[f(\xi(.)) - \psi f'\xi'\frac{w}{\eta\psi^2}]d\tau > 0 \quad (54)$$

Furthermore, from (6):

$$\frac{\delta \dot{H}(t)}{\delta \psi} = [f(\xi(.)) - \psi f' \xi' \frac{w}{\eta \psi^2}] - \sigma \frac{\delta H(t)}{\delta \psi} \tag{55}$$

The first term in (55) is positive, the second term negative. It follows that, for a zero depreciation rate, higher abled migrants have a steeper profile of human capital stock. For $\sigma > 0$, the human capital profile of a higher abled migrant is steeper before and after the peak point.

In the peak point of human capital stock, $\dot{H}(t) = 0$. Accordingly, it follows from (15) that, for a given level of ability ψ, the peak point of human capital stock t' is implicitly determined by the following relation:

$$\psi f(\xi(\frac{w}{\eta(t')\psi})) = \sigma H(t') \tag{56}$$

It follows by the implicit function rule:

$$\frac{\delta t'}{\delta \psi} = \frac{f(\xi(.)) - \psi f' \xi' \frac{w}{\eta(t')\psi^2} - \sigma \frac{\delta H(t')}{\delta \psi}}{\psi f' \xi' \frac{w}{\eta(t')^2 \psi} \dot{\eta}(t)} \tag{57}$$

The denominator in expression (57) is positive, the numerator ambiguous in sign. However, it follows from (54) that the numerator is positive for small σ. In this case, human capital stock profiles of higher abled migrants are not only steeper before and after the peak point, but they peak at a later t. (Such a case is illustrated in figure 2).

Profiles of Investment

The change in the fraction of human capital invested into the production process as a result of a change in ability is given by

$$\frac{\delta s(t)}{\delta \psi} = \frac{-\xi' \frac{w}{\eta(t)\psi^2}}{H(t)} - \frac{\xi(.) \frac{\delta H(t)}{\delta \psi}}{H(t)^2} \tag{58}$$

Since $(\delta H(0)/\delta\psi) = 0$, the second term disappears for $t = 0$. It follows that $(\delta s(0)/\delta\psi) > 0$. Accordingly, the fraction of human capital reinvested into further production in $t = 0$ will be the higher, the higher the level of ability. However, the second term in (58) is increasing over time. Accordingly, the difference in investment profiles of migrants with different levels of abilities will diminish over time. Whether profiles of migrants with different abilities will coincide at some t depends on the properties of the production function. Note that, if the production technology is such that $f'(x)\lim_{x\to 0} \to \infty$, $s(t) = 0$ only for $t = T$. Profiles will coincide at the end of the duration cycle (exactly, in $t = T$), which is then identical to the investment cycle. Since a Cobb-Douglas type of technology has the above property, figure (4) illustrates such investment profiles for migrants with different ability levels. However, if $f'(x)\lim_{x\to 0}\to c$, the duration of the migrant may well be longer than his investment period. Furthermore, the length of the investment cycle is then depending on the ability level. This aspect is analyzed below.

Profiles of Measured Earnings

Inserting the optimal s^* and H^* into (4) and differentiating with respect to ψ yields:

$$\frac{\delta Y(t)}{\delta \psi} = w\int_0^t \left[e^{\sigma(\tau-t)}f(\xi(\frac{w}{\eta(t)\psi})) - \psi f'\xi'.\frac{w}{\eta(t)\psi^2}\right] d\tau + \xi'\frac{w^2}{\eta(t)\psi^2} \tag{59}$$

The kernel of the integral is positive for $t > 0$, the second term is negative for $t < T$. Accordingly, $(\delta Y(0)/\delta\psi) < 0$. At the beginning of the investment cycle, higher abled migrants have lower measured earnings. Earnings profiles will cross over at t', with $(\delta Y(t')/\delta\psi) = 0$. Since $(\delta Y(T)/\delta\psi) > 0$ (because the second term in (59) will eventually vanish at the end of the investment cycle), there will accordingly be a crossover point for some $t > 0$. If the depreciation rate is equal to zero ($\sigma = 0$), it follows from the strict monotonicity of the earnings function that the crossover point is unique. Note again that, depending on the production technology, the duration cycle may or may not coincide with the investment cycle.

