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a literature survey

Andersen, Lill; Lind, Kim Martin

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The Correlation between Openness and Long-Run Economic Growth

- A literature survey

Lill Andersen and Kim M. Lind

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Preface

Trade and growth take a prominent position on the international agenda. The ongoing international trade negotiations under the auspices of the WTO provide expectations that developing countries may become more integrated in the world economy in order to promote growth and prosperity in these countries. Globalisation has evolved rapidly among the developed countries where trade has grown considerably, while developing countries only display more modest progress in trade, which is seen as one of the reasons for lack of growth in many developing countries particularly in Sub-Saharan Africa.

This report is the first work product from the project "Endogenous growth, trade and development: The road towards eradication of poverty?" financed by Forskningsrådet for Udviklingsforskning (RUF). The purpose of the project is to examine (theoretically and empirically) the connections between openness and growth, and derived effects on poverty and income structure. Thus, the project aims at examining how development aid can be designed in order to further openness, growth and employment and ease possible negative effects on poverty.

Lill Andersen and Kim Martin Lind from the International Economics and Policy Division at FOI have prepared the report. Rie Paving Mortensen has contributed with writings on unified growth theory and appropriate technologies. Michael Haase has found and provided relevant literature as well as prepared a first draft of the survey. The authors have benefited from useful comments and suggestions from Ronald A. Babula, Rie Paving Mortensen, and Helene Hartmann.

Institute of Food and Resource Economics, May 2006.

Søren E. Frandsen

Executive summary

The objective of this paper is to provide an overview of the theoretical and empirical literature that analyses the correlation between openness and economic growth in order to evaluate the state of the art. The review incorporates many types of international linkages: international commodity trade, international knowledge spillovers, international technology diffusion, imitation, and multinational corporations. However, in defining the boundaries of the review, it has been decided to focus on long-run growth effects of openness that are not country or case-specific. Hence, we consider theoretical models that generate endogenous long-run growth, and empirical studies concerned with correlation patterns that apply to many countries.

The survey starts by providing an overview of growth mechanisms stressed in the theoretical literature. Traditionally, economists have focussed on physical capital accumulation as the main source of growth while treating technological progress as exogenous. During the last 20 years a new wave of research on economic growth has cast human capital formation, and research and development of new or better technologies as the ultimate sources of growth, thereby explaining long-run growth. These theories have been criticised for resting on a knife-edge issue, incorporating scale effects, and contradicting empirical evidence of income convergence across countries. The survey shows that all these criticisms may be rejected, leaving economists with rich, dynamic frameworks that allow for theoretical analyses of long-run growth effects of many types of international linkages.

Following this overview, empirical literature on the correlation between international trade and growth are summarised. While there is overwhelming empirical evidence of positive *level* effects of international trade and other international linkages, the jury is still out on the question of whether there are positive *dynamic* effects of openness. The numerous attempts to establish a robust link have not proven to be entirely convincing, first, because data are scarce and of a low quality especially for many developing countries, and, second, because openness can affect the growth mechanisms of an economy in many ways. Thus, simple measures of openness may not be able to capture the full extent of the impacts, and country specifics play a major role. Hence, there is a need for targeted and rigorous econometric analyses of the correlation between openness and growth based on high-quality data and appropriate theoretical specifications.

The remainder of the paper is devoted to surveying the theoretical literature that investigates the correlation between openness and long-run growth. Opening up for communication and cooperation at an informal level may facilitate the international diffusion of general knowledge which unambiguously promotes growth across countries because it raises productivity in the research sector, and because more labour is allocated towards research activity. The dynamic effects of opening up for international commodity trade are more uncertain. International trade promotes growth because it induces a more efficient allocation of resources between manufacturing and research. Hence, countries with a comparative advantage in research and development (R&D) specialize relatively in research activity while other countries specialize relatively in manufacturing. As a result the growth rate of the world economy increases compared to autarky. However, the dynamic gains from trade may be unequally distributed across countries and in some cases countries may actually lose. The majority of the analyses predicts that countries with a relative abundance of human capital, countries with a large initial stock of general knowledge, and countries at a more advanced technological stage experience higher growth as a result of international trade. This is because these countries have an initial comparative advantage in producing the good with the largest growth potential, and this initial advantage gives rise to a dynamic process that extend the advantage over time. Along with the rich countries extending their comparative advantages, the poor countries may find themselves specializing in production activities with low growth potentials, thereby experiencing lower growth as a result of international trade.

