

Stages of Development in an Endogenous Growth Model with International Trade

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1. Introduction

During the last 100 years the world has experienced huge increases in the incomes of nations and people. However, the bulk of these increases has accrued to already wealthy countries and some developing countries that have been able to gain a share of the exchange of goods and services on the international markets. However, most developing countries and in particular African economies have been left out and lacked the growth dynamics of countries like China, India, Mauritius and South Korea.

The countries of the world seem to be divided into various stages of development. Some countries are at a very low stage of development such as most of the African countries. In these countries the primary source of growth is physical capital accumulation. Other countries are in an intermediate stage such as several of the Asian countries. These countries are characterised by both physical and human capital accumulation. Furthermore, the intermediate countries pursue a strategy of adopting and imitating technology developed elsewhere. The high-income countries are in the highest stage of development. In these countries research and development is conducted in parallel to factor accumulation. These empirical observations suggest an approach to explaining development that is characterised by different stages along the development path.

In this paper we develop a model based on Funke and Strulik (2000) where it is possible to distinguish different stages of development. The model encompasses three stages: A low income stage characterised by factor accumulation; an intermediate income stage characterised by adoption of technologies; and a high income stage characterised by research and development. The transition from

one stage to another stage is determined endogenously. The transition from low to intermediate income stage occurs as a result of opening up for international trade, which enable domestic producers to adopt technologies developed abroad. The transition to the high income stage occurs when the human capital stock reaches a critical level where research and development becomes a profitable activity. However, this uni-directional path of development may not proceed unimpeded, and there is a danger that the underdeveloped country is caught in an underdevelopment trap. This may be the case if it is very scarcely endowed with skilled labour, since it implies a substantial comparative disadvantage in R&D.

Several empirical studies provide evidence of a positive relationship between openness to international trade and growth in per capita GDP. Articles by Dollar (1992), Ben-David(1993), Sachs and Warner (1995), Harrison(1995) and Edwards (1998) are some of the most well-known examples in the literature. However, the conclusions are not beyond dispute and others maintain that trade only imply shifts in the level of welfare but with insignificant effects on growth.

The paper is organised as follows. Section two refers to existing theories of development in stages. In section three the theoretical framework is presented and the long-run solution for the model is derived for a closed economy. Section four focuses on the effects of international trade using the framework of section three. The last section concludes and discusses the future developments and applications of the theoretical framework.

2. Stage-theory of development

The development process that a country runs through from a low-income, stagnant, traditional economy to a high-income, dynamic, growing economy can be described as a series of stages. Each stage in the development process is characterised by a set of measures related to the developmental level of the economy. Such measures traditionally include GDP per capita, the investment rate, the capital-output ratio and several others. One way to apply the concept of stages is to use it to categorise an otherwise continuous development process by somewhat arbitrary choices of delineation measures. An example could be the World Banks definition of *low income*, *lower middle income*, *upper middle income* and *high income* economies, where the distinguishing measure is GNI per capita. However, the term “stage-theory” implicitly suggests that the different stages are delineated by some specific characteristics that are in some sense fundamentally different across stages. Simon Kuznets (1971) c.f. Meier (1995) defined stage-theory as:

“... a stage theory of long-term economic change implies: (1) distinct time segments, characterized by different sources and patterns of economic changes; (2) a specific succession of these segments, so that *b* cannot occur before *a*, or *c* before *b*; and (3) a common matrix, in that the successive segments are stages in one broad process – usually one of development and growth rather than of devolution and shrinkage. Stage theory is most closely associated with a uni-directional rather than cyclic view of history. In the cyclic view the stages are recurrent; in a uni-directional view, a stage materializes, runs its course, and never recurs. Even in the process of devolution and decline, the return to a level experienced previously is not viewed as a recurrence of the earlier stage.”

Thus, Kuznets' definition implies a distinct causality and specific delimited stages. Models with different equilibria or steady-states are not necessarily stage-theories in the Kuznets sense, because the equilibrium outcomes may be independent of one another.

The original stage-theory was formulated by Rostow (1952; 1960) where he distinguishes five stages: *the traditional society*, *the establishment of the preconditions for take-off*, *the take-off into self-sustained growth*, *the drive to maturity* and *the age of high mass consumption*. The first stage is characterised as a traditional, stagnant, predominantly agricultural society with a low capital accumulation rate. In the second phase, where the preconditions for take-off is established, some leading entrepreneurs emerge typically as a result of external stimuli, which increase rate of investment to net national income up to 5%.. The take-off occurs when the investment rate increases from less than 5% to more than 10%, one or more substantial manufacturing sectors with a high growth rate emerge, and societal, judicial, political and institutional changes that are conducive to growth emerge. The last two stages can be described as convergence to a high-income level, where the economy finally reaches a steady-state equilibrium.

Rostow's stage-theory has received quite a lot of criticism. In particular, Rostow fails to provide an adequate description of the transition from one stage to the next. Furthermore, empirical analyses show that the very summary measures, in particular the investment rate, that is used to characterise the different stages do not account for the different development paths followed by different countries such as the quite different development processes followed by Great Britain, France, Germany and the USA.

Baldwin et al (2001) presents an endogenous growth model with four stages and two regions (North and South). Initial conditions and factor endowments are equal. The stages are distinguished by transaction costs both of trading goods and in dispersing ideas. The model entails only one accumulating factor namely capital, which is interpreted as knowledge capital that are localised implying that knowledge is not dispersed globally. In the first stage trade in goods are low due to high transportation costs. An exogenously induced decrease in transportation costs makes trade a profitable venture. This induces industry to agglomerate in one region while declining in the other and the industrial region experience a take-off. The authors go on by assuming that it is in the north that industry accumulates. In the third stage the economy has reached a steady-state equilibrium where incomes in the north is higher than in the south. In the fourth stage, the costs of diffusion of knowledge are decreases. Hence, the south takes advantage of the accumulated knowledge in the north and converges to the high-income level. Thus, the rate of technology diffusion is determined by the costs of exchanging information and not by the level of human capital in the country as in other models of income differences across countries in endogenous growth models. The implication of the model is therefore, that the substantial decreases in the costs of exchanging information that have occurred in the last two or three decades would induce convergence of all developing countries to the high-income level. A cross-country panel data study by Comin and Hobijn (2004) spanning from 1788-2001 shows the level of human capital is an important determinant of the rate of technology adoption. The convergence in technology adoption since WWII can be ascribed to the convergence in factor endowments particularly the level of human capital. Furthermore, the study finds that openness to trade as well as the strength of the judicial and legislature systems are important determinants. The type of political regime and judicial systems are found to be of greater importance in the post WWII period. In this sense, government plays a larger role for economies today than they did before.

