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Satiation and Underdevelopment

Peter Funk

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Abstract

In this article we show how absolute poverty and per capita growth can be sustained simultaneously in a fully integrated world economy even in the absence of population growth. In contrast to the literature we use a model of endogenously sustained growth in which not only the *intensity* of progress is determined endogenously, but also the *direction* of change. The essential assumptions driving the results are that once a person has satisfied his basic needs, he prefers high-quality commodities to low-quality commodites and that innovation-possibilities within high-quality sectors are not unskilled labour-using.

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Wirtschaftspolitische Abteilung, Universität Bonn, Adenauerallee 24-26, D 53113 Bonn

Tel.: 49-228-739230, Fax: 49-228-739221, e-mail: or106@unitas.or.uni-bonn.de

1 Introduction

Both the persistence of extreme poverty of a large percentage of the world population as well as continuous growth of *aggregate* world production and consumption during the past centuries are empirical facts that can hardly be denied. Though world wide real income has risen continuously even in *per capita* terms, it is doubtless that the persistence of poverty is at least partly due to a tremendous population explosion. Is population growth the only crucial factor for sustained misery in a growing world economy? Would continuous growth of aggregate output eventually benefit *all* mankind if population growth could be brought to a halt? Those who argue that actual poverty release programs, income redistribution schemes and minimal wages are little effective or even counter-productive in the battle against poverty, can they explain the decline in absolute poverty observed in some countries by simply referring to the market forces of a growing economy?

In this article we show how poverty and growth can be sustained simultaneously in a fully integrated world economy even in the absence of population growth.

In contrast to the literature we use a model of endogenously sustained growth in which not only the *intensity* of progress is determined endogenously, but also the *direction* of change. Given the state of knowledge in each period there is a set of perceived potential innovations. Which of these potential innovations are actually implemented depends on their expected profitability. Although innovations that improve the well-being of the poor are feasible throughout the whole course of development, they turn out not to be sufficiently profitable to be actually carried through.

The essential assumptions driving the result are (1) relative satiability in low-quality commodities by the wealthy and (2), innovation-possibilities in high-quality commodity industries are not biased in favor of unskilled labor. They conform with empirical observation as well as with the more applied literature. The implications of these assumptions are strengthened furthermore if, in addition, the empirically well established negative correlation between wealth and education on the one hand and fertility on the other hand is assumed.

Induced technical progress. In a framework in which the direction of technical progress is determined endogenously one might expect that a persistent decrease in relative prices of one factor should make innovations profitable that use this factor relatively intensively.

As Hicks [1932] has put it:

> "· · · A change in the relative prices of the factors of production is itself a spur to invention, and to invention of a particular kind – directed to economizing the use of a factor which has become relatively expensive."

If this were so, factor-incomes should develop in the long term on a more or less balanced path due to the forces of induced technical progress.

One can, in fact, show quite generally that the income shares of no factor can *persistently* fall in the course of development if the evolution of innovation is sufficiently symmetric with respect to the different factors and if, for factors that are substitutes, there are sufficiently strong spill-overs from progress that saves one factor to progress that saves other factors (Samuelson [1965], Funk [1995]). However, why should innovation possibilities evolve symmetrically? The proposition saying that growth cannot be extremely unbalanced concerning factor income shares does not hold if the evolution of innovation possibilities is not sufficiently 'balanced'. In our framework the evolution of innovation possibilities is described by an exogenously given 'innovation function' which defines a set of potential innovations for each state of knowledge. Clearly, the shape of this function plays a decisive role for the purpose of this chapter.

Since it seems obvious that one can 'explain' any bias in the evolution of factor incomes if one assumes a sufficiently strong bias in the 'innovation function', we try to built in such biases only where we have very good reasons to do so and we assume symmetry otherwise. The only asymmetry that we will assume is that *innovation-possibilities within sectors are not unskilled labor using.* This essentially means that the efficient scale ratio of skilled to unskilled workers is not lower for potential innovations than for known technologies. Without that assumption unskilled labor using innovations would be chosen whenever unskilled labor becomes cheap relative to other factors.

Dual Economy. We use a Lewis [1954]-type two sector model with one low-quality sector employing mainly unskilled workers and one high-quality industrial sector employing both unskilled and skilled workers.

In such a framework continuous growth of the unskilled labor productivity in the low-quality sector would eventually lead out of the underdevelopment trap. Thus we need to show that productivity growth mainly occurs in the skilled labor intensive sector. This is a hypothesis in much of the literature on growth and inequality (even in the 'new growth literature', see for instance Matsuyama [1992]), which in our framework should be derived endogenously.

Thus we have to explain *why* there is insufficient unskilled labor using progress in the low-quality sector. In our simple model without capital this simply means that we have to explain why there is insufficient productivity growth (In an extension we discuss how this can be adapted to allow for capital using progress in the low-quality sector without endangering the present results). As we have mentioned we do not want to restrict the set of *possible* innovations unless we have good reasons to do so. While there may be a priori reasons to assume that most engineering ideas allowing to improve upon high-quality commodities are unlikely to be unskilled labor-using, we cannot find equally good reasons to assume that there are *no* possible innovations in low-quality sectors. Correspondingly, we stick to the rule that innovation *possibilities* are more or less symmetric between sectors. We show, however, that once the high-quality technologies are sufficiently developed, it will no longer be sufficiently *profitable* to further develop the low-quality sectors. For this aim we use the empirical regularity that the demand for low-quality products obeys Engel's Law. More precisely, we will assume that *once a person has satisfied his basic needs, he has a strict preference for high-quality commodities*.

In general, unbalanced productivity growth between two sectors does not necessarily imply unbalanced evolution of the factor incomes in the two sectors. Depending on the elasticities of substitution in consumption and on the resulting demands for the two outputs, factor incomes in the low-quality sector may grow as fast as those in the high-quality sector, even if productivity growth is very unbalanced between the sectors. However, Engel's Law also excludes this possibility (In this respect our explanation conforms with standard explanations for rising inequality).

Engel's Law could not account for persistent poverty if productivity growth in and between the two sectors were balanced. With unbiased development in the two sectors real income of unskilled labor *in terms of low-quality products* would rise even if their income in terms of high-quality products would fall.

Human capital accumulation. We have argued that the one systematic bias in the evolution of innovation-possibilities that we belief to be empirically justified is one against unskilled labor in the high-quality industry. We have mentioned this as one condition necessary to allow for the persistence of poverty. Of course, to get our results, we have to make sure that a fraction of individuals remains unskilled in the course of development. Whether a person is skilled or not should at least partly be explained endogenously. We assume that skill is a function of past and present education and that education in turn is a function of wealth. Thus, persistent poverty of the unskilled also prevents the unskilled to escape their fate by acquiring education.