The main potential source of dynamic gains from openness to poor countries seems to be international technology diffusion taking the form of either imitation or multinational corporations. Lower costs of production enable producers in developing countries to capture market shares and quasi-rents by under-pricing the original innovator thereby increasing long-run growth in the developing country. However, when it comes to international technology diffusion, there is also a danger of poor countries not reaping the dynamic gains: If use of technologies developed in rich countries requires the existence of complementary inputs which are not present in developing countries, this may refrain them from using the new technology and gain productivity growth.

The theoretical analyses of the dynamic effects of international commodity trade and international technology diffusion point to a common policy advise regarding developing countries: in order to reap the benefits from openness it may be necessary to develop certain structural characteristics of the economies. This may ensure that poor countries do not specialize in production activities with low growth potentials in the long run, and that they are able to reap dynamic gains from technological advances in developed countries.

1. Introduction

The link between trade and growth has at least since the publication of Adam Smith's "Wealth of Nations" been under scrutiny by the academic profession. David Ricardo's theory of comparative advantage has laid the foundation for the belief among the vast majority of economists that international trade augments national as well as personal income, although some opposition to this view has been mounted by Marxist inspired theorists. However, even though the dispute concerning the benefits of international trade on the level of income has been largely won by the "pro-traders", the issue of whether trade, international diffusion of technology, and other international linkages are conducive to growth remains unresolved. It is, however, an important question since even small differences in annual growth rates have large consequences for standards of living when cumulated over a generation or more.

In the public debate particularly in the context of the multilateral trading regime as administered by the World Trade Organization (WTO) often the viewpoint and implicit presumption is that trade is a catalyst for growth. For example, the first sentence in the ministerial declaration from the DOHA Ministerial Meeting in 2001 reads "The multilateral trading system embodied in the World Trade Organization has contributed significantly to economic growth, development and employment throughout the past fifty years".[1] Nevertheless, convincing irrefutable evidence for this underlying hypothesis cannot be said to have been found. A large amount of anecdotal evidence and case study results exist that seem to support the view, although these studies have been criticised on both econometric grounds as well as for theoretical deficiencies.

When it comes to trade policy the unresolved question of the link between trade and growth implies often conflicting views on the role of trade policy. An example is the debate of the import-substitution strategy versus the export-oriented policy. Up until the 1980's a prevailing view on the role of trade policy was founded in the infant industry argument. Economies in lower stages of development need to protect domestic industries from foreign competition until they have reached a sufficient level of competitiveness. Thus, import barriers were generally viewed as a vehicle for growth. The experience, however, of the so-called Asian tiger economies have shifted focus from the inward-looking to a more outward-looking export oriented view. Consequently, more focus is directed towards trade liberalization instead of domestic barriers as a vehicle for growth.

[1] http://www.wto.org/english/thewto_e/minist_e/min01_e/mindecl_e.htm

During the last 20 years the theoretical development has provided economists with rich dynamic frameworks that suggest quite a number of different ways in which international trade, international knowledge diffusion, imitation, and other types of international linkages may affect long-run growth rates. The advent of the new growth theories highlights the importance of empirical analyses on the role of openness in order to provide measurements of the relative importance of various strategies and policies suggested in the theoretical literature.

The aim of this report is to survey the theoretical and empirical literature on openness and economic growth. Core issues are:

- Which mechanisms foster a correlation between openness and growth? How are they incorporated into formal models of economic growth, and which main results are derived from these frameworks?
- Does the empirical and theoretical literature provide a decisive answer to the question in hand: does openness promote growth? If not - what are the conditions under which openness (does not) promotes growth?
- Are there specific conditions/problems to take account of when considering developing countries? Are the dynamic effects of imitation and foreign direct investment different from the effects of international trade between developed countries?