Ability Level and Length of Investment Cycle

Let t'' characterize the end of the investment cycle. Consequently, $s(t'') = 0$. It follows by the implicit function rule:

$$\frac{dt''}{d\psi} = -\frac{\frac{\delta s}{\delta \psi}}{\frac{\delta s}{\delta t}} \tag{60}$$

$(\delta s/\delta\psi)$ is given by expression (58). However, for $s\to 0$, (58) can be written as:

$$\left[\frac{\delta s}{\delta \psi}\right]_{s\to 0} \to \frac{-\xi'\frac{w}{\eta\psi^2}}{H} \tag{61}$$

For $f'(sH)_{sH\to 0}\to c(H)$, expression (61) is greater than zero. It further follows for $\delta s/\delta t$:

$$\left[\frac{\delta s}{\delta t}\right]_{t\to t'} \to \frac{-\xi'\frac{w}{\eta^2\psi}\dot{\eta}}{H} < 0 \tag{62}$$

Accordingly, an increase in the level of ability will increase the length of the investment cycle: higher abled migrants do invest over a longer period into their human capital than do lower abled migrants.

A.3 Differences in Purposes after Return

Profiles of Human Capital Stock

If the constraint that requires that $H(t) \geq \bar{H}$ becomes binding, $\eta^A(T) > 0$. It follows:

$$\frac{\delta H(t)}{\delta \eta^A(T)} = -\int_0^t e^{-\sigma(t-\tau)} F'\Gamma' \frac{w}{\eta(t)^2} \frac{\delta \eta(t)}{\delta \eta^A(T)} d\tau \left.\begin{matrix} > 0 & : & \eta^A(T) > 0 \\ = 0 & : & \eta^A(T) = 0 \end{matrix}\right\} \tag{63}$$

Accordingly, the stock of human capital is higher for all t if the migrant intends to accumulate a certain stock of human capital higher than the stock of human capital he would accumulate anyway: $H(T)^F < \bar{H}$, with $H(T)^F$: stock of human capital acquired in the unrestricted problem. The change in the growth of human capital stock as a result in a change in $\eta^A(T)$ is given by the following expression:

$$\frac{\delta \dot{H}(t)}{\delta \eta^A(T)} = -F'\Gamma' \frac{w}{\eta^2(t)} \frac{\delta \eta(t)}{\delta \eta^A(T)} - \sigma \frac{\delta H(t)}{\delta \eta^A(T)} \tag{64}$$

For a migrant with further intentions after return the human capital profile will be steeper before and after the peak point. The peak point of human capital stock will be later for this migrant if σ is sufficiently small:

$$\frac{\delta t'}{\delta \eta^A(T)} = \frac{-F'\Gamma' \frac{w}{\eta^2(t')} \frac{\delta \eta(t')}{\delta \eta^A(T)} - \sigma \frac{\delta H(t')}{\delta \eta^A(T)}}{F'\Gamma' \frac{w}{\eta^2(t')} \dot{\eta}} > 0 \tag{65}$$

Profiles of Investment

The change in the fraction to be reinvested as a reaction in changes in $\eta^A(T)$ is given by:

$$\frac{\delta s(t)}{\delta \eta^A(T)} = \frac{-F'\Gamma' \frac{w}{\eta^2(t)} \frac{\delta \eta(t)}{\delta \eta^A(T)}}{H(t)} + \frac{F(\Gamma(\frac{w}{\eta(t)})) \int_0^t \left[e^{-\sigma(t-\tau)} F'\Gamma' \frac{w}{\eta(t)^2} \frac{\delta \eta(t)}{\delta \eta^A(T)} \right] d\tau}{H(t)^2} \tag{66}$$

It follows from (66) that $(\delta s(0)/\delta \eta^A(T)) > 0$. The migrant who wants to accumulate a stock of human capital higher than the one he would accumulate anyway will invest a higher fraction of human capital into further production in $t = 0$. However, since the second term in (66) is negative and increasing over time, this difference will diminish.