In Howitt and Mayer-Foulkes (2003) a stage-theory like model based on the Aghion and Howitt (1992, 1998) model is constructed. The model is based on the assumption that modern R&D involves highly scientifically advanced skills. Three different levels of convergence is produced by the model: A high-income stage called modern R&D where new technologies are developed, an implementation stage where no R&D is carried out but new technologies developed by the R&D countries are absorbed, and a stagnation stage where new technologies cannot be applied. In this model it is the level of human capital that determines a country's capability for applying and developing new technologies. The model does not predict a uni-directional progress from a low-income to a high-income level and is as such not a stage model. Instead the model produces three different equilibria or steady-states. Which steady-state a country belongs to depends highly on the initial factor endowments. Deliberate costly government action is required in order to move from one steady-state to a higher.

In Acemoglu et al (2003) an endogenous growth model is constructed where governmental policies play an important role. Initially an economy pursue an investment-based strategy relying on existing firms in order to maximise investment. Due to imperfect markets, credit constraints, and the governments focus on investments, insiders are protected and benefit from the imperfect markets. Because of the monopolistic rents accruing to insiders they can create a shield effect by buying political power. This implies that the economy could pursue the investment-based strategy for too long and never switch to an innovation-based strategy where new technologies are created through R&D. Thus, although the investment-based strategy produce higher growth for low-income economies pursuing this strategy for too long can lead to an underdevelopment trap. The model underlines the importance of good and timely governmental policies but also provides an explanation for why socially bad policies may be pursued for too long leading to non-desirable economy-wide outcomes.

A more deterministic explanation for income differences across countries is presented in Kejak (2003) where underdevelopment traps in an endogenous growth model of the Lucas-Uzawa type occurs when the initial factor endowments are too low. The speed of human capital accumulation is too slow in reaching a critical mass; hence the country is trapped in underdevelopment.

The over-all picture of why a country belongs to a low-income group or a higher income group is mixed. Some point out the significance of initial conditions in particular the level of human capital. A natural question to pose is then: why did some countries have favourable initial conditions and others not? Other studies emphasise the importance of governmental policies and, related thereto, judicial systems thus providing a more optimistic view by allowing for ways to escape the underdevelopment trap. The role of trade has not received much attention in the context of endogenous growth models and stage-theories. However, the few studies that exist gives openness-to-trade an important role in the development process. In particular, trade induce domestic producers to apply new technologies in order to be able to compete thereby increasing the country's technology level. Trade also provides a means by which to absorb new technologies at a lower cost and increase the stock of human capital.

3. The theoretical framework

3.1. The model

We set up a model that is capable of describing the development of an economy in stages. The framework is inspired by Funke and Strulik (2000) who present a growth model containing stages of development. Their model encompasses the standard neoclassical growth model and modern endogenous growth theory. They show that while the neoclassical growth model (Solow (1956)) serves as the best approximation for the initial period of development where only physical capital is accumulated, the best description of the next stage of development is a model of physical capital accumulation and improvements in the quality of labour (Lucas (1988)). In the third and last stage of development growth is driven by innovations, a mechanism which models of endogenous growth through R&D (Romer (1990), Grossman and Helpman (1991)) approximate best. The transition to a higher stage of development is explained endogenously since the development process itself changes the investment habits of individuals. During the first stage of development the wage rate per unit of human capital grows which at some point in time induces households to invest permanently in human capital formation. At this point in time the economy enters the second stage of development. The source of transition from this stage to the last stage of development is increasing potential profit of investment in R&D.

In the present set-up the first stage is characterised by physical and human capital accumulation.¹ As the amount of human capital increases so does the potential profit of investment in R&D, and at some point in time the economy is endowed with so much human capital that the value of an innovation equals the cost of innovating. From then on the economy engages in research and development. Opening up the economy during the stage of factor accumulation introduces an intermediate stage of adoption. During this stage the economy does not develop new technologies itself but it adopts the technologies invented by its trading partners. Hence, the model can describe development in three stages: factor accumulation, adoption and R&D.

The economy consists of a constant number of households that demand two different products: a traditional product that is produced using human capital and unskilled labour, and a high technology product that is produced using human capital, unskilled labour and different types of producer durables. The total amount of unskilled labour is fixed over time. It is assumed that production of the traditional good is relatively more intensive in unskilled labour and less intensive in human capital than production of the high tech good is. The total factor productivity in high tech manufacturing increases with the number of differentiated producer durables. Durables are assumed to be produced with the same technology as high technology final output which is equivalent to assuming that it takes a fixed amount of foregone consumption of the high tech good to create one unit of any type of durable. While economic growth is fostered by technological progress, technological progress is driven by human capital accumulation: Designs for new producer durables are invented in the research sector with the use of human capital only. The incentives to conduct R&D are preserved through (i) monopolistic competition in the market for producer durables that ensures monopoly profits and (ii) a licence law that gives the innovating firm an infinite patent on the design it has invented.

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¹ We may include an initial stage where the primary source of growth is physical capital accumulation in a forthcoming version of the paper.

The process of development of a closed economy is as follows. In the early periods of development the economy is endowed with a low amount of human capital that depresses the potential profit of innovating. Hence, agents have no incentives to conduct R&D. But since human capital is a productive input into the production of the two types of final output, agents have an incentive to spend time on education, and this incentive is preserved through physical capital accumulation that raises the productivity of human capital in the high technology sector. As the amount of human capital grows the country may reach a point in time where the amount of knowledge is sufficient to equalize the value and cost of an innovation. From this point on the country undertakes R&D. Thus, the market mechanisms may ensure that the developing country eventually becomes a member of the relatively small group of rich countries that conduct R&D. This development depends on a number of structural characteristics, e.g., the existence of an education system and a legal system that enforces license laws.

In subsections 1-3 the model is presented while the development of a closed economy is described in section 3.2.

3.1.1. Producers

High technology goods production

Production of the high technology good requires human capital, unskilled labour and an index of producer durables according to a Cobb-Douglas production function:

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$$(1) \quad Y = A_I (D)^{\eta_1} (L_Y)^{\eta_2} (u_I H)^{1-\eta_1-\eta_2} \quad i \in (A, B)$$

$$0 < \eta_1, \eta_2 < 1, A_I > 0, D \geq 0, L_Y \geq 0, H \geq 0, 0 \leq u_I \leq 1$$

Superscript i indicates country.