The scope of the survey is delineated by including only theoretical analyses of openness and growth conducted with the use of rich dynamic set-ups that include imperfect markets, externality effects, and endogenously determined long-run growth. Studies that highlight level effects and temporary growth effects will not be referred to. In the empirical part of the survey we try to deduce some correlation patterns on growth and trade that apply to many countries. Therefore, focus is on cross-country regressions, precluding country-specific analyses and case studies.

Chapters 2-4 serve as the foundation of chapters 5-7. The report is organised as follows. In chapter 2 different mechanisms of growth stressed in the theoretical literature are presented. Chapter 3 relates the theoretical frameworks' predictions about convergence of income across countries or regions to empirical evidence. In chapter 4 we focus on the development process that may transform a stagnating, low-income economy to a growing high-income one. Section 5 deals with the empirical evidence regarding a correlation between openness and growth. Different measurement methods of openness are presented, and results from cross-country regressions are surveyed. In chapter 6 we focus on international commodity trade and the concept of comparative advantage in dynamic theoretical frameworks. Next, in chapter 7 other aspects of openness are analysed: international diffusion of general knowledge, diffusion of specific technological knowledge, multinational corporations, imitation, and the notion of appropriate technologies. Chapter 8 contains concluding remarks.

2. Growth mechanisms

At least two empirical regularities concerning economic growth are worth mentioning:

- In many countries per-capita output grows over time, and its growth rate does not tend to diminish. Kaldor (1961) observed this in one of his “stylized facts”, and more recent evidence is provided by Romer (1986) and Scott (1989);
- The growth rate of output per worker differs substantially across countries in a given period of time and across different historical periods in a given country. This is another of Kaldor’s “stylized facts”. Grossman and Helpman (1991) and Barro and Sala-i-Martin (1995) provide more recent evidence of the cross-country variation.

The objective of growth theory is to explain some of the mechanisms behind the empirical regularities concerning growth. It is an important task in order to ensure continued welfare of rich countries and to provide development and growth of poor countries.

This chapter presents different mechanisms of growth stressed in the theoretical literature, how they are incorporated into formal theoretical models of growth and development, and the long-run behaviour of these models. Traditionally, economists have looked to capital formation for explanations of increasing standards of living. As a consequence, the early theoretical growth literature focuses on capital accumulation as the main source of growth while treating technological progress as exogenous in economic analyses. Alternatively, technological progress may be treated as an outgrowth of activities in the economic realm – either by viewing knowledge creation as a random occurrence or by introducing a formal theory of human capital accumulation. Section 3.1 reviews models of growth through capital accumulation.
Schumpeter (1942) and Schmookler (1966) argue that expected profitability of inventive activity determines the pace and direction of industrial innovation. When correct, the theory of growth should explain the links between (i) industrial innovation and growth, and (ii) market conditions and innovation rates. Recent theoretical growth literature presented in section 3.2 attempts to explain these two links, and casts research and development of new or better technologies as the ultimate source of growth.

2.1. Factor accumulation

The first formal growth model is associated with Solow (1956) and Swan (1956) who focus on capital accumulation and exogenous technological progress as the mechanisms that drive growth. The model is characterized by a neoclassical production function of diminishing returns to single factors and constant returns to all factors exemplified in the following Cobb-Douglas representation:

$$Y = (AL)^{\alpha} K^{1-\alpha}, \;\; 0 < \alpha < 1 \tag{1}$$

Y is output that is produced with the use of labour, *L*, and capital, *K*. *A* represents the state of technology and α is a parameter that determines the elasticity of substitution between the two inputs of production.

An increase in one of the productive factors creates output growth in the short run through increased productivity of the other factor. However, for a given state of technology (*A* constant over time), diminishing returns limits the size of the productivity gain as the factor quantity increases. According to the neoclassical theory, this implies that the marginal productivity of investments decreases until investments only raise physical capital as much as it depreciates. Therefore, for a given labour force, long-run output growth is feasible only when it is assumed that technological progress raises *A* such that the marginal productivity of capital is constant in the long run, and the rate of capital accumulation equals the rate of technological progress.[2] Even a growing labour force requires technological progress to ensure long-run growth in output per worker.