B The Sufficient Conditions

It remains to show that the necessary conditions are also sufficient for an optimum. While the standard approach in a fixed time problem to show optimality of an admissible pair,[30] that satisfy the necessary conditions, is to verify that the Hamiltonian exhibits certain concavity properties,[31], the construction of sufficiency conditions is more difficult for free final time control problems. A sufficiency theorem for free final time problem is provided by Seierstad (1984-b). The basic idea is to require a pair (x^*, u^*) not only to be optimal for one specific t, but to maximize the value function among all optimal fixed final time solutions over the period considered. However, such sufficiency conditions are likewise not applicable to minimal time problems. An admissible pair for a minimal time problem is optimal if there exists no other admissible pair, fulfilling the necessary conditions and the target conditions (i.e. some endpoint restrictions on the state variables) in a shorter time period and if the above mentioned concavity properties of the corresponding fixed time horizon problem are fulfilled. While the latter can be proved quite easily by employing the standard concavity conditions for the Hamiltonian, it is quite difficult to find general conditions to ensure the former requirement. A sufficiency theorem is provided by Seierstad (1984-a) (see also Seierstad and Sydsaeter (1987)). Although the condition imposed on the optimal solution is rather restrictive and its formulation not intuitively obvious, it seems applicable for the above maximization problem. The intuition of the condition will be given below. It will then be shown that the condition holds for the problem on hand.

Consider a minimal time problem, with x, λ, u being vectors of state- costate- and control variables, respectively. Assume that an admissible pair $(x^*(t), u^*(t))$, defined on the interval $[0, T]$, satisfies the fixed final time sufficient condition for some adjoint function $\lambda(t)$. It follows that[32]

$$\int_0^T f^0(x^*(\tau), u^*(\tau))d\tau - \int_0^T f^0(x(\tau), u(\tau))d\tau = \Delta \geq \lambda^*(T)(x(T) - x^*(T)) \qquad (67)$$

where $f^0(.)$ is the objective function and $(x(t), u(t))$ is any admissible pair. Note that, in a minimal time problem, $\Delta = 0$. Since a minimal time problem is only meaningful if at least one state variable has to hit a certain target, assume the endpoint restriction $x(t) \geq \bar{x}$,

---

[30]Let x be a vector of state- and u be a vector of control variables. An admissible pair (x, u) is one which satisfies the system of differential equations for the state variables, any boundary conditions on the control variables and the endpoint restrictions on the state variables.

[31]Mangasarian (1966) shows that the necessary conditions are also sufficient if the Hamiltonian is concave in state- and control variables. Arrow and Kurz (1970) proposed a generalization of the Mangasarian result. They show that it is sufficient that the Hamiltonian, maximized with respect to the control variables, is concave in the state variables.

[32]This result is derived in Seierstad and Sydsaeter (1977).

with $\bar{x} > x(0)$ and t the optimal endpoint. From the transversality conditions it follows for the optimal solution specified above:

$$(x^*(T) - \bar{x})\lambda^*(T) = 0 \tag{68}$$

For $\lambda(T) \neq 0$, it follows that $x^*(T) = \bar{x}$. Now, assume that, for some $t' < T$, there exists a pair $(\tilde{x}, \tilde{u})$, with $\tilde{x}(t') = \bar{x}$. Extend the pair $(\tilde{x}, \tilde{u})$ on $[t', T]$, with $\tilde{u}(\tau) = \tilde{u}(t')$ and $\tilde{x}(\tau)$ being the solution of the system for $\tilde{u}(\tau)$, $\tau \in [t', T]$. The core idea of the sufficiency condition provided by Seierstad (1984-a) is now to show that, if (x^*, u^*) fulfills the sufficient condition for the fixed time horizon problem with endpoint T, there exists no pair $(\tilde{x}, \tilde{u})$ for which $\tilde{x}(t') = \bar{x}$, with $t' < T$.