International Trade. It seems natural to address the question of sustained poverty and growth in a framework of international trade (although the essence of the present article does not depend on this).The coexistence of less developed countries (LDC's) and high developed countries (HDC's) matters. In order to emphasize the accidental nature of which country is a LDC and which is a HDC we assume that initially all countries are identical in per capita characteristics, except that one part of the world has an initial lead of a certain number of periods compared to the rest of the world. Under autarchy all countries, as well as all classes in all countries, smoothly develop along identical lines. Under free trade, however, the endogenous choice of innovations persistently hinders the development of the wealth (and the skills) of the landless unskilled workers in the LDC. Underdevelopment, caused and sustained by free trade, is directly linked to an increase in polarization in the LDC. Note that factor mobility (between countries) is not crucial for the results.

The Kuznets Curve. In his work on the relation between growth and inequality Kuznets [1955, 1966] has argued that income inequality first rises and then declines with development. A substantial literature has tried to test the corresponding 'Kuznets Curve' using cross-section data and to furnish theoretical explanations. The explanation for the lower-income branch of the Kuznets Curve given in Williamson [1991], for instance, much resembles that of the present paper. In particular Williamson argues that countries like Korea or Taiwan were no good candidates for the Kuznets Curve, possibly because they underwent substantial land reforms at early states of industrialization. In our framework poverty can persist only in countries with a distinct class of workers that own no land. The 'virtuous East Asians' don't fit well, India and the 'bad Latin Americans'[1] do fit

[1] In a recent study Cowell et al. [1995] show that over the previous decade (1981 to 1990) Brazil, with the world's tenth largest GDP, and the largest GDP of all LDC countries, underwent an increase in income

well, concerning assumptions as well as concerning results. In contrast to Kuznets and some of the following literature we do not claim that there are any laissez-faire forces that automatically reverse the trend towards rising inequality when development proceeds. It simply depends on whether the unskilled eventually manage to acquire skill.

The new trade literature. In recent years a large number of articles have begun to reexamine the findings of the static gains from trade literature in dynamic models of trade, endogenous technological progress, and of growth (see for instance Lucas [1988], Grossman and Helpman [1991, chapter 9], Matsuyama [1992], Young [1991], Stokey [1991]). In particular this 'new trade' literature has given conditions under which trade can dampen technological progress and output growth in some of the trading countries. The aim and the nature of the arguments of the present paper differ from those of the development branch of the 'new trade' literature in several aspects.

First, the present analysis differs in what it tries to explain. Most models of the 'new trade' literature work with a 'representative consumer' for each of the trading countries. Correspondingly, the increase of inequality in these models is one between LDC's and HDC's. Endogenous polarization within the LDC's plays no role. Furthermore, the increase of inequality between LDC's and HDC's is measured in relative terms. Though trade may *reduce* the rate of aggregate output growth in a LDC, it will typically not obstruct sustained growth of aggregate output in that country. In addition, due to the usual static gains from trade, reduced output growth in the LDC does not necessarily mean that the welfare growth of the representative consumer in the LDC is reduced. In contrast, underdevelopment in the present paper means *sustained* poverty in *absolute* terms.

Second, the present analysis partially differs with respect to the *causes* of sustained underdevelopment. In the literature the effect of trade on output growth and technological progress in a given country mainly depends on whether static comparative advantage leads the country to specialize in a sector with a high rate of technical progress. Whether there is little or much technical progress in a given *sector* is not determined within the models. As for most of growth theory, growth is one-dimensional by assumption. There is one possible path of technological development in each country (with only their speeds derived endogenously). In contrast, the key feature of the present approach is the endogenous

inequality according to all standard inequality indices.

determination of the *direction* of change. Persistent poverty and growing inequality arises rather directly from the fact that the resources, necessary for change, systematically flow away from innovations that would benefit the initially unskilled of the LDC. Furthermore our arguments also hold in a fully integrated world economy. They do not crucially depend on either restricted or unrestricted factor mobility and may be applied to persistent poverty (of the unskilled for instance) within national economies.

The remaining of the article is organized as follows. In section 2 the model of development is introduced and preferences, technologies, and innovation-possibilities are specified. Section 3 describes equilibrium development under autarchy and under free trade. In section 4 we discuss extensions and the robustness of the results (with respect to preferences, innovation-function, technologies, factor mobility, knowledge spillovers).

2 The Framework of Development

As an illustration consider the following introductory story. The world consists of two continents A and B. For centuries the two continents develop independently without knowing about their mutual existence. Initially, the full labor force is devoted to the production of the most basic commodities. The resources that can be used to improve technological knowledge are scarce. In each period the profit expectations of different innovations determine which innovations are chosen. Development of improved technologies reduces the cost of production in terms of labor and land. Once a sufficiently high level of consumption is reached, workers start substituting parts of their consumption of basic commodities for leisure and education. This in turn will make profitable the introduction of more sophisticated technologies necessary for the production of higher quality outputs. Wealth and education also improve the art of navigation to an extent that the first sufficiently developed continent discovers the other continent. After the discovery there is world-wide free trade and free access to all traditional technologies. As before, the scarce resources that are necessary to carry forward technological knowledge are used to implement those innovations that guarantee the highest profits. The two continents are symmetric in all (per capita) aspects except that one continent (A) has an initial lead of n periods over the other (B). If navigation were impossible the two continents would develop along identical lines. At time t continent B would be in the position that continent A had held at time $t-n$. However, navigation becoming possible with development, continent A *will* discover continent B. What are the effects of the discovery on the continuation of development of the two continents?

A formal description of the model follows. There are two continents A and B. For expositional simplicity it is assumed that there is a new generation of individuals in every period (more generally, one can consider an overlapping generations model, see Funk [1995b]). The area of continent $C \in \{A, B\}$ is L_C and the population size of C is N_C. L_B/L_A is large and while $(L_A/N_A) = (L_B/N_B)$.

We first specify a very simple class of preferences, endowments, technologies, and innovation possibilities that reflect the key features of the corresponding elements of the introduction.

Commodities and preferences. In each country a low-quality commodity and a high-quality commodity can be produced. Consumers can in principle consume all four commodities and they can spent their time on work, education or leisure. Within continents, across continents and across generations they have an identical utility function $u(x, e, y_1, y_{A2}, y_{B2})$, where x is the number of hours worked per day, e is the number of hours spent for education (with $x+e \leq \bar{x}$), $y_1 = y_{A1}+y_{B1}$ is the total amount of low-quality commodities consumed, and where (y_{A2}, y_{B2}) are the amounts of high-quality commodities consumed. One can think of y_{C1} and y_{C2} as two varieties of food differing in quality, but identical in nutritional value. This interpretation suggests, that hungry consumers do not much care for education, leisure and quality, while satiated consumers do care for all these. What is needed for our results is firstly, that the marginal rates of substitution (MRS) between low-quality and education (u_1/u_e) is large if a consumer is hungry (i.e. if the total quantity consumed is below a certain level $\underline{y} > 0$ (the hunger-line)) and secondly, that the MRS between low-quality and education (u_1/u_e) as well as the MRS between low-quality and high-quality (u_1/u_{C2}) are small if a consumer is satiated.