Following the theoretical work by Solow and others, some empirical economists and econometricians have analysed the forces behind economic growth. They used the methodology of growth accounting where the objective is to break down the growth rate of aggregate output into contributions from the growth of inputs.[3] Many studies find that for developed countries the contribution from technological progress accounts for at least half of overall growth. Solow (1957) found that technological progress accounts for as much as 85-90 per cent of GDP growth. Hence, technological

[2] In equation (1) it is assumed that technological progress is labour augmenting (Harrod neutral). Alternatively, technological progress may relate to the total factor productivity (Hicks neutral) or to capital (Solow neutral). However, only labour augmenting technological progress is consistent with the existence of a steady state.

[3] See Barro and Sala-i-Martin (1995) chap. 10.4 for a more detailed survey of the methodology and results.

progress - not explained in the model - accounts for most of the observed growth. However, the presumption that technological progress accounts for most of the observed growth does not imply that investment in capital is relatively unimportant in determining a country's growth rate. Kaldor (1961) and Solow (1957) mention that it is through investments that technological progress is integrated into the production process.[4] However, this functional relationship between technological progress and investments raises new problems to a model of exogenous technological progress.

The first successful attempt to explain technological progress was made by Arrow (1962) who linked the state of technology to cumulative investment experience, *A(K)*. By assuming that the effect of capital on productivity is external to an individual investor, Arrow preserved the perfect competition paradigm but obtained long-run growth in the absence of exogenous technological progress as long as the state of technology is sufficiently responsive to capital.

The idea of non-diminishing returns to the accumulable factor(s) from a social point of view was further exploited by Frenkel (1962), Romer (1986) and Rebelo (1991) who developed the so-called AK-model. According to this set-up, the economy is characterised by diminishing returns to capital for the individual firm but constant returns to capital from a social point of view. Hence, the production function of an individual firm may be given by equation (2):

(2) $$y = \overline{A} l^{\alpha} k^{1-\alpha} ,$$

where y is output, l is labour and k is capital of the firm. $\overline{A}$ represents an external effect that Frenkel specifies as a function of the overall capital/labour ratio of the economy:

(3) $$\overline{A} = A\left(\frac{K}{L}\right)^{\alpha} ,$$

where A is a fixed productivity parameter, K is the aggregate stock of capital and L is the total amount of labour in the economy. Although the external effect is endoge-

[4] Likewise, Aghion and Howitt (1998) develop a model where technological progress is determined by endogenous innovations. They show that even though a growth accounting exercise performed on an economy described by this model would attribute a very small fraction of growth to technological progress, the economy would ultimately stop growing altogether if innovation were shut down.

nous to the economy, it is assumed to be given for each firm, because a firm internalizes only a negligible amount of the effect that its own investment decision has on the aggregate stock of capital. Since there is non-increasing returns to scale for individual firms, the model is consistent with perfect competition but due to the external effect of investments, the model generates perpetual growth in the absence of exogenous technical progress.

The long-run rate of growth depends on parameters of preferences and technology such that policy changes can have long-run growth effects. If Frenkel had taken the externality effect to be a function of the total (rather than the average) stock of accumulated capital $(\bar{A}=AK^{\alpha})$ then the growth rate would be positively correlated with the scale of the economy: the larger the population, the faster the economy grows.

This genre of models typically reinterprets the concept of capital as a broad measure of knowledge consisting of both physical and human capital.[5] Other external effects that prevent the marginal product of knowledge from declining in the literature include government activity (e.g., Barro (1990) and Futagami et. al. (1993). Aschauer (1989) provides empirical evidence). In general, the existence of external effects creates a divergence between the social valuation of knowledge and the private valuation which implies that the growth rate in a decentralized economy falls short of the optimal rate. This leaves room for active government policy that increases the private rate of return on investment without introducing new distortions to the economy.

Human capital

Human capital was originally defined by Schultz (1961) and Becker (1964) as knowledge, skills, education, health, and training of individuals. It is treated as capital because it is an integral part of people that is long-lasting in the way a machine, plant or factory lasts. Hence, expenditures on education, training, medical care, and so on are investments in human capital. Growth theories focus on two distinct roles of human capital. One theory focuses on the accumulation of human capital, while the other sees human capital as a facilitator of technological development. According to the first theory, the growth of human capital influences GDP growth (Lucas (1988) and others), while it is the stock of human capital that influences GDP growth according to the second theory (Romer (1990) and others – to be reviewed in section 2.2).