This is ensured if the pair $(\tilde{x}, \tilde{u})$, defined on $[t', T]$, has the property that:

$$\dot{\tilde{x}}(\tau)\lambda^*(T) \geq 0, \qquad \tau \in (t', T) \tag{69}$$

with strict inequality in at least one τ. To see this, note that $\int_{t'}^{T} \dot{\tilde{x}}(\tau)\lambda^*(T) = \tilde{x}(T)\lambda^*(T) - \tilde{x}(t')\lambda^*(T) > 0$. Consequently, $\tilde{x}(T) > \bar{x}$. Furthermore, for $\lambda^*(T) \neq 0$, $x^*(T) = \bar{x}$. Accordingly, it follows that $\lambda^*(T)(\tilde{x}(T) - x^*(T)) > 0$, which contradicts (67). As a result one can state that, if the pair (x^*, u^*) fulfills the fixed time sufficient conditions for an optimum on $[0, T]$ and if (69) is fulfilled $\forall t' \in [0, T]$, then (x^*, u^*) is optimal.

Applied to the problem above, sufficiency of a solution defined on the interval $[0, T]$ is ensured if the optimal pair of control- and state variables fulfills the necessary conditions and if the Hamiltonian, maximized with respect to the control, is concave in the state variables (Arrow and Kurz (1970)). For the control s^* fulfilling conditions (6), (7), and (9), the quadratic form of the Hamiltonian is given by:

$$d^2\hat{\mathcal{H}} = -\lambda_1\gamma_1 G''(.)dH^2 \tag{70}$$

Consequently, the Hamiltonian, maximized with respect to the control variables is either concave or strictly concave, depending on whether the integration function is linear or decreasing in the stock of human capital, H, respectively. The solution $[A^*, H^*, s^*, T]$, fulfilling the necessary conditions, with $A^* \geq \bar{A}$, is accordingly optimal in the fixed final time problem defined on $[0, T]$. It remains to check whether condition (69) holds for all $t' \in [0, T]$. The target of the problem is to require that $A(T) \geq \bar{A}$, with $H(T)$ free. It follows that $\lambda^*(T) = \lambda_1(T) > 0$. Now, for any $t' \in [0, T]$, expression (69) is given for the problem on hand:

$$\lambda^*(T)\,\dot{\tilde{A}}(\tau)\,, \qquad \text{with } \tau \in (t', T) \tag{71}$$

Let $A(t') \geq \bar{A}$. From the optimality conditions it follows that $s(t') = 0$ and, consequently, $s(\tau) = 0$, $\forall \tau \in (t', T)$. Therefore:

$$\dot{\tilde{A}}(\tau) = rA(\tau) + wH(\tau) - \gamma_0 - \gamma_1 G(H(\tau)) > 0 \quad \forall \tau \in (t', T) \tag{72}$$

(72) implies that $\tilde{A}(T) > A^*(T) \geq \bar{A}$. It is directly obvious from the above explanations that this contradicts the sufficiency conditions for the fixed final time problem. Consequently, the solution $(A^*(T), H^*(T), s^*(T), T)$ is optimal.

C Figures

FIG. 1: TOTAL INVESTMENT.