For easier exposition we are a bit more specific: Firstly, the hungry have no desire for leisure or education:

$$\exists \underline{y} > 0 : \frac{u_e}{u_1} = |\frac{u_e}{u_x}| = 0 \text{ if } y_1 + y_{A2} + y_{B2} < \underline{y}. \tag{1}$$

Secondly, the satiated *do* care for education and their marginal utility of a low-quality commodity is nowhere greater than that of a high-quality commodity:

$$\exists \overline{y} > \underline{y} > 0 : \frac{u_e}{u_1} > y_1 + y_{A2} + y_{B2} \text{ if } y_1 + y_{A2} + y_{B2} > \overline{y} \text{ and } e = 0, \tag{2}$$

$$\frac{u_{C2}}{u_1} > 1 \text{ if } y_1 + y_{A2} + y_{B2} > \overline{y}. \tag{3}$$

Thus, in the present formulation, the 'satiation' in low-quality commodities needs not be very strong. Complete satiation in low-quality by the wealthy would mean that both $\frac{u_e}{u_1}$ and $\frac{u_{C2}}{u_1}$ are infinite for $y_1 + y_{A2} + y_{B2} > \underline{y}$ and $e = 0$, in which case (2) and (3) would be satisfied. Later we will see that strengthening the satiation in low quality (increasing (u_{C2}/u_1) from 1 to ∞) will allow to weaken the assumptions on the innovation-function.

Preferences are standard in all other aspects, i.e. preferences for (y_{A2}, y_{B2}) given the quantities of the other commodities are strictly convex and $\frac{u_{A2}}{u_{B2}}$ tends to zero (infinity) if y_{A2} (y_{B2}) tends to infinity and y_{B2} (y_{A2}) remains bounded.

Every worker owns one unit of labor. Besides labor, the production of consumption commodities requires land. Land on both continents is owned by a class of local landlords and, in the present section, landlords cannot work.

Education and skill. In principal both y_{C1} and y_{C2} can be produced on continent $C \in \{A, B\}$. The low-quality commodity can be produced with the labor of uneducated workers (and with land), whereas the high quality commodity needs in addition the labor of workers with sufficiently high education $\tilde{e} > \underline{e}$.

Education accumulates from generation to generation, i.e. at period t, $\tilde{e}^t$ is the level of education a given individuum inherits from his mother plus the education e^t he consumes himself. This kind of accumulation of education is for instance assumed and defended in Lucas [1988]. The relevant aspect concerning education and skill for our purpose is a strong correlation between real income, education and skill. In section 4 we comment on the possibility to finance education by means of credit if individual consumers live longer than a single period.

The initial level of education at $t = 0$ is zero for all individuals.

Individual firm's technologies and the state of knowledge. The state of knowledge on each continent in a given period t is defined as the set of technologies that can be used by individual firms at t. Technologies are partially land-specific. This means that B-technologies cannot directly be used on A-land and vice versa. In other words, intercontinental knowledge spill-overs are limited or subject to imitation costs. At time t the technology of an individual firm producing commodity h on continent $C \in \{A, B\}$ is $Y^t_{Ch} = \{(x_u, x_s, l, y) \in I\!R^4_+ \mid f^t_{Ch}(x_u, x_s, l) \geq y\}$, where x_u is unskilled labor, x_s is skilled labor, l is land.

All individual production functions are of the form

$$f^t_{Ch}(x_u, x_s, l_C) = \begin{cases} 2a^t_{Ch}(G^t_{Ch}(x_u, x_s, l_C) - c^t_{Ch})^{1/2} & \text{if } G^t_{Ch}(x_u, x_s, l_C) \geq c^t_{Ch} \\ 0 & \text{otherwise,} \end{cases} \tag{4}$$

where $G^t_{Ch}(\cdot)$ has the form of a standard constant returns to scale production function.

Aggregate technologies and temporary equilibrium. The aggregate technology $\hat{Y}^t_{Ch}$ producing commodity h on continent C is the smallest cone containing the technology Y^t_{Ch} a single firm can use. The aggregate production functions F^t_{Ch} corresponding to the technologies Y^t_{Ch} are the usual linear homogeneous macroeconomic production functions. Given technological knowledge at period t we will consider competitive equilibria in the economy with these aggregate technologies. The idea is that in a sufficiently large economy with free entry to all existing individual technologies aggregates behave as if the economy were perfectly competitive given the appropriate constant returns technologies. [2]

For the class of individual production functions specified in (4) it is easy to verify that the aggregate production function corresponding to $\hat{Y}^t_{Ch}$ (i.e. the smallest cone containing Y^t_{Ch}) is

$$F^t_{Ch}(x_u, x_s, l) = \frac{a^t_{Ch}}{\sqrt{c^t_{Ch}}} G^t_{Ch}(x_u, x_s, l). \tag{5}$$

[2] Note that this appraoch corresponds to the traditional view on perfect competition. For a formal foundation see Novshek and Sonnenschein [1978] (in a General Equilibrium Cournot framework) or Funk [1996a] (in a General Equilibrium Bertrand framework). If consumers would live longer than a single period, we had to consider temporary equilibria, see Funk [1996b]. In the present framework, the competitive equilibria given a state of knowledge are degenerate temporary equilibria.

For the sake of exposition we further specify the function G^t_{Ch}. In the low-quality industry no skill is required (but skilled labor can in principle do the unskilled job) and concerning land and labor the function is of the Cobb-Douglas type:

$$G^t_{C1}(x_u, x_s, l) = (x_u + x_s)^{\alpha^t_{C1}} l^{1-\alpha^t_{C1}}.$$

In the high-quality industry both skilled and unskilled labor are needed. They are needed in fixed proportions γ^t. Concerning land and labor the function is of the Cobb-Douglas type:

$$G^t_{Ch}(x_u, x_s, l) = [(1 + \gamma^t) \min\{x_u, (x_s/\gamma^t)\}]^{\alpha^t_{C2}} l^{1-\alpha^t_{C2}}.$$

The compound labor, $\min\{x_u, (x_s/\gamma^t)\}$, is normalized such that for the same parameters (a, c, α) the efficient mix of skilled and unskilled labor ($x_s = \gamma^t x_u$) can produce as much of y_2 as they can produce of y_1. The assumption of fixed unskilled-skilled labor ratios in high-quality technologies will allow to determine the wages for unskilled labor in both sectors independently of its productivity in the high-quality sector, as this is the case in Lewis' dual economy. This simplifies calculations. If this specification is relaxed we need a stronger bias in the innovation function (see section 4). The Cobb-Douglas specification is not relevant.