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[5] The treatment of capital as a composite good may be justified by assuming either that the two types of capital are perfect substitutes or that production shows roughly constant returns to scale in the two types of capital taken together (Rebelo (1991)).

While the growth theorists of the 1950's focus on physical capital as the accumulable factor of the economy, Lucas (1988) treats human capital and physical capital as two distinct productive inputs that are produced according to different technologies. Hence, he specifies an education sector where human capital is produced according to a linear technology:

(4) $$\dot{h} = \delta(1-u)h$$

h is human capital (or skill level) per worker, *u* is employment in production, total time is fixed and normalised to 1, $\delta > 0$ is a productivity parameter and $\dot{h}$ the derivative of h with respect to time. Goods production uses physical capital and human capital as inputs according to a constant-returns-to-scale technology.[6] Hence, the economy is characterised by two accumulable factors of production instead of a single accumulable (physical capital) and one non-accumulable (labour) as is the case in the neoclassical model. Accordingly, the model implies no diminishing marginal productivity of investments, and thereby assures endogenous perpetual growth with the growth rate determined by parameters of preferences and technology.

This model treats the decision to accumulate human capital as equivalent to a decision of going to school. Lucas sets out an alternative model in which all human capital accumulation is learning-by-doing. He assumes that there are two consumer goods but no physical capital accumulation. Each good is consequently produced with the use of human capital specialized to the production of that good according to a constant-returns-to-scale technology. The effect of learning-by-doing is captured by assuming that the growth of human capital specialized to the production of good i increases with the effort devoted to producing that good:

(5) $$\dot{h}(i) = \delta(i)u(i)h(i),$$

where $h(i)$ is human capital specialized to the production of good i, $u(i)$ is the fraction of the workforce devoted to producing good *i*, $\delta(i) > 0$ is a productivity parameter and $\dot{h}(i)$ is the derivative of *h* with respect to time. As in the previous model of human capital accumulation, the constant returns to human capital ensure a positive long-run growth rate in the absence of exogenous technological progress.

[6] Lucas assumes an external effect of human capital in the goods production. This effect is intended to capture the influence people have on the productivity of others. In order to facilitate the exposition this effect is excluded here. Also, the validity of this assumption is questionable in the light of an empirical study by Mankiw, Romer and Weil (1992).

2.2. Product development

Hall & Jones (1999) show great productivity differences among developed countries, which is supported by Klenow & Rodriguez-Clare's (1997) result that over 60% of differences in 1985 per capita income cannot be explained by differences in quantities of physical or human capital. Hence, these analyses suggest that factor accumulation is not the primary source of growth. In line with these empirical findings, one theory of economic growth focuses on research and development of new or better products as the ultimate source of growth. According to this theory, profit-seeking firms consciously engage in research and development, which in turn fosters technological progress. Grossman and Helpman (1991) provide empirical evidence of growing spending by OECD members on commercial research in real terms. Moreover, they find a steadily increasing relative importance of commercial research compared to other economic activities for the same selection of countries. Hence, industrial R&D now receives a substantial allocation of resources in most industrial countries.

Paul Romer was the first to incorporate intentional R&D by profit-seeking firms into a formal model (Romer (1990)). He combined valuable diversity and productivity gains in R&D, which fosters sustained long-run growth. Romer's framework is detailed below.

The value of diversity arises from its enhancement of manufacturing productivity for a given volume of inputs or from its enhancement of household utility for a given volume of consumption.[7] Romer assumes that it raises the productivity of manufacturing and describes the supply side of the economy as consisting of three sectors: a final goods sector that manufactures a homogenous consumer good; an intermediate goods sector that manufactures intermediate goods to be used in manufacturing; and a research sector that generates designs for new intermediate goods.[8] [9]

Manufacturing takes place according to the following extended Cobb-Douglas technology:

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[7] Dixit and Stiglitz (1977) developed a specification of an index that imposes a constant and equal elasticity of substitution between every pair of goods. Romer (1990) used the specification to develop an extension of the Cobb-Douglas production function, while Grossman and Helpman (1991) used it as an index of consumption.