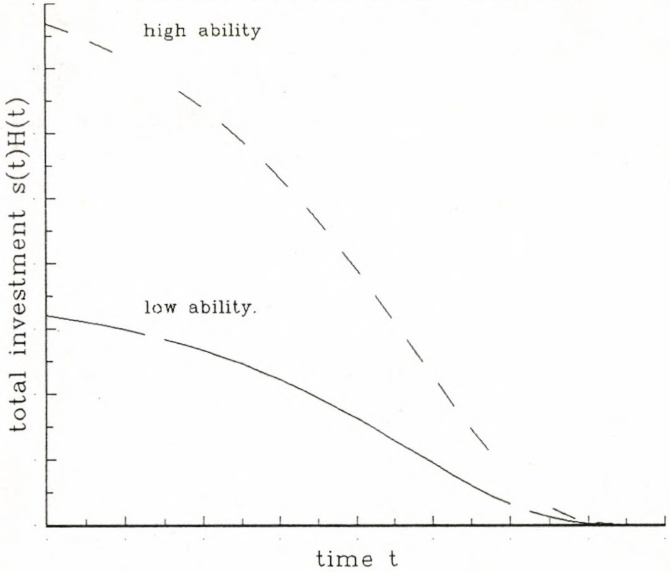


FIG. 2: HUMAN CAPITAL

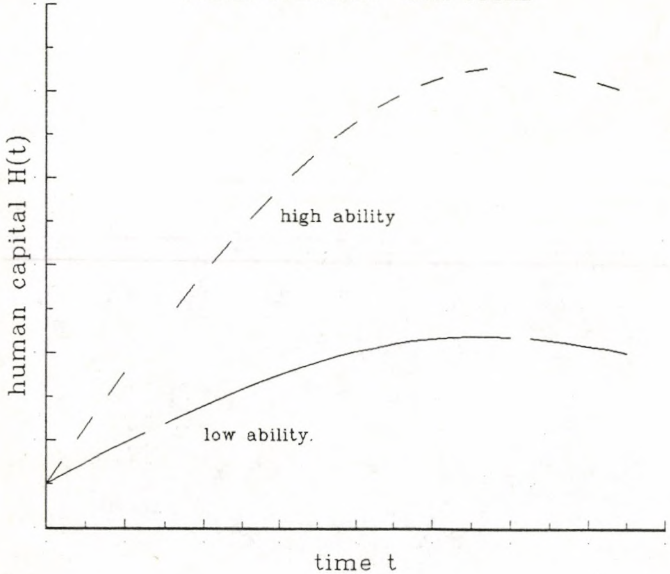


FIG.3: MEASURED EARNINGS

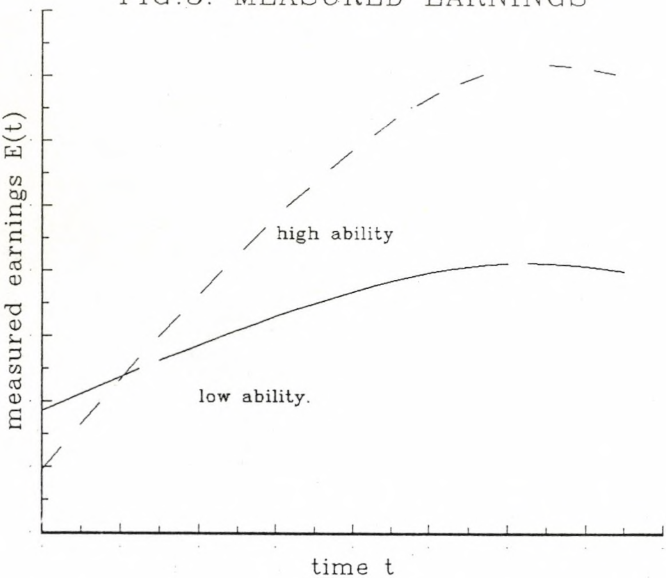


FIG.4: FRACTION INVESTED