Y is production of high technology final output in country I ; A_I is a technology parameter; D is an index of producer durables; L_Y is the amount of unskilled labour employed in high technology production; u_I is the share of time per person allocated to production of Y ; H is the stock of human capital; η_1 is the elasticity of Y wrt D and η_2 is the elasticity of Y wrt L_Y .

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Following Grossman and Helpman (1991) the index of producer durables is defined as

$$(2) \quad D = \left(\int_0^n x(j)^\alpha dj \right)^{\frac{1}{\alpha}}$$

where $x(j) \geq 0$ is input of producer durable j , $n \geq 0$ is the number of available varieties of durables, and $0 < \alpha < 1$ is a parameter that determines the elasticity of substitution, ε , between producer durables in the index, $\varepsilon = 1/(1 - \alpha) > 1$. In a closed economy the number of different producer durables equals the number of designs that has been invented in that country in the past.

There is assumed to be perfect competition in the market for high technology goods. Hence profit maximization implies that the marginal cost equals the marginal value of a unit of each type of input:

$$(3) \quad x(j) = \eta_1 \frac{Y}{P_D} p(j)^{\frac{1}{\alpha-1}}$$

$$(4) \quad p_L = \eta_2 \frac{Y}{L_Y}$$

$$(5) \quad w = (1 - \eta_1 - \eta_2) \frac{Y}{u_1 H}$$

where the price of Y is normalized to one, $p(j)$ is the price of intermediate good- j , $P_D \equiv \int_0^n p(j)^{\frac{\alpha}{\alpha-1}} dj$ is a price index, $p_L > 0$ is the price per unit of unskilled labour, and $w > 0$ is the wage rate per unit of human capital.

Traditional goods production

Production of the traditional final output uses human capital and unskilled labour:

$$(6) \quad Z = B(L_Z)^\beta (u_2 H)^{1-\beta}$$

$$B > 0, 0 \leq u_2 \leq 1, 0 < \beta < 1$$

Z is production of traditional final output, B is a technology parameter, u_2 is the share of time per person allocated to production of Z and β is the elasticity of Z wrt. unskilled labour. It is assumed that production of the traditional final output is relatively more intensive in unskilled labour and less intensive in human capital than the production of high tech final output is, implying that $\beta > \eta_1 + \eta_2$.

Perfect competition in the market for traditional goods and profit maximization yield the usual marginal cost equals marginal value conditions:

$$(7) \quad p_L = \beta \frac{p_Z Z}{L_Y} \text{ and}$$

$$(8) \quad w = (1 - \beta) \frac{p_Z Z}{u_2 H}$$

where $p_Z > 0$ is the price of Z relative to the price of Y .

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Production of producer durables

Since producer durables are imperfect substitutes in the high technology goods production there is monopolistic competition in the markets. If the innovator of a design manufactures $x(i)$ units of the durable embodied in that design, it rents those durables to high tech final output firms for a rental rate $p(i)$. Hence, the flow of rental income is $p(i)$ times $x(i)$. It is assumed that it takes v units of high tech output to produce a durable implying that the cost of producing $x(i)$ units of durable i is the interest cost on the $v x(i)$ units of high tech output. Then the optimization problem for the producer of durable j is

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$$(9) \quad \text{Max} \quad \pi(j) = (p(j) - r v) x(j)$$

s.t.
$$x(j) = \eta_1 \frac{Y}{P_D} p(j)^{\frac{1}{\alpha-1}}.$$

Solving the problem implies that each durable producer charges the same price

(10)
$$p(j) = \frac{\nu v}{\alpha}$$

such that durables are produced in equal quantities across varieties:

(3')
$$x(j) = \frac{\alpha \eta_1 Y}{\nu r n} \text{ and profit may be written as}$$

(9')
$$\pi(j) = (1 - \alpha) \eta_1 \frac{Y}{n}.$$

R&D

Designs/blueprints for new producer durables are invented in the research sector. It is assumed that new ideas is determined by the amount of knowledge employed in the R&D-sector. This assumption excludes external~~ality~~ and scale effects from the analysis – effects that are otherwise in the literature found to be important for the effects of international trade on trade patterns and growth rates (e.g., Grossman and Helpman (1991), Young (1991)).² Without external~~ity~~ effects and under constant returns to scale the aggregate stock of differentiated durables evolves according to

(11)
$$\dot{n} = \delta (u_3 H)$$

where $\dot{n} = \frac{\partial n}{\partial t}$ is the change per unit of time, t , in new durables, $\delta > 0$ is a technology parameter, and

$\theta \leq u_3 \leq 1$ is the share of time per person allocated to production of new designs.

Equalizing marginal cost and value of an innovation gives the following optimality condition:

(12a)
$$w = \delta \nu \quad \text{if} \quad u_3 > 0$$

(12b)
$$w > \delta \nu \quad \text{if} \quad u_3 = 0$$

where ν is the value of an innovation. If the wage rate is too large compared to the value of an innovation, the marginal cost of an innovation exceeds the marginal value and no firms will conduct R&D.

We assume exclusive patent rights. Thus the innovator of a variety enjoys the exclusive right to produce that variety, and the value of an innovation is determined as the present discounted value of all future profit streams from renting the durable to high tech final goods firms. The no arbitrage condition for investors requires that the interest rate equals the dividend rate plus the rate of capital gain:

(13)
$$g_v = r - \frac{\pi}{\nu}$$

where $r > \theta$ is the interest rate and π is determined by (9').

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² External~~ity~~ effects may be added to the model at a later stage.

Human capital accumulation

Perpetual growth in ideas requires growth in human capital which will happen if people spend a fraction of their time on education. This non-market activity is described by the Lucas (1988) production function:

$$(14) \quad \dot{H} = \xi (1 - u_1 - u_2 - u_3) H$$

where $\xi > 0$ is an efficiency parameter in education. Total time per person is normalised to one such that 1 minus time spend on production, $(1 - u_1 - u_2 - u_3)$, is spent on education.

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3.1.2. Consumers

Consumers maximise utility over an infinite horizon. It is assumed that consumers share identical preferences such that the representative household's utility is described by the following intertemporal function:

$$(15) \quad U_t = \int_{\tau=t}^{\infty} e^{-\rho(\tau-t)} [\sigma \log C_Y(\tau) + (1-\sigma) \log C_Z(\tau)] d\tau$$

where $\rho \geq 0$ is the rate of time preference, $C_Y \geq 0$ is consumption of the high technology good, $C_Z \geq 0$ is consumption of the traditional good, $0 \leq \sigma \leq 1$ is the weight consumers put on consuming the high technology good compared to the traditional good. Consumers must decide i) how to allocate each period's consumption across the two consumer goods, ii) how to allocate consumption over time and iii) how to allocate time between market production and education subject to the technology for accumulating human capital (equation (14)) and the budget constraint,

$$(16) \quad C_Y + P_Z C_Z + \dot{B} = w (u_1 + u_2 + u_3) H + rB + p_L \bar{L},$$

where B is financial wealth and $\bar{L}$ is the fixed amount of unskilled labour per capita.