[8] Romer originally interpreted the output from the intermediate sector as capital goods (durables). The choice of interpretation does not change the main conclusions from the model.

[9] Alternatively, one may assume that research on a new design and the production of the new intermediate good take place within the same firm (as in, e.g., Grossman and Helpman (1991)).

(6) $$, Y = H_Y^{\alpha} L^{\beta} \int_0^A x(i)^{1-\alpha-\beta}, \; 0 < \alpha, \beta < 1$$

where Y is output, H_Y is human capital devoted to manufacturing, L is labour and $x(i)$ is the amount of intermediate good-i used in manufacturing. The total stocks of human capital and labour in the economy are taken as given. A is the number of differentiated intermediate goods that is currently being produced. Hence, intermediate goods are imperfect substitutes in manufacturing, and there is monopolistic competition in the market for intermediate goods. A license law prevents any firm from producing an intermediate good without the consent of the patent holder of a design, which in turn ensures that successfully innovating firms are compensated with monopoly rents. In this sense the outcomes of R&D are excludable. But since each research project is assumed to contribute to a stock of general knowledge representing a collection of ideas and methods that will be useful to later generations of innovators, the outcome of R&D is in this sense non-rival. It is assumed that the stock of general knowledge can be measured by the number of existing designs. In this case, an additional design raises the productivity of all future researchers. Research firms use the stock of general knowledge and human capital to produce new designs implying the following production technology of the research sector:

(7) $$\dot{A} = \Gamma H_A A^{\psi}, \; 0 \leq \psi \leq 1$$

Where A is the stock of general knowledge measured by the number of existing designs, $\dot{A}$ is the derivation of A with respect to time, H_A is human capital devoted to research, Γ is a productivity parameter, and ψ is a parameter that describes the degree of knowledge spillovers. The size of the parameter ψ is crucial to the long-term behaviour of the model. In order to ensure perpetual per-capita growth it is necessary to assume that the output of designs is linear in A, that is ψ=1. For values of ψ less than 1, per-capita growth may persist for a longer or shorter period of time but will eventually cease in the absence of any growth-promoting shocks to the economy. Romer assumes ψ=1 based on his observation of a lack of substantial recent evidence that research opportunities are diminishing.[10] The assumption should be understood as an approximation of a wider case – chosen for expository purposes.

Linearity in A implies that the long-run rate of growth is positively related to the amount of human capital devoted to research and negatively related to the interest rate. Hence, any policy change that affects either the amount of human capital de-

[10] Romer (1990), page S84.

voted to research or the interest rate has long-term growth effects. However, in an empirical study Jones (1995) points out that while OECD countries have seen permanent policy changes (trade liberalization, an increase in the average years of schooling, increases in investment and in R&D levels), there has been no visible tendency for growth in output per person or productivity to increase. The finding of permanent policy changes combined with constant long-run growth induced Jones to develop a model of so-called semi-endogenous growth by assuming diminishing marginal returns to knowledge with a value of ψ strictly less than one. Now, the long-run rate of growth of income per capita is zero in the absence of any growth promoting shocks to the economy, and a positive rate of population growth is the only source of long-run GDP growth. Young (1998), Segerstrom (1998) and others have built alternative semi-endogenous growth models.

In Romer's framework, long-run equilibrium is inefficient due to monopolistic competition and knowledge spillovers. An additional design raises the productivity of all future researchers but because this benefit is non-excludable it is not valued by the market. For this reason, too little resources are devoted to research and the growth rate is too low compared to social optimum. Moreover, due to monopolistic competition intermediate goods are sold at a price that exceeds marginal costs. This induces manufacturing firms to choose techniques that are below society's optimal level in intermediate goods and above in labour. Since the manufacturing sector competes with the research sector for labour, this distortion also tends to produce a suboptimal low allocation of resources to the research sector.