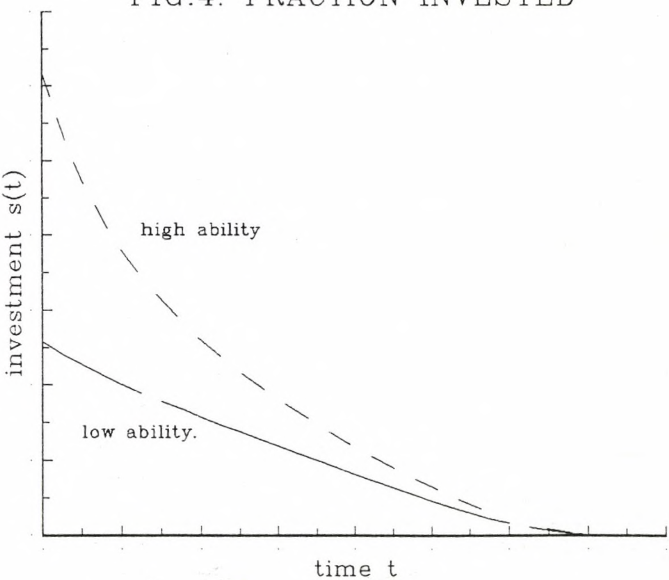


FIG.5: HUMAN CAPITAL

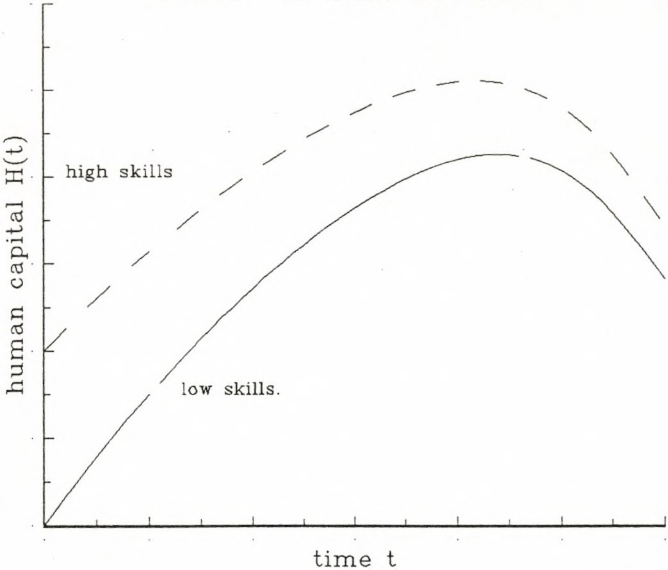


FIG.6: FRACTION INVESTED

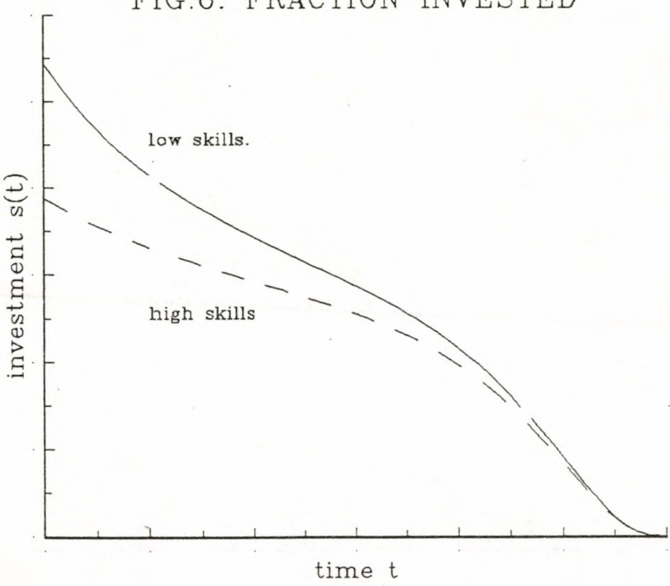


FIG.7: MEASURED EARNINGS