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Solving the problem gives the following first order conditions:

$$(17) \quad g_{C_Y} = r - \rho$$

$$(18) \quad \sigma P_Z C_Z = (1 - \sigma) C_Y$$

$$(19a) \quad g_w = r - \xi \quad \text{if} \quad 1 - u_1 - u_2 - u_3 > 0$$

$$(19b) \quad g_w < r - \xi \quad \text{if} \quad 1 - u_1 - u_2 - u_3 = 0$$

The first condition is the Keynes-Ramsey rule. The second condition determines the relative consumption of the two consumer goods in each period of time with the high technology good determined as the fraction σ of the period's total spending on consumer goods. The last condition is an arbitrage condition for the time allocation. It says that if the interest rate exceeds the growth rate of the wage rate plus the marginal productivity in education then the returns to education is so low that it is inoptimal to accumulate human capital. If, on the other hand, the interest rate equals the wage growth rate plus the marginal productivity in education, people will spend a positive amount of time on education provided that $\xi > \rho$ (to be shown later).

In the following, population size is normalized to one such that all aggregate magnitudes can be interpreted as per capita quantities.

3.1.3 Resource restrictions

Since durables are produced out of high tech final output the following accounting measure of total capital applies:

$$(20) \quad \dot{K} = Y - C_Y$$

where total capital is defined as $K = v \int_0^n x(i) di$ since it takes v units of foregone consumption of the high tech good to create one unit of any type of durable. According to equation (3') each durable is produced in identical quantities. Hence, we may write $K = v n x = \frac{\alpha \eta_1}{r} Y$.

The traditional output is used only for consumption. Hence total production equals total consumption of the good:

$$(21) \quad Z = C_Z$$

3.2. The development of a closed economy

In this section we illustrate the workings of the model by considering the development of a closed economy that does not trade internationally. The economy is endowed with a constant number of differentiated producer durables and is scarcely endowed with human capital. This means that the marginal productivity of both accumulable factors, the producer durable and human capital, is high and so is the wage rate per unit of human capital. Hence, the marginal cost of an innovation which equals the wage rate is larger than the marginal value of an innovation and there is no R&D in the economy. Accordingly, agents spend their time on final output production and education that raises the amount of physical and human capital in the economy. As the amount of human capital increases, the wage rate decreases, and at some point in time the wage rate will equal the marginal value of an innovation. From this point on agents conduct R&D. This leads to a transitional path towards a balanced growth equilibrium with R&D and human capital accumulation.

It is assumed that the economy reaches the point in time where the wage rate equals the value of an innovation while the economy moves along the balanced growth path with factor accumulation but no R&D. This assumption simplifies the description of the point in time when the economy starts to conduct R&D without altering the results qualitatively. The balanced growth path of the economy with human capital accumulation is defined as a path along which (i) the time allocation between high tech manufacturing, traditional manufacturing and education is constant over time and (iii) human capital, output of the high tech good and the traditional good and physical capital per capita grow at constant rates:

Definition 1. A balanced growth path with factor accumulation

Human capital per capita grows at the constant rate g_H which is defined as

$$g_H = \xi - \rho$$

Per-capita output of the high technology good, Y , grows at the rate $g_Y = g_K$, while per-capita output of the traditional good, Z , grows at the rate g_Z :

$$g_Y = g_K = \left(\frac{1 - \eta_1 - \eta_2}{1 - \eta_1} \right) (\xi - \rho) \text{ and } g_Z = (1 - \beta) (\xi - \rho).$$

The wage rate decreases over time at the rate

$$g_w = - \left(\frac{\eta_2}{1 - \eta_1} \right) (\xi - \rho).$$

Unless the productivity parameter in the human capital accumulation technology (ξ) is sufficiently high compared to the rate of time preference (ρ), no human capital accumulation will take place along the balanced growth path. In that case the economy will be caught in an underdevelopment trap of stagnation. Hence, it is assumed that $\xi > \rho$ which ensures a positive growth rate of human capital per capita in equilibrium. It is seen that the higher the productivity of human capital in the education sector is (the higher is ξ) and the more weight agents put on consumption tomorrow compared to consumption today (the lower is ρ), the faster the economy grows. The assumption that $\beta > \eta_1 + \eta_2$ implies that $g_Y > g_Z$. Hence, even in the absence of growth in the number of producer durables, the high tech goods production per capita grows faster than the production of traditional goods per capita due to (i) the fact that the sector uses physical capital that can be accumulated and (ii) the assumption that the sector is more intensive in both accumulable factors than the traditional goods sector is. The growth rate of GDP is the weighted average of the growth rates of the two final outputs where the weights are the relative outputs of the two goods to GDP. It is seen that the less intensive the manufacturing sectors are in human capital (the larger is β , η_1 and η_2) the lower are the growth rates.

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The wage rate declines over time along the balanced growth path. This feature is an implication of the assumption of constant returns to scale in manufacturing such that the larger the stock of human capital is, the lower is the productivity of an additional unit of human capital in the manufacturing sectors. Hence, the wage rate per unit of human capital declines over time, and at some point in time it is so low as to equalize the marginal cost and value of an innovation and thereby initiate R&D activity.³ Provided that this point in time is reached while the economy moves along the balanced growth path, it is characterised by the following amount of human capital per capita:

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$$H_T = \frac{(1 - \eta_1 - \eta_2) \rho}{(1 - \alpha) \eta_1 \delta u_1^*}$$

where H_T is the amount of human capital that allows the economy to jump from one stage of development to a higher stage, and $0 < u_1^* < 1$ is the constant fraction of time devoted to high tech manufacturing along the balanced growth path. It is seen that the amount of human capital needed to initiate R&D depends upon the following parameters:

- The more intensive high tech goods production is in human capital (the larger is $1 - \eta_1 - \eta_2$), the more human capital is allocated away from education and the larger is H_T ;
- The more weight agents put on consumption today compared to consumption tomorrow, the less do they value fast economic growth and the larger is H_T ;

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³ That the wage rate per unit of human capital declines over time does not mean that the wage rate per unit of time devoted to market activity declines over time. This growth rate equals the sum of the growth rate of the wage per unit of human capital plus the growth rate of human capital = $[(1 - \eta_1 - \eta_2)/(1 - \eta_1)](\xi - \rho) > 0$.