The result of too little R&D in a decentralized economy is not a robust feature of this class of models. Young (1991) develops a variant of the above-mentioned model, which incorporates the notion of learning-by-doing. In this framework, the learning-by-doing renders enhanced efficiency of existing intermediate goods as they are more intensively used in production. This externality implies that overly optimal levels of resources are devoted to research activity at the cost of learning-by-doing in the production sector. Alvarez-Palaez and Groth (2005) show that too much R&D may occur when the following three parameters are disentangled: the parameter determining the elasticity of substitution between intermediate goods, the returns to specialization parameter and the parameter of elasticity of substitution of output with respect to the index of intermediate goods. By disentangling these parameters, a third market failure appears, namely an effect of increased specialization on the productivity of existing intermediate goods in final goods production. This effect may offset the effects of monopolistic competition and knowledge spillovers and generate too much R&D in decentralized equilibrium.

Another class of models also challenges the robustness of the inefficiency result. While models of product differentiation assume away any obsolescence of old intermediate goods, models of increasing product quality (vertical innovation) build on Schumpeter's (1934) notion of creative destruction (Aghion and Howitt (1992), Grossman and Helpman (1991)). With these models, innovation improves the quality of a fixed set of intermediate goods or a fixed set of consumer goods, and new generations of goods displace old generations from the market. Researchers target their efforts at particular goods that they see on the market, and attempt to develop superior versions of these goods. In this set-up research is not deterministic as in models of expanding product variety but entails uncertain prospects. Hence, provided that a firm invests a given amount of resources in R&D activity, the arrival of innovations is described by a Poisson process. Despite these differences, the same economic mechanism sustains long-run growth in models of rising product quality as in models of expanding product variety.[11] However, the models diverge when it comes to welfare. In models of rising product quality, the presence of an additional externality tends to generate excessive research in decentralized equilibrium. This negative spillover takes the form of a "business-stealing effect", whereby a successful innovator destroys the surplus attributable to the previous generation of intermediate good by making it obsolete. The private research firm does not internalize this loss but a social planner does. This effect will tend to generate a more-than-optimal level of research in a decentralised economy. It can be shown that when there is a high degree of monopoly power and innovations are modest, the business-stealing effect dominates and decentralised growth is excessive (see, e.g., Aghion and Howitt (1998), chapter 2).

Romer's model of expanding product variety has been used widely in the literature and modified in many ways. These models may include various forms of factor accumulation but in the absence of innovations, the accumulation process eventually ceases. To mention a few modifications that will be referred to in later chapters: Grossman and Helpman (1991) assume that the manufacturing of intermediate goods uses two types of labour but no intermediate goods, and Rivera-Batiz and Romer (1991) assume that the research technology is identical to the manufacturing technology such that it uses intermediate goods and labour as well as human capital.

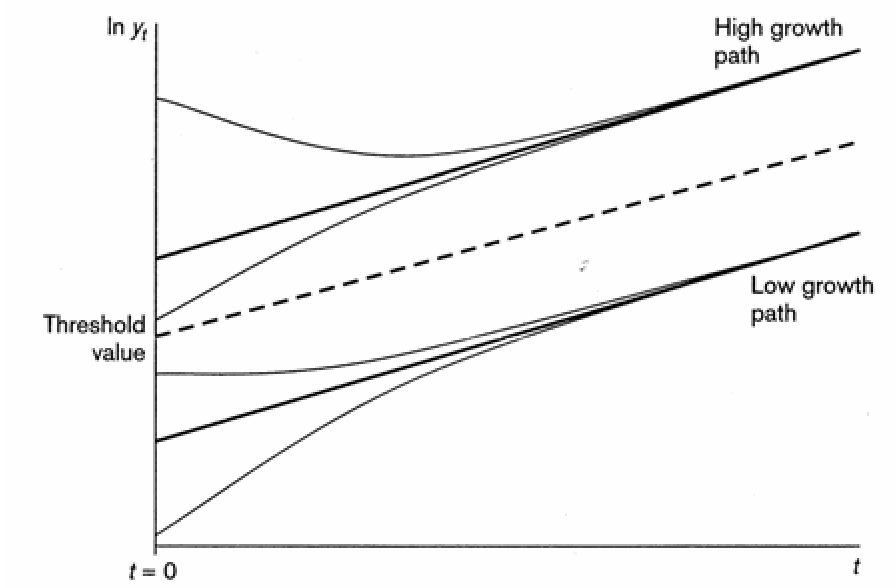
[11] Grossman and Helpman (1991), chapter 4 compares the two models and explain why the alternative models share the same reduced form.