Innovation possibilities and innovations. We first define innovation possibilities for the case of two autarchic continents. Given the state of knowledge $\{Y^t_{C1}, Y^t_{C2}\}$ in C at t there is a set of perceived potential innovations. There is an *innovation-function* that defines a set of potential innovations for each state of knowledge. On each continent there are scarce resources that can be used to improve upon existing technologies. In order to concentrate on the simplest case that allows to study the direction of change we assume that the resources of one continent just suffice to implement one innovation per period. Thus, one of the potential innovations can be chosen by an innovator. A more elaborated model would introduce a full-fledged market for innovations and would allow for innovations that differ in their resource requirements (see Funk [1995b]). All this is not relevant for the points we want to make here. In essence, what is required for our arguments is that the resources for change in a period are too costly to implement *all* the perceived potential innovations of that period.

We specify a very simple innovation function that serves our aims and satisfies the requirements of the introduction. All potential innovations are neutral with respect to all three factors, i.e., they do not affect the parameters γ and α (what matters is that γ can not be increased). Given a state of knowledge, parametrized by the collection of vectors $(a^t_{Ch}, c^t_{Ch}, \gamma^t_{Ch}, \alpha^t_{Ch})_{h\in\{1,2\}}$, an innovator in C has the choice between two potential innovations. He can choose a low-quality technology producing y_{C1} or a high-quality technology producing y_{C2} with the following parameters:

$$\begin{cases} \text{produce } y_{C1} \text{ with parameters} & (\sqrt{\theta}a^t_{C1}, \frac{1}{\theta}c^t_{C1}, \gamma^t_{C1}, \alpha^t_{C1}), \\ \text{produce } y_{C2} \text{ with parameters} & (\sqrt{\theta}a^t_{C2}, \frac{1}{\theta}c^t_{C2}, \gamma^t_{C2}, \alpha^t_{C2}), \end{cases} \tag{6}$$

where $\theta > 1$.

Note that the simple formulation with θ constant over time corresponds to the usual assumption in endogenous growth models that the productivity of research grows exponentially (for biassed innovation function and changing parameters θ see section 4).

The innovator can use his innovation as a monopolist for one period. His technology is small compared to the aggregate technology of the competitive sector. Thus, one can neglect the question of how the profits of the innovator are distributed. Furthermore, the innovator can take as given all prices of the competitive sector and chooses the innovation which guarantees the highest profits.

Imitations. After one period, there is free entry in C also to the new technology, and profits of the previous innovator are reduced to zero. Correspondingly, the new aggregate technology in the industry of the innovation is the smallest cone containing the improved technology used by the innovator. If Ch is the chosen industry at t in our example, then the aggregate production function at $t+1$ in sector Ch is

$$F^{t+1}_{Ch}(x_u, x_s, l) = \frac{\sqrt{\theta}a^t_{Ch}}{\sqrt{c^t_{Ch}/\theta}} G^t_{Ch}(x_u, x_s, l) = \theta F^t_{Ch}(x_u, x_s, l). \tag{7}$$

Development. Depending on the new state of knowledge there is a new set of potential innovations (defined by the innovation function) of which the most profitable is carried through, which in turn defines the state of knowledge of the next period. Thus, we get a sequence of states of knowledge, which we call **equilibrium development of knowledge**, and a corresponding sequence of temporary equilibrium allocations and prices, which, as before, we call **equilibrium development.**

Autarchy and free trade. Innovation-function and equilibrium development as defined above describe the situation of either continent under autarchy. In accordance with our introductory story we assume that the two continents are autarchic at time $t = 0$ and that discovery is unavoidable as soon as the individuals of one continent reach a level of (accumulated) education as high as $\bar{e}$ (with $\bar{e} \geq \underline{e}$). At $t = 0$ all workers are unskilled. The high-quality technologies are not yet activated. Continent A has an initial lead of n periods, and the productivity of the aggregate low-quality technology of B $((a^0_{B1}/\sqrt{c^0_{B1}}))$ is normalized to one, i.e. $F^0_{B1}(x_u, 0, l) = x^a_u l^{1-a}$ and $F^0_{A1}(x_u, 0, l) = \theta^n x^a_u l^{1-a} = \theta^n F^0_{B1}(x_u, 0, l)$. The state of knowledge at $t = 0$ does not allow for satiation of workers, i.e. $(\partial F^0_{A1}(N_A, 0, L_a)/\partial x_u) = \theta^n (N_A/L_A)^{1-\alpha} < \underline{y}$ (remember that the labor endowment of an individual worker is normalized to one).

Under free trade the set of potential innovations given the world wide state of knowledge, $\{Y^t_{A1}, Y^t_{B2}, Y^t_{C1}, Y^t_{C2}\}$, is the union of the sets of potential innovations of the two continents under autarchy. As before, there is free entry to all known technologies. In order to fix ideas we assume that all resources (except land) can flow freely from continent to continent. Note that also the resources necessary for change (researchers or entrepreneurs) are mobile between continents. This is not essential for the results (see section 4). Resources that are necessary to augment knowledge suffice to implement two innovations per period. The land-specificity of technologies implies that the knowledge about how to use A-land that is described by Y^t_{Ah} can not simply be applied to B-land. Some resources have to be spent first. In other words, inter-continental knowledge-spillovers are incomplete, i.e. innovations are necessary to transfer knowledge of A-technologies to B-technologies.

3 Equilibrium Development

We first derive some properties of temporary equilibrium given any state of knowledge $\{Y^t_{A1}, Y^t_{B2}, Y^t_{C1}, Y^t_{C2}\}$. If aggregate technology F^t_{Ch} is active at t, then we can determine the profitability (in terms of output h) of an innovation improving upon this technology, irrespective on which other technologies are active. Given prices, wages and land rents

$(p^t_{Ch}, w^t_{Cu}, w^t_{Cs}, r^t_C)$, the profits of aggregate production of Ch are:

$$\Pi^t_{Ch}(x_u, x_s, l) = p^t_{Ch}\frac{a^t_{Ch}}{\sqrt{c^t_{Ch}}}x^a_h l^{1-\alpha} - w^t_{Ch}x_h - r^t_C l, \tag{8}$$

where $x_h = x_u + x_s$, where $w^t_{Ch} = w^t_{Cu}$ are the wages for unskilled labor in C at t if $h = 1$, where $x_h = (1+\gamma^t)\min\{x_u, (x_s/\gamma^t)\}$ and where $w^t_{Ch} = (1+\gamma^t)\min\{w^t_{Cu}, (w^t_{Cs}/\gamma^t)\}$ if $h = 2$.