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- The less intensive high tech production is in producer durables (the lower is η_1) and the larger the elasticity of substitution between producer durables is (the larger is α), the lower are the incentives to invent new varieties of producer durables and the larger is H_T ; Deleted: is Deleted: is
- The lower the productivity in R&D is (the lower is δ), the more human capital is needed in the research sector to equalize marginal cost and value of an innovation and the larger is H_T ; Deleted: is
- The less time devoted to high tech goods production (the lower is u_1^*), the less important is high tech goods production compared to traditional goods production, and the lower are the incentives to invent new producer durables and the larger is H_T ; Deleted: is

From the point in time when human capital equals H_T , the economy begins to spend time on research activity ($u_3 > 0$), and after a transition period the economy reaches a new balanced growth path along which it accumulates human capital and conducts R&D. This path is described as follows.

Definition 2. A balanced growth path with human capital accumulation and R&D

Per-capita human capital and the number of designs for differentiated producer durables grow at the same constant rate:

$$g_H = g_n = \xi - \rho$$

Per-capita output of the high tech good and physical capital per capita grow at the rate

$$g_Y = g_K = \frac{(1-\alpha)\eta_1 + \alpha(1-\eta_1-\eta_2)}{\alpha(1-\eta_1)}(\xi - \rho),$$

while output of the traditional good per capita grow at the rate

$$g_Z = (1-\beta)(\xi - \rho).$$

By comparison with the growth rates along the balanced growth path with only factor accumulation it is seen that (i) the growth rates of human capital per capita is identical and equals the growth rate of the number of designs. Hence, the ratio of human capital to the number of designs is constant along the balanced growth path; (ii) the growth rate of Y is larger in the presence of R&D; (iii) the growth rates of Z are identical along the two balanced growth paths. All in all, this means that the growth rate of GDP is larger in the presence of R&D than when there are no market incentives to do R&D. Moreover, the relative importance of high tech goods production compared to traditional goods production is larger in the equilibrium with R&D.

One new feature of this balanced growth equilibrium is that the growth rate of Y depends negatively on α which means that the larger is the elasticity of substitution between durables in high tech goods production (the larger is ϵ) the lower is the growth rate of output of the sector. This is because a higher elasticity of substitution in the final goods production lowers the marginal productivity of an extra durable, thereby depressing the growth effect of variety in high tech manufacturing. As the elasticity of substitution between durables approaches infinity, the growth effect of variety and the price of durables approach zero and ultimately the incentives to conduct R&D disappear. Hence, this result underlines that imperfect substitution and monopolistic competition is a prerequisite for R&D to take place. Deleted: es Deleted: s

4. Effects of international trade

Grossman and Helpman (1991) analyse dynamic effects of comparative advantages focusing on R&D as the primary source of economic growth. Their analysis reveals, among other things, that growth effects of international trade depends on the extent of spillover effects. Hence, one has to distinguish between, e.g., knowledge spillovers that are global in scope and knowledge spillovers that are geographically constrained. When they are global in scope the results from static trade analyses apply: A country that is well endowed with human capital specializes relatively in R&D and high-tech manufacturing, while a country with an abundance of unskilled labour specializes relatively in traditional manufacturing. When spillovers are geographically concentrated, the relative advantage in R&D performance is endogenously determined. Therefore, the comparative advantage in research is not only determined by the endowment of human capital but also by the scale of the country and the size of the initial knowledge capital of the economy.

In this section we consider the patterns of specialization and international trade as well as growth effects that arise when opening up the framework of section 3. There are two countries: a rich developing country (A) that accumulates human capital and performs R&D, and a developing country (B) that accumulates physical and human capital but does not perform R&D. Throughout the analyses we focus on the development of country B.

The developing country is assumed initially to be endowed with a relatively low amount of human capital while the endowment of unskilled labour is relatively large compared to the rich country. Due to the low initial amount of human capital that depresses the potential profit of innovating, agents in country B lack the incentives to conduct R&D. So time is shared between final goods production and education. Now, assume that during this stage of development, the developing country opens up for international trade in both consumer goods, producer durables and financial capital. This enables the country to adopt producer durables that are invented and produced in the rich country. Hence, the number of producer durables available for high tech goods production in country B increases, which has a positive effect on the marginal productivity of unskilled labour and human capital in high tech goods production. This induces agents to raise the amount of time devoted to education, thereby accelerate human capital accumulation. The larger variety of producer durables and the larger amount of human capital favours production of the high tech good since it is assumed to be relatively more intensive in these factors than the traditional goods production. Hence, in the absence of international trade in consumer goods, international trade in producer durables speed up the growth rate and allocates more resources to high tech goods production relative to traditional goods production. All in all, this speeds up the growth rate of GDP compared to a closed economy. Moreover, it may speed up the development process since the country accumulates faster a sufficient amount of human capital to generate R&D activity.

However, international trade in consumer goods may alter this positive picture of the dynamic effects of international trade. Country B is assumed to be better endowed with unskilled labour while country A is further developed than country B wrt. human capital such that the rich country has a larger amount of human capital per capita than the developing country has. Hence, a larger fraction of the total

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In this section we consider the growth effects and the patterns of international trade using the framework of section 3. There are two countries: a rich developing country (A) that accumulates human capital and performs R&D, and a developing country (B) that accumulates physical and human capital but does not perform R&D. Throughout the analyses we focus on the development of country B. [1]

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production of the high tech good may take place in the rich country, while a larger fraction of the traditional good may take place in the poor country. As the production of high tech goods decreases compared to the traditional goods production, the human capital accumulation slow down. Then international trade may slow down GDP growth and the development process due to comparative advantages. If the compositions of unskilled labour and human capital in the two countries are sufficiently dissimilar, international trade may even cause the developing country to be caught in an underdevelopment trap. In that case comparative advantages result in the developing country specializing in production of the traditional good, while the rich country specializes in R&D and production of the high tech good. Hence, opening up for international trade may catch the developing country in an underdevelopment trap of low economic growth and no prospects of entering the R&D stage of development.