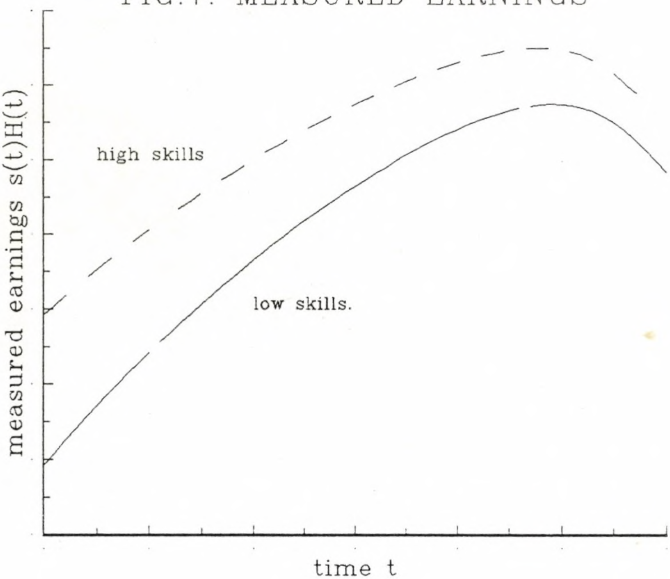


FIG.8: SHADOW PRICE

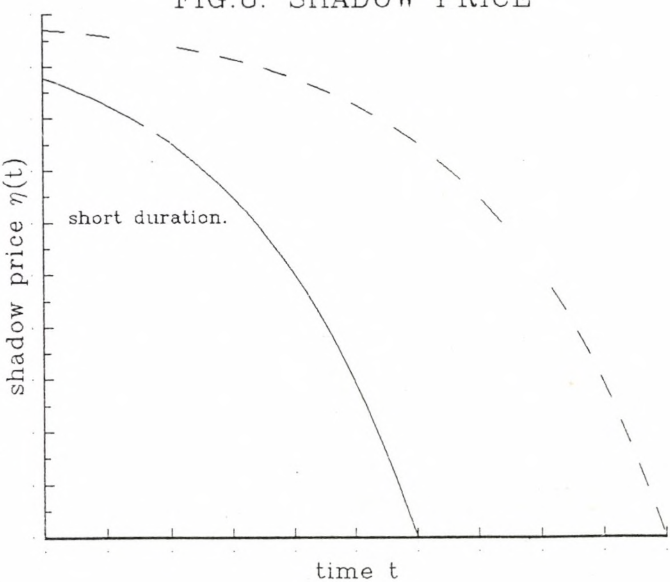


FIG.9: MEASURED EARNINGS

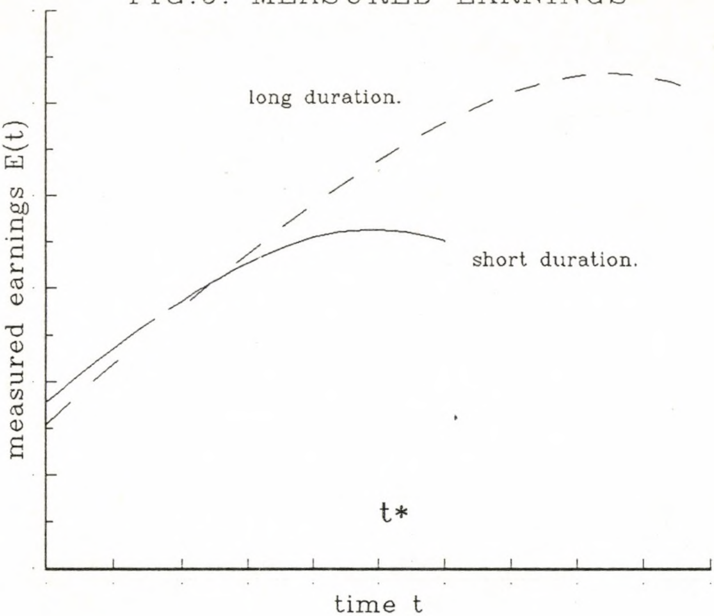


FIG.10: SHADOW PRICE

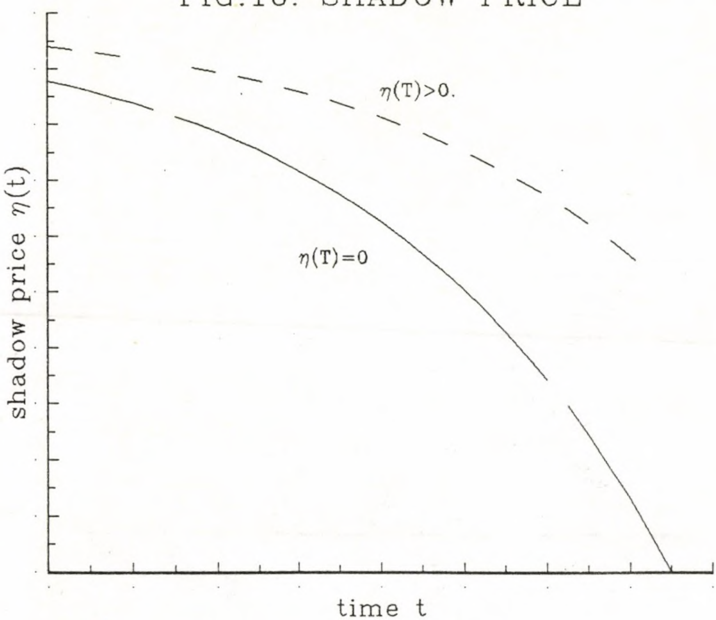