Maximizing (8) with respect to (x_h, l), expressing l in terms of x_h (using the first order conditions) leads to maximal profits as a function of x_h:

$$\Pi^t_{Ch}(x_h, p^t_{Ch}, w^t_{Ch}, r^t_{Ch}) = [p^t_{Ch}\frac{a^t_{Ch}}{\sqrt{c^t_{Ch}}}(\frac{w}{r}\frac{1-\alpha}{\alpha})1-\alpha - \frac{1}{\alpha}w]x_h. \tag{9}$$

Since aggregate technologies exhibit constant returns to scale, $\Pi^t_{Ch}(x_h, p^t_{Ch}, w^t_C, r^t_C) = 0$ for all x_h at temporary equilibrium prices. Hence, if Ch is active at temporary equilibrium, (9) implies

$$p^t_{Ch}\frac{a^t_{Ch}}{\sqrt{c^t_{Ch}}} = \frac{w^\alpha r^{1-\alpha}}{\alpha^\alpha(1-\alpha)^{1-\alpha}}. \tag{10}$$

The maximal profits of an innovator improving upon active F^t_{Ch} are:

$$\pi^t_{Ch}(p^t_{Ch}, w^t_C, r^t_C) = p^{2t}_{Ch}\theta a^2_{Ch}\frac{\alpha^\alpha(1-\alpha)^{1-\alpha}}{w^\alpha r^{1-\alpha}} - \frac{c_{Ch}}{\theta}\frac{w^\alpha r^{1-\alpha}}{\alpha^\alpha(1-\alpha)^{1-\alpha}}. \tag{11}$$

Inserting (10) into (11) and using $a^t_{Ch}\sqrt{c^t_{Ch}} = \theta^m a^t_{Ch}\sqrt{c^t_{Ch}/\theta^{2m}} = a^0_{Ch}\sqrt{c^0_{Ch}} = 1$ (where $2m$ is the number of times the corresponding technologies have been improved upon), we get

$$\pi^t_{Ch}(p^t_{Ch}, w^t_C, r^t_C) = p^t_{Ch}(\theta - \frac{1}{\theta}). \tag{12}$$

Development before discovery. At an early state of development wage incomes in A and in B (respectively $\partial F^0_{B1}(N_B, 0, L_B)/\partial x_u = \theta^t(N_B/L_B)^{1-\alpha}$ and $\partial F^0_{A1}(N_A, 0, L_a)/\partial x_u = \theta^{t+n}(N_A/L_A)^{1-\alpha}$) remain below $\underline{y}$. Consumers neither demand leisure nor education. Since there is no skilled labor, innovators will improve upon the low-quality technology and make profits of $(\theta - \frac{1}{\theta})$ units of the low-quality commodity in each period. Income and consumption of workers on both continents rises continuously.

After a certain number of periods, consumption of a worker $w^t_{Au} = \theta^{t+n}(N_A/L_A)^{1-\alpha}$ crosses the satiation line $\overline{y}$. At this time latest, workers will start educating themselves.

Suppose not, i.e., suppose that $e^t_A = 0$. Then from (2) it follows that $(u^t_e/u^t_1) > w^t_{Au}$. This is a contradiction, since the A-workers could increase there demand for education. Therefore $e^t_A > 0$ for t sufficiently large. Thus, the workers of A start to accumulate education. Sooner or later, say in period $\bar{t}$, the critical level of education, $\underline{e}$ will be reached in A and the high-quality technology can in principle be activated. We assume that n (the number of periods A is ahead of B) is large enough to guarantee that at $\bar{t}$ the consumption of B-workers has not yet reached the level $\underline{y}$.

Note that the wages of the workers in A doing the skilled and the unskilled jobs must be the same since all workers in A could in principle perform the skilled job. $F^{\bar{t}}_{A2}$ is not activated yet. Thus, the wages in A are determined by the low-quality technology.

Innovators in A will switch to the high-quality industry if $\pi^{\bar{t}}_{A2}(p^{\bar{t}}_{A2}, w^{\bar{t}}_{A1}, r^{\bar{t}}_A) > \pi^{\bar{t}}_{A1}(1, w^{\bar{t}}_{A1}, r^{\bar{t}}_A)$ (we have normalized $p^{\bar{t}}_{A1} = 1$). The profits of an innovator choosing to produce $A2$ are

$$\pi^{\bar{t}}_{A2}(p^{\bar{t}}_{A2}, w^{\bar{t}}_{A2}, r^{\bar{t}}_A) = p^{\bar{t}}_{A2}\frac{a^0_{A2}}{\sqrt{c^0_{A2}}}\frac{\sqrt{c^{\bar{t}}_{A1}}}{a^{\bar{t}}_{A1}}(\theta - \frac{1}{\theta}). \tag{13}$$

Thus innovators in A switch to $A2$ if

$$\frac{u^{\bar{t}}_{A2}}{u^{\bar{t}}_1}\frac{a^0_{A2}}{\sqrt{c^0_{A2}}} > \frac{a^{\bar{t}}_{A1}}{\sqrt{c^{\bar{t}}_{A1}}}. \tag{14}$$

Or, because of (3) they switch if $\frac{a^0_{A2}}{\sqrt{c^0_{A2}}} > \frac{a^{\bar{t}}_{A1}}{\sqrt{c^{\bar{t}}_{A1}}}$. Thus for sufficiently large $\frac{a^0_{A2}}{\sqrt{c^0_{A2}}}$ innovators in A will switch to the high-quality technology. The stronger the satiation in the low-quality commodity, the smaller $\frac{a^0_{A2}}{\sqrt{c^0_{A2}}}$ can be. In section 4 we will define a slightly more complex innovation-function, allowing for research spill-overs between industries. The restriction on $\frac{a^0_{A2}}{\sqrt{c^0_{A2}}}$ is no longer needed, then.

Once the high-quality technology has been activated on A, the profits from an innovation in $A2$ are $p^{\bar{t}}_{A2}(\theta - \frac{1}{\theta})$ (independently of the presence of spillovers). The profits from innovating in $A1$ are at most $(\theta - \frac{1}{\theta})$ (they are lower in the absence of spillovers, since F^t_{A1} is not active). Because of (3) it follows that $A2$ is improved in each period. All A-workers work in the high-quality industry, some doing skilled and others doing unskilled jobs, but all receiving identical wages.