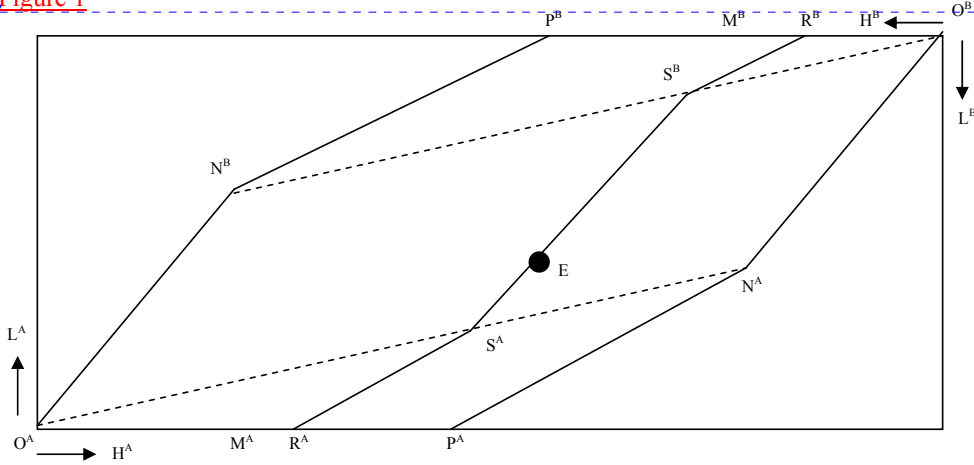
If this is not the case, i.e. if the countries' compositions of unskilled labour and human capital are not too dissimilar at the time when the countries start to trade, then country B accumulates human capital and produces the high tech good, and at some point in time the marginal cost and value of an innovation equalize, and the economy develops from the adoption stage to the R&D stage. After a period of transition, the countries reach a balanced growth path where factor prices are equalized across countries, both countries conduct R&D, human capital and the number of designs grow at the same constant rate across countries, and the production of high tech goods and traditional goods, respectively, grow at the same constant rates across countries. However, the developing country may still be relatively better endowed with unskilled labour, and the rich country may be better endowed with human capital, such that unequal shares of the total production of each type of consumer good are produced in the two countries.

To describe this long-run equilibrium where both countries conduct R&D we employ the solution method from Grossman and Helpman (1991).⁵ First, we characterise the long-run equilibrium of a hypothetical integrated world economy, that is, an economy in which goods, factors, capital and knowledge move freely across international borders. This can be done with the use of the closed economy framework of the previous subsection. Then we construct feasible allocations of resources for the two countries that have the same techniques of production in every location as in the integrated equilibrium and that yield the same aggregate outputs of goods, knowledge and human capital. If this can be accomplished in a way that (i) satisfies the separate no-arbitrage conditions for the two countries and (ii) has each country producing a number of producer durables and possessing a stock of human capital that is consistent with prior investments in R&D and education, then the proposed allocations constitute an equilibrium with factor price equalization. This pattern of specialization and trade is uniquely determined. Hence, the proposed allocation is the long-run balanced growth path. The allocation is depicted in figure 1 at a given point in time, that is for a given amount of total human capital in the two countries.

⁵ Grossman and Helpman (1991) chap. 7.

Figure 1

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The dimensions of the rectangle in the figure represents the global endowments of unskilled labour and human capital at a given point in time during the balanced growth path. The line segment $O^A M^A$ represents the amount of human capital devoted to R&D at this point in time in the integrated economy. The segment $M^A P^A$ represents the amount of human capital devoted to education while the segment $P^A N^A$ represents the vector of human capital and unskilled labour that is used in high tech manufacturing. Finally, the line segment $N^A O^B$ represents the vector of resources that is used in traditional manufacturing. As the assumption $\beta > \eta_1 + \eta_2$ implies, the figure is drawn such that high tech manufacturing is relatively more intensive in the use of human capital and less intensive in the use of unskilled labour than traditional manufacturing is.

The point E represents the separate resource endowments of the two countries. Since the point lies to the right and below the middle of the rectangle it reflects the assumption that country A is relatively better endowed with human capital while country B is relatively better endowed with unskilled labour. As long as E lies in the interior of $O^A P^A N^A O^B P^B N^B$ the endowment ratios are sufficiently similar to be compatible with an equilibrium characterised by incomplete specialization.

For the endowment point E we conjecture an equilibrium allocation of resources for each separate country that yields the same aggregate resource allocation between activities as the allocation of the integrated world economy. The line segment $O^A R^A$ is the amount of human capital devoted to R&D and human capital accumulation in country A, while the segment $O^B R^B$ is the amount of human capital devoted to these activities in country B. $O^A R^A + O^B R^B = O^A P^A$, i.e., the total amount of human capital devoted to R&D and human capital accumulation in the two countries equals the allocation in the integrated world equilibrium. The allocation of human capital to R&D and education in the two countries are uniquely determined by the conditions that the number of designs invented in each country and the amount of human capital accumulated in each country at any point in time are consistent with the rates of innovation and human capital accumulation that take place there. The line segment $R^A S^A$ which is parallel to the segment $P^A N^A$ is the vector of resources devoted to high tech

manufacturing in country A, and the segment $R^B S^B$ is the vector of resources allocated to this activity in country B. Again the length of the segments are identical to the total allocation of resources to high tech manufacturing in the integrated world equilibrium. Finally, the line segments $S^A E$ and $S^B E$ represent the vectors of resources allocated to traditional manufacturing in the two countries such that total traditional output equals the output of this good in the integrated equilibrium.

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The proposed resource allocation is the unique allocation at a given point in time during the balanced growth path when the endowment ratios are sufficiently similar to be compatible with an equilibrium characterised by incomplete specialization provided that (i) the allocation is feasible; (ii) the allocation constitutes an equilibrium for the world economy when factor and commodity prices in each country is the same as in the integrated equilibrium and (iii) the rates of growth of designs and human capital in the two countries are consistent with the number of designs invented in each country and the amount of human capital accumulated in each country in the past.

Comparative advantages determine the pattern of specialization. Since country A is assumed to be relatively better endowed with human capital this country conducts relatively more R&D and manufactures relatively more high tech output than country B compared to its output of the traditional good. This pattern of specialization may give rise to alternative patterns of international trade. With regard to intraindustry trade, firms in each country export the unique producer durable that they have invented. The pattern of interindustry trade depends on whether financial assets are traded or not internationally, and the size of long-run trade imbalances. Assume that agents may trade their financial assets on international capital markets, then a country may run a deficit on the trade account balanced by a surplus on the service account. In that case, if the size of the long-run trade imbalance is not too large then the pattern of international trade corresponds to the Heckscher-Ohlin theorem: Country A develops a sectoral trade surplus in the high tech good while country B is a net exporter of the traditional good. If, on the other hand, the size of the long-run trade imbalance is large the country in deficit may become a net importer of both the high tech good and the traditional good.