FIG.11: MEASURED EARNINGS

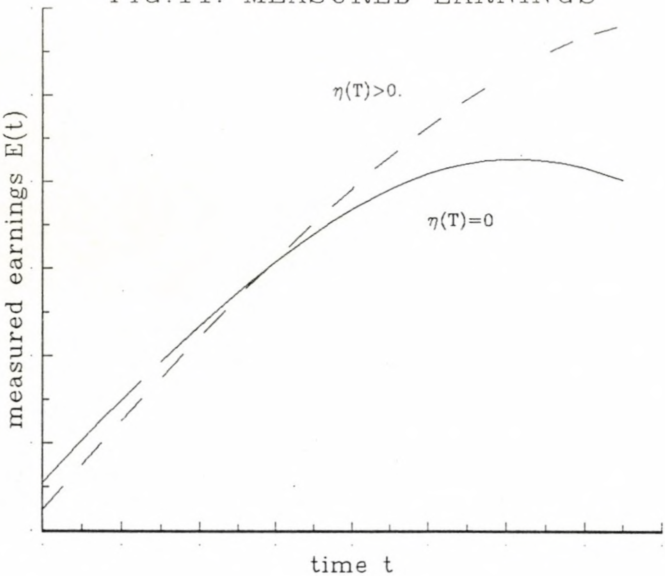
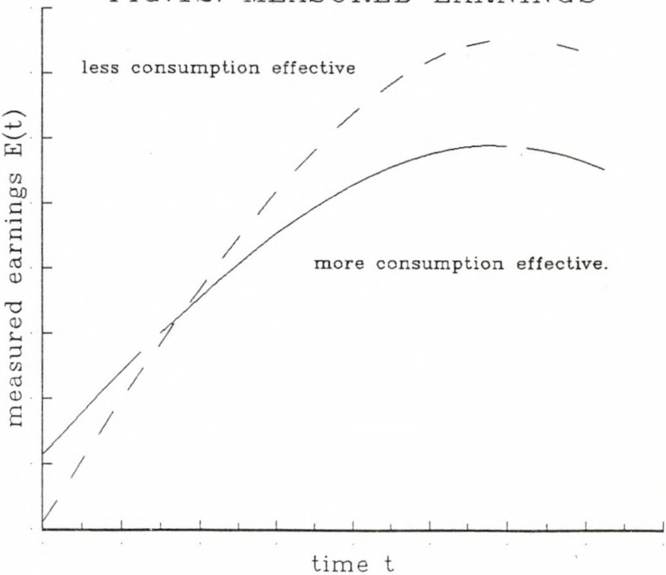


FIG.12: MEASURED EARNINGS



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