The first period of free trade. Following our introductory story, sufficient education in A is followed by the discovery of B and by free trade. Let this be at period $\hat{t}$ and let n be sufficiently large to make sure that B-workers have not yet reached the satiation line.

The high-quality technology of B has not yet been activated (i.e., is not known yet). Thus, the (skilled) A-workers will continue to work in the high quality technology of A (they are at least as productive in $Y^{\hat{t}}_{A2}$ as in $Y^{\hat{t}}_{A1}$ and, therefore, as in $Y^{\hat{t}}_{B1}$, and the price $p^{\hat{t}}_{A2}$ of the high-quality commodity of A is at least as high as the price $p^{\hat{t}}_{1}$ of the low-quality commodity). Neither Y_{A2} nor Y_{A1} can use B-land. All A-land will either be used in Y_{A2} alone, or in Y_{A2} and Y_{A1}. At most $\frac{N_A}{\gamma}$ unskilled workers are employed in Y_{A2}. Y_{A1} may or may not be active (the productivity of $A1$ is higher than that of $B1$ but the land-rents are higher in A than in B). Whether Y_{A1} is active or not and how many unskilled workers are employed in Y_{A1} is not essential for our arguments (it depends on the strength of satiation (p^{t}_{A2}), on how desirable working is for the skilled, on the time that has lapsed between $\bar{t}$ and $\hat{t}$, on θ, α and (L_A/L_B)). The two industries in A compete for A-land and all three activated industries compete for the unskilled B-workers. Since it is assumed that (L_B/L_A) is sufficiently large, most B-workers stay in $B1$. The marginal revenues in Y_{B1} and Y_{A1} are equalized and, for $\frac{L_B}{L_A}$ large enough, determine the outside-option wage in Y_{A2}, as well. Thus, their wage $w^{\hat{t}}_{u} = \frac{\partial F^{\hat{t}}_{B1}}{\partial x_u} = \frac{\partial F^{\hat{t}}_{A1}}{\partial x_u}$ (the last equality only if $A1$ is active) so that their income in terms of the low-quality commodity remains below $\underline{y}$. Since $p^{\hat{t}}_{A2} > 1$ it follows that for all B-workers $y^{\bar{t}}_{1} + y^{\bar{t}}_{A1} + y^{\hat{t}}_{A2} < \underline{y}$. Thus, in the first period of discovery the B-workers will not start educating themselves.

Which technologies will innovators choose to improve? Profits of improving $A2$ exceed those of improving $B1$ and $A1$. This follows directly from (3) and (12):

$$\pi^{\hat{t}}_{A2}(p^{\hat{t}}_{A2}, w^{\hat{t}}_{A2}, r^{\hat{t}}_{A}) = p^{\hat{t}}_{A2}(\theta - \frac{1}{\theta}) > \pi^{\hat{t}}_{B1}(p^{\hat{t}}_{B1}, w^{\hat{t}}_{B1}, r^{\hat{t}}_{B}) = (\theta - \frac{1}{\theta}) \tag{15}$$

(and $\pi^{\hat{t}}_{A1}(p^{\hat{t}}_{A1}, w^{\hat{t}}_{A1}, r^{\hat{t}}_{A}) \leq (\theta - \frac{1}{\theta})$, with equality if $F^{\bar{t}}_{A1}$ is active or if there are complete spillovers between $A2$ and $A1$).

Thus, innovations occur in one of the high-quality industries. This may be in $A2$ or in $B2$, depending on the MRS $(u^{\hat{t}}_{B2}/u^{\hat{t}}_{A2})$ at $y_{B2} = 0$. If innovations do not occur in $B2$ immediately after discovery, the assumptions on preferences make sure that it will happen sooner or later as we will see. Of course, in the narrow framework of the model this depends on our assumption that labor is mobile across countries, since some skilled labor have to move from A to B. The essence of the arguments does not depend on this assumption (see section 4).

Development after discovery. In the second period after discovery, the aggregate high-quality technology of B has been activated and more skilled A workers move to B.

The high-quality technologies of the two continents together employ at most N_A skilled workers and, therefore, at most $\frac{N_A}{\gamma}$ unskilled labor. Since N_B is sufficiently large, the wage of the unskilled is determined by the low-quality industry of B and the amount of B-land that is not used by the high-quality technology. In the worst case (from the point of view of the unskilled) Y_{B2} uses all B-land and most B-workers will not work (Lewis' subsistence sector becomes Marx' industrial reserve army). Wages are zero in this case. Otherwise, the wage of the unskilled in terms of the low-quality good is their marginal product in the low-quality technology. In A the low-quality industry stagnates at the productivity level $\theta^{\bar{t}+n}$. Since (L_B/L_A) is large it follows that the B-workers moving to A cannot much rise the pre-discovery wages for unskilled labor. In B, productivity of the low-quality technology stagnates at the pre-discovery level $\theta^{\hat{t}}$.

An upper bound on the wages of the unskilled can be derived by assuming the best case for the unskilled. This is that low-quality technologies can use the largest possible amount of land (i.e. $L_A + L_B$) with the lowest possible number of workers (i.e. $N_B - \frac{N_A}{\gamma}$) and in addition that these remaining workers are allocated optimally between the two low-quality technologies. More precisely, an upper bound on unskilled wages is given by the maximum with respect to N_{B1} (the number of workers employed in $B1$) of

$$\frac{N_{B1}}{N_B}\frac{\partial F_{B1}^{\hat{t}}(N_{B1}, L_B)}{\partial x} + \frac{N_{A1}}{N_B}\frac{\partial F_{A1}^{\bar{t}+n}(N_{A1}, L_A)}{\partial x}, \tag{16}$$

where $N_{A1} = N_B - N_{B1} - \frac{N_A}{\gamma}$ is the number of unskilled workers employed in $A1$. For $N_B/N_A = L_B/L_A$ sufficiently large this upper bound is smaller than $\underline{y}$.

The skilled A-workers and the land-owners of both continents consume high quality commodities of both continents and the unskilled B-workers consume the low-quality commodities only. Some skilled A-workers work in the high-quality sector of B (how many depends on the demand by skilled workers and landlords for y_{B2}) and some unskilled B-workers work in the high-quality sector of A (and possibly in the low-quality sector of A, too).

The innovators in the second period will choose one of the high-quality sectors for the same reasons as before. Which high-quality sector they choose depends on $(u_{B2}^{\hat{t}}/u_{A2}^{\hat{t}})$.

The situation in all following periods does not much change. Only the high quality industries are improved upon, since (p^t_{C2}/p^t_{A1}) is always larger than 1. None of the two high-quality industries is neglected in the long run because $\frac{p^t_{A2}}{p^t_{B2}} = \frac{u_{A2}}{u_{B2}}$ tends to zero if y_{A2} tends to infinity and y_{B2} remains bounded and vice versa. The order in which the two high-quality industries are improved depends on the specific utility function, but it is clear that the productivity of the skilled labor in both high-quality industries will tend to infinity.