The pattern of specialization also has implications for the long-run rates of growth in the two countries. Along the balanced growth path the rates of growth of each factor are identical across countries and equal the growth rates of the integrated world economy. These rates are identical to the growth rates of a closed economy along a balanced growth path where agents accumulate human capital and perform R&D. According to definition 2 of the previous subsection these rates were determined as

$$g_H = g_n = \xi - \rho, \quad g_Y = \frac{(1-\alpha)\eta_1 + \alpha(1-\eta_1-\eta_2)}{\alpha(1-\eta_1)}(\xi - \rho) \quad \text{and} \quad g_Z = (1-\beta)(\xi - \rho).$$

Along the balanced growth path the growth rate of high tech production in each country exceeds the growth rate of traditional production. The pattern of specialization where country A specializes relatively in high tech production and country B specializes relatively in traditional production implies a faster GDP growth rate in country A than in country B. As the economies develop, the total amount of human capital increases while the amount of unskilled labour remains fixed. However, this change in the factor composition of each country does not alter the patterns of specialization along the balanced growth path since the relative allocation of resources to high tech manufacturing, traditional manufacturing, education and R&D remains constant in each country. Hence, the trade pattern does not change over time along the balanced growth path.

The characterisation of the long-run FPE equilibrium does not add any insight into the effects and patterns of international trade compared to the analysis by Grossman and Helpman (1991). However, characterisation of the developing process until the balanced growth path is reached may add some insight that is useful for the design of development aid and advise. Even though the analysis points to the possibility that the market mechanisms can solve the problems of poverty and development there are some considerations to take into account. First, the developing country may be caught in an underdevelopment trap. This is the case if it is sufficiently scarcely endowed with human capital at the point in time when it opens up for international trade. In this case the country specializes in traditional goods production and will never enter the adoption and R&D stages of development. Second, even if the poor country accumulates human capital and at some point in time reach the stage where the amount of knowledge is sufficient to generate R&D, this development process may take many, many years. Barro and Sala-I-Martin (1995) estimates that around 2 per cent of the difference between rich and poor states in the US is eliminated per year. If rich and poor countries are assumed to converge at the same speed then it will take a poor country like Sierra Leone with a GDP of 500\$ per capita 113 years to reach a GDP per capita which is 90 pct. Of the GDP per capita in the US. Hence, there is plenty of room for active development aid and advise.

5. Conclusions

The framework described in the paper encompasses three stages of development where the transition from one stage to a higher stage is the result of the developing process in it-self. Opening up to international trade may accelerate the developing process. However, the mechanics of comparative advantages may steer the economy into an underdevelopment trap. To avoid this gloomy perspective it is important that governmental policies preserve the incentive of the agents to accumulate skills by providing a well-functioning education system. Even though the economy escapes the underdevelopment trap the development process towards the high income stage may take many decades. The model suggests that education and judicial systems are prerequisites for achieving higher stages of growth.

The transition path of the model has only been cursorily treated in the paper. We intend to make a more thorough and rigorous analysis supplemented by numerical simulations. Also, we wish to develop the model by including two additional stages: An initial stage of only physical capital accumulation and a stage of technology imitation prior to the final stage of R&D. Finally, the potentially important effects of spill-overs stressed by Grosman and Helpman (1991) suggest to include externality effects in the model. Ultimately the objective is to conduct an empirical analysis of the linkages between trade, growth and structural characteristics based upon the theoretical framework. Thereby, we hope to provide a quantitative assessment of the relative importance of the dynamic effects suggested by the model.

References

Acemoglu, D., P. Aghion and F. Zilibotti (2003). *Distance to Frontier, Selection, and Economic Growth*. NBER Working Paper.

- Aghion, P. and P. Howitt (1992). "A Model of Growth through Creative Destruction," *Econometrica*, vol. 60, pp. 323-351.
- Aghion, P. and P. Howitt (1998). *Endogenous Growth Theory*. Cambridge, USA: MIT Press.
- Baldwin, R.E., P. Martin and G.I. Ottaviano (2001). "Global Income Divergence, Trade and Industrialization: The Geography of Growth Take-Offs," *Journal of Economic Growth*, vol. 6, pp. 5-37.
- Barro, R.J. and X. Sala-i-Martin (1995) *Economic growth*. New York.
- Ben-David, D. (1993): "Equalizing Exchange: Trade Liberalization and Income Convergence," *Quarterly Journal of Economics*, vol. 108, pp. 653-79
- Comin, D. and B. Hobijn (2004). "Cross-country technology adoption: making the theories face the facts," *Journal of Monetary Economics*, vol. 51, pp. 39-83.
- Dollar, D. (1992): "Outward-oriented Developing Economies Really do grow more rapidly: Evidence from 95 LDCs, 1976-1985," *Economic Development and Cultural Change*, vol. 40.
- Funke, M. and H. Strulik (2000). "On endogenous growth with physical capital, human capital and product variety," *European Economic Review*, vol. 44, pp. 491-515.
- Grossman, G.M. and E. Helpman (1991). *Innovation and Growth in the Global Economy*. Cambridge, USA: MIT Press.
- Harrison, A. (1995). *Openness and Growth: A Timeseries, Cross-country Analysis for Developing Countries*. NBER Working Papers No. 5221.
- Howitt, P. and D. Mayer-Foulkes (2003). *R&D, Implementation and Stagnation: A Schumpeterian Theory of Convergence Clubs*. Working paper.
- Hunt, D. (1989). *Economic Theories of Development – An analysis of competing paradigms*. New York: Harvester Wheatsheaf.
- Kejak, M. (2003). "Stages of Growth in Economic Development," *Journal of Economic Dynamics and Control*, vol. 27, pp. 771-800.
- Kuznets, S. (1971). "Notes on Stage of Economic Growth as a System Determinant," in *Comparison of Economic Systems: Theoretical and Methodological Approaches*, ed. by A. Eckstein. Berkeley: University of California Press.
- Lucas, R.E. jr. (1988). "On the Mechanisms of Economic Development," *Journal of Monetary Economics*, vol. 22. pp. 3-42.

- Meier, G.M. (1995). *Leading Issues in Economic Development*. New York: Oxford University Press.
- Romer, P.M. (1990). "Endogenous Technological Change," *Journal of Political Economy*, vol. 98, pp. 71-102.
- Rostow, W. (1952). *The Process of Economic Growth*. New York: Norton.
- Rostow, W. (1960). *The Stages of Economic Growth: A Non-Communist Manifesto*. Cambridge, U.K.: Cambridge University Press.
- Sachs, J.D. and A. Warner (1995). "Economic Reform and the process of Global Integration," *Brookings Papers on Economic Activity*, vol. 1995, No. 1, 25th Anniversary Issue.
- Solow, R.M. (1956). "A Contribution to the Theory of Economic Growth," *Quarterly Journal of Economics*, vol. 70, pp. 65-94.

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Figure 1...¶

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The developing country (B) is assumed initially to be endowed with a relatively low amount of human capital while the endowment of unskilled labour is relatively large compared to the rich country. Due to the low initial amount of human capital that depresses the potential profit of innovating, agents in country B lack the incentives to conduct R&D. So time is shared between final goods production and education. Now, assume that during this stage of development, the developing country opens up for international trade in both consumer goods, producer durables and financial capital. This enables the country to adopt producer durables that are invented and produced in the rich country. Hence, the number of producer durables available for high tech goods production in country B increases, which has a positive effect on the marginal productivity of unskilled labour and human capital in high tech goods production. This induces agents to raise the amount of time devoted to education, thereby accelerat

production of the high tech good since it is assumed to be relatively more intensive in these factors than the traditional goods production. Hence, in the absence of international trade in consumer goods, international trade in producer durables speed up the growth rate and allocates more resources to high tech goods production relative to traditional goods production. All in all, this speeds up the growth rate of GDP compared to a closed economy. Moreover, it may speed up the development process since it accelerates

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However, international trade in consumer goods may alter this positive picture of the dynamic effects of international trade. Country B is assumed to be better endowed with unskilled labour while country A is further developed than country B wrt. human capital such that the rich country (A) has a larger amount of human capital per capita than the

developing country (B) has. Hence, a larger fraction of the total production of the high tech good may take place in the rich country, while a larger fraction of the traditional good may take place in the poor country. As the production of high tech goods decreases compared to the traditional goods production, the human capital accumulation slows down. Then international trade may slow down GDP growth and the development process due to comparative advantages. If the compositions of unskilled labour and human capital in the two countries are sufficiently dissimilar, international trade may even cause the developing country to be caught in an underdevelopment trap. The comparative advantages result in so extensive specializing that the developing country produces a very small amount of the high-tech good, which makes it impossible to ever develop into the R&D stage.

If this is not the case, i.e. if the countries' compositions of unskilled labour and human capital are not too dissimilar at the time when the countries start to trade, then country B accumulates human capital and produces the high tech good, and at some point in time the marginal cost and value of an innovation equalize, and the economy develops from the adoption stage to the R&D stage. After a period of transition, the countries reach a balanced growth path where factor prices are equalized across countries, both countries conduct R&D, human capital and the number of designs grow at the same constant rate across countries, and the production of high tech goods and traditional goods, respectively, grow at the same constant rates across countries. However, the developing country may still be relatively better endowed with unskilled labour, and the rich country may be better endowed with human capital, such that unequal shares of the total production of each type of consumer good are produced in the two countries.

To describe this long-run equilibrium where both countries conduct R&D we employ the solution method from Grossman and Helpman (1991).

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¹ First, we characterise the long-run equilibrium of a hypothetical integrated world economy, that is, an economy in which goods, factors, capital and knowledge move freely across international borders. Then we construct feasible allocations of resources for the two countries that have the same techniques of production in every location as in the integrated equilibrium and that yield the same aggregate outputs of goods, knowledge and human capital. If this can be accomplished in a way that (i) satisfies the separate no-arbitrage conditions for the two countries and (ii) has each country producing a number of producer durables that is consistent with prior investments in R&D, then the proposed allocations constitute an equilibrium with factor price equalization. This pattern of specialization and trade is uniquely determined. Hence, the proposed allocation is the long-run balanced growth path. The allocation is depicted in figure 1 at a given point in time, that is, for a given amount of total human capital in the two countries.

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Figure 1...

¹ Grossman and Helpman (1991) chap. 7.

The dimensions of the rectangle in the figure represents the global endowments of unskilled labour and human capital at a given point in time during the balanced growth path. The line segment $O^A M^A$ represents the amount of human capital devoted to R&D at this point in time in the integrated economy. The segment $M^A P^A$ represents the amount of human capital devoted to education while the segment $P^A N^A$ represents the vector of human capital and unskilled labour that is used in high tech manufacturing. Finally, the line segment $N^A P^B$ represents the vector of resources that is used in traditional manufacturing. As the assumption $\beta > \eta_1 + \eta_2$ implies, the figure is drawn such that high tech manufacturing is relatively more intensive in the use of human capital and less intensive in the use of unskilled labour than traditional manufacturing is.

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The proposed resource allocation is the unique allocation at a given point in time during the balanced growth path when the endowment ratios are sufficiently similar to be compatible with an equilibrium characterised by incomplete specialization provided that (i) the allocation is feasible; (ii) the allocation constitutes an equilibrium for the world economy when factor and commodity prices in each country is the same as in the integrated equilibrium and (iii) the rates of growth of designs and human capital in the two countries are consistent with the number of designs invented in each country and the amount of human capital accumulated in each country in the past.

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At the point in time described by figure 1 country B

As the economies develop the total amount of human capital increases which “trækker figuren ud” / “gør den mere aflang”. But along a balanced growth path this does not alter the relative allocation of resources to high tech manufacturing, traditional manufacturing, education and R&D. Hence, the trade pattern does not change over time along the balanced growth path.

The characterisation of the long-run FPE equilibrium does not add any insight into the effects and patterns of international trade compared to the analysis by Grossman and Helpman (1991). However, characterisation of the developing process until the balanced growth path is reached may add some insight that is useful for the design of development aid and advise. Even though the analysis points to the possibility that the market mechanisms can solve the problems of poverty and development there are a couple of considerations to take into account. First, the developing country may be caught in an underdevelopment trap. This is the case if it is sufficiently scarcely endowed with human capital at the point in time when it opens up for international trade. In this case the country specializes in traditional goods production and does never enter the adoption and R&D stages of development. Second, even if the poor country accumulates human capital and at some point in time reach the stage where the amount of knowledge is sufficient to generate R&D, this development process may take many, many years. Barro and Sala-I-Martin (1995) estimates that around 2 per cent of the difference between rich and a poor states in the US is eliminated per year. If rich and poor countries are assumed to converge at the same speed then it will take a poor country like xx Y years to catch up with the US economy. Hence, there is plenty of room for active development aid and advise.