Note that, depending on the utility function, the skilled labor may decide to work less and less. Thus, the amount of land used in the low-quality industries may in principle rise over time. However, the wage of the unskilled can never exceed the marginal product of unskilled labor in the low-quality industries. The upper bound (16) remains valid and does not change when time proceeds. This is summarized in the following proposition.

Proposition 1 *The high-quality commodities of the two continents become free commodities for all A-citizens as well as for those B-citizens that own resources that are sufficiently scarce for the A-citizens (here these are the landowners and the owners of the resources for change). In contrast, the consumption of the unskilled workers stagnates below the hunger line. They never start to accumulate education and remain unskilled.*

Isolated development. Clearly, the two continents would develop on identical lines if none would ever discover the other. The B-workers would acquire skill n periods after the A-workers. Asymptotically the productivity in both high-quality industries tends to infinity and the high-quality commodity of both continent becomes a free good for each citizens of that continent. *If free trade is opened in a later period of development (i.e., at any date after $\bar{t}+n$), then both high-quality commodities would become free commodities for all groups of consumers world wide.*

4 Comments and Extensions

4.1 Trade-off between Innovation Bias and Satiation.

(1) In the section 3 we have assumed that the initial productivity of the high-quality technology in A is sufficiently high. This was necessary to guarantee that innovators in A switch

to the high-quality technology. As is clear from (14), we can do without this assumption by strengthening (3), assuming that $\frac{u_{C2}}{u_1}$ rises sufficiently with increasing consumption. Instead of strengthening (3) one can also assume the presence of spillovers between the two industries of one continent. Consider the following innovation-function replacing (6). Given a state of knowledge, parametrized by the collection of vectors $(a^t_{Ch}, c^t_{Ch}, \gamma^t_{Ch}, \alpha^t_{Ch})_{h\in\{1,2\}}$, an innovator in C has the choice between four potential innovations. He can choose to

$$\begin{cases} \text{produce } y_{C1} \text{ with parameters} & (\sqrt{\theta}a^t_{C1}, \frac{1}{\theta}c^t_{C1}, \gamma^t_{C1}, \alpha^t_{C1}), \\ \text{produce } y_{C1} \text{ with parameters} & (\sqrt{\theta}a^t_{C2}, \frac{1}{\theta}c^t_{C2}, \gamma^t_{C2}, \alpha^t_{C2}), \\ \text{produce } y_{C2} \text{ with parameters} & (\sqrt{\theta}a^t_{C1}, \frac{1}{\theta}c^t_{C1}, \gamma^t_{C1}, \alpha^t_{C1}), \\ \text{produce } y_{C2} \text{ with parameters} & (\sqrt{\theta}a^t_{C2}, \frac{1}{\theta}c^t_{C2}, \gamma^t_{C2}, \alpha^t_{C2}), \end{cases} \tag{17}$$

where $\theta > 1$.

These spillovers are an alternative way to guarantee that innovators in A switch from Y_{A1} to Y_{A2}. Inserting the zero-profit condition (10) corresponding to $A1$ into the innovators profit (11) corresponding to the innovation producing $A2$ improving upon the parameters of $A1$ we get:

$$\pi^{\bar{t}}_{A2}(p^{\bar{t}}_{A2}, w^{\bar{t}}_{A2}, r^{\bar{t}}_{A}) = p^{\bar{t}}_{A2}(\theta - \frac{1}{\theta}). \tag{18}$$

Thus, innovators in A will switch to $A2$ since $\frac{u^{\bar{t}}_{A2}}{u_1 \bar{t}} = p^{\bar{t}}_{A2} > p^t_{A1}$.

(2) If we raise the extent of satiation we can allow for a bias in the innovation function in favor of the low-quality sector. Suppose for instance that (6) is replaced by the more general:

$$\begin{cases} \text{produce } y_{C1} \text{ with parameters} & (\sqrt{\eta}a^t_{C1}, \frac{1}{\eta}c^t_{C1}, \gamma^t_{C1}, \alpha^t_{C1}), \\ \text{produce } y_{C2} \text{ with parameters} & (\sqrt{\theta}a^t_{C2}, \frac{1}{\theta}c^t_{C2}, \gamma^t_{C2}, \alpha^t_{C2}), \end{cases} \tag{19}$$

where $\theta > 1$ and $\eta > 1$. Then (15) still holds if

$$\frac{u_{C2}}{u_1} > \left(\frac{\eta - 1/\eta}{\theta - 1/\theta}\right) \text{ for } y_1 + y_{A2} + y_{B2} > \overline{y}. \tag{20}$$

Thus, (20) defines the necessary extent of satiation for our results to remain valid in the presence of a bias in the innovation function in favor of the low-quality industry.

(3) Constant parameters θ and η correspond to exponential growth of research productivity. In the endogenous growth literature this is the standard assumption that makes possible sustained growth. There are two natural objections to constant and independent values θ

and η. Firstly, one may argue that continuous research in one direction should be subject to decreasing returns to scale. In this case our $\theta(t)$ should tend to one in the course of development. Secondly, even if we belief in exponential growth of research productivities one may hold that there should be positive spillover from research in one direction on the productivity of research in other directions. In both cases the RHS of (20) would tend to infinity. Thus in order to preserve our results (3) has to be strengthened. A natural way to do this is to assume that $\frac{u_{C2}}{u_1}$ rises with rising consumption, i.e. that the extent of satiation in low-quality rises with rising consumption. In this case the LHS of (20) too rises with development.

If $\left(\frac{\eta-1/\eta}{\theta-1/\theta}\right)$ *rises in the course of development, then Proposition 1 remains valid if the satiation of the rich skilled workers and the landlords, measured by* $\frac{u_{C2}}{u_1}$, *grows at least as fast in the course of development (due to rising consumption of high-quality) as does* $\left(\frac{\eta-1/\eta}{\theta-1/\theta}\right)$.

In case of complete satiation ($\frac{u_1}{u_{C2}} = 0$ if $y_1 + y_{A2} + y_{B2} > \overline{y}$) the low-quality sector remains backward, whatever are the values of $\eta > 1$ and $\theta > 1$.

4.2 Upgrading Quality versus Reducing Costs.

All innovations in the previous section are process-innovations. In a more realistic setting the set of potential innovations of each or of most periods should contain quality-improving innovations, as well. For example, let $v(x, e, \sum_k q_k^A y_k^A, \sum_k q_k^B y_k^B)$ be the identical utility for all consumers, where q_k^C is a parameter for the k-th quality of a consumption commodity produced in C, with $q_k^C > q_{k-1}^C$ for all k, and where y_k^C is the consumed quantity of the corresponding quality. For each existing quality k, and on each continent C, there is a potential process-innovation and a potential product-innovation. A product-innovation improves upon the best technology that produces k on C in equal proportions. A product-innovation of the k-th quality on C produces quality $k+1$ with the (best) traditional technology for k on C, except that the education requirement of the skilled labor-input x_s may have risen. As in the previous section, the production of a high-quality product can also use unskilled labor, x_u. The exact level of education of x_s is irrelevant. In order to make sure that consumers are not satiable in quality it is assumed that $(q_{k+1}^C/q_k^C) \not\to 1$ if k tends to infinity. Suppose that at the time of discovery, continent A's lead over continent

B (with respect to quality, production costs and accumulated education) does prevent the B-workers to work as skilled labor in the highest quality technology of A. In contrast to the previous section the price consumers are willing to pay for a quality improvement in terms even of the wages of the skilled labor will in general not converge to zero. As a consequence the profits of quality innovations in the highest-quality technology in terms of the wages for skilled labor will be bounded away from zero. Therefore, one only needs to assume that the potential cost-reduction of the technology that was in use in B at the time of discovery is not too drastic. The world-economy after discovery will develop along similar lines as in the previous section. The wealthy will consume better and better qualities and the initially poor will remain poor and consume the unchanged low-quality. Of course, the assumptions of the previous section that led to the reserve army have to be maintained.

It should be noted that in an economy in which innovators have a repeated choice between cost-reduction and quality-improvement, long-run efficient change is not guaranteed, even if all individuals are absolutely identical. In Funk [1995b] an example is given, in which quality-improvements are chosen in each period, although *all* consumers would prefer the cost-reductions to be chosen in each period. Similarly, in the above setting the innovators may neglect the process-innovations even if all consumers (including the wealthy) would prefer otherwise. The theme of the present chapter is that of the persistence of poverty and not that of this (additional) inefficiency. However, the bias of development in favor of quality-innovations and against cost-reductions not only causes an additional persistent inefficiency (from the point of view of the wealthy) but may also be the main cause for the persistence of inequality.

4.3 Capital.

In order not to overload the basic model we did not include capital as a factor of production. If our low-quality industry is interpreted as the agricultural sector, then we should allow for periods of substantial capital using technical change in this sector. In fact, equipment and fertilizers have tremendously raised the capital intensity whereever agriculture has experienced high rates of productivity growth. There are several ways to account for this productivity growth within our framework of development. Let capital be a third factor of production in the individual production function, i.e. let $G(\cdot)$ of (5) be a function of labor x, capital c, and land l. Furthermore, assume that all technical change in agriculture is embodied either in labor or in capital. Labor augmenting progress would be possible via human capital accumulation only, which in our framework depends on sufficient wealth of the individual worker. Capital augmenting progress would mean landlords buying better machines, which would be produced in an intermediate sector (which may coincide with the high-quality sector). As before, sufficient satiation in low-quality technologies by the wealthy will keep direct investment in R&D for agricultural equipment at a low level. However, some machines designed for the high-quality sector uses may typically be applicable for agricultural purposes or, more realistically, may be adapted at low cost to the requirements of agricultural production. In our simple framework this would mean that the productivity of research (η) on agricultural equipment would grow each time the high-quality technology is improved. As a result the agricultural sector will experience capital augmenting progress. If capital is a sufficiently good substitute for unskilled labor (which it typically is, both in the case of equipment as in the case of fertilizers), the wages for unskilled labor will stagnate as they did in the previous section.

4.4 Resources for Change.

In reality, the quality and the intensity of research may depend on the level of wealth and education. In this case the quality or quantity of resources at the time of discovery that are necessary for the production of new knowledge may be less developed in B than in A. For our conclusions to remain valid, the resources that would be used to improve B-technology in the case of autarchy do not necessarily need to flow to the research sector of A. The more active individuals of B may just be the first to move to A and work in normal productive activity, for instance. Or, these resources may remain in B and work in the (export-oriented) high skill sector of B. The only crucial requirement is that the B-resources are sufficiently useful for the high-quality production (not necessarily in the research sector) or for the improvement of the high-quality technology. Essentially, all we need is that due to the existence of the developed sector *the creative forces flow away from the initially backward sector*. It is not important to which alternative use they turn.

4.5 Factor Mobility.

The benchmark of free trade in section 3 was a fully integrated world economy. Correspondingly we have assumed that workers (after discovery) are fully mobile between the two continents. If instead they are less mobile or even completely immobile the persistence of poverty prevails. If the unskilled B-workers cannot immigrate to A, the pressure on their wages is higher even. If the skilled A-workers are reluctant to emigrate, the temporary equilibrium wages for skilled labor in B have to be higher than those in A. This will reduce the speed of the development of $B2$ and change the pattern of trade, but not alter the conclusions about persistent poverty. The rise of the land rent in B will be less fast than in the previous section. Consequently, the landlords of B will not enjoy the same degree of development as the A-citizens. They will be rich in terms of the low-quality commodities, but poor in terms of the high-quality commodities. Therefore, their incentives to join the skilled labor force of $B2$ rises. As a consequence part of the traditional rich in B may decide to join the skilled labor market. This allows to replace the skilled A-workers in B with skilled B-workers without affecting the conclusions about poverty and polarization in B.

4.6 Credits

There are ways out of the underdevelopment trap, even in the hypothetical world of pure laissez-faire that has been postulated. A person's skill level in the examples was partly determined by the consumed education of his ancestors. Suppose, instead, that the skill level of a worker depends on his own education, mainly. Furthermore, an individual's life was restricted to a single period, which is not a very convincing assumption. Suppose that people live longer. Then, at least in a first-best world with perfect capital markets and perfectly enforceable contracts there are ways out of the underdevelopment trap even in a laissez-faire environment:

(1) The unskilled can take credits when they are young, educate themselves until they are skilled, work as skilled labor and then pay back their credits.

(2) Firms and unskilled workers can write contracts in which firms offer training to individual unskilled workers against the promise to work for a certain while once sufficient skill has been acquired at a wage below the market wages for independent skilled labor.

The feasibility of both of these possibilities heavily depends on the enforceability of such contracts. It may prove impossible to make sure that a credit given to an uneducated person is *used* in the way that puts him in a position to pay back the loan. Similarly, it may be difficult for a firm who trains a worker, to tie this worker to the firm if his wage remains significantly lower than the market wage for that job. In particular in LDCs it seems unlikely that private contracts alone can break the vicious circle 'low skill, low income, low education, low skill'.

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