3. Convergence

The development of endogenous growth theory of the late 1980's and early 1990's initiated a renewed debate on economic growth. Much of this debate was concerned with the empirical implications of the various frameworks and the relation between theory and data. Empirical studies of growth have yielded little consensus concerning the appropriate models and set of variables to include. For example, Durlauf, Johnson and Temple (2004) have found 145 different growth determinants used in the literature. Nevertheless, some results regarding the question of convergence of income across countries have been corroborated by repeated studies.

There exist three main definitions of convergence: Absolute, conditional and club convergence. Absolute convergence is when per capita incomes in all areas converges to the same long-run growth path, so that all areas tend to converge to the same level of income per capita. Conditional convergence occurs when an area's per capita income converges to a country-specific long-run growth path given by the area's basic structural characteristics. Club convergence happens when countries that are structurally alike *and* have similar initial conditions converge to the same level of per capita income. Figure 1 illustrates the hypotheses of club convergence. The hypotheses imply different relations between the initial per capita income levels and subsequent growth rates in income per capita across areas. According to the hypothesis of absolute convergence, areas with relatively low levels of per capita income in an initial year will grow relatively faster after that initial year. The hypotheses of conditional convergence and club convergence imply the same relationship but convergence is conditioned on the areas being structurally alike (and in the case of club convergence similar initial conditions).

Figure. 1. Club convergence



Source: Jacobsen and Sørensen (2005), fig. 2.7, page 48

The diagram shows the log of per capita income on the vertical axis and time on the horizontal axis. The dotted line show the threshold value where countries above this level converges to the high growth club and countries below the threshold value converges to the low income club.

Empirical evidence of conditional convergence

There exists a wide empirical literature that tests the influence of initial income per capita on subsequent growth rates. Several studies employing different sets of countries and regions have found evidence of conditional convergence with a speed of convergence at around 2% per year. These studies have included OECD countries, US states, counties in Sweden, Japanese prefectures, European countries, Canadian provinces and Australian states (Barro and Sala-i-Martin (1991); Barro and Sala-i-Martin (1992); Mankiw, Romer and Weil (1992); Cashin (1995); Cashin and Sahay (1996); Persson (1997); Shioji (2001)). Thus, a general trend for countries to move towards similar per capita income levels when accounting for appropriate differences appears to be substantiated from the literature.

The empirical evidence of conditional convergence has served as a criterion for judging the relevance of the neoclassical growth model versus endogenous growth models. The reason is the following: given diminishing returns to capital (as in the neoclassical model), lower initial values of per capita income generate higher investment returns and consequently faster transitional growth, once the determinants of the long-run equilibrium are controlled for - that is conditional convergence. The assumption of constant returns to capital implies that the returns to investment are independent of the level of capital, such that there is usually no negative relationship between initial income levels and subsequent growth rates. Hence, one does not usually expect conditional convergence in models of closed economies consistent with endogenous growth. This coincidence with the stylized fact of conditional convergence is an often-used argument for exogenous growth models.[12]

However, even though the Solow model is consistent with conditional convergence, the model's text book version suggests a speed of convergence that far exceeds the empirically observed speed of around 2% per year (Barro and Sala-i-Martin (1995) and Sørensen and Whitta-Jacobsen (2005)). The Solow model with a capital share of 1/3 and a labour share of 2/3 predicts a rate of convergence to steady state of 5.6 per cent per year (Barro and Sala-i-Martin (1995)).[13] Mankiw, Romer and Weil (1992) resolve the problem by setting up an augmented Solow model that includes human capital:

$$Y = (AL)^{\alpha} K^{\beta} H^{1-\alpha-\beta}, \ 0 < \alpha, \beta < 1 \qquad (8)$$

They show that the model provides a good description of cross-country data. Moreover, setting $\alpha = \beta = 1/3$ the model can account for a very low speed of convergence in accordance with empirical evidence.

However, it is not possible to reject endogenous growth theory based on the convergence result. Ventura (1997) questions whether it is altogether appropriate to use the empirical evidence of conditional convergence to discriminate between the various growth theories. Ventura focuses on one of the problems: that growth theories are typically not designed to resolve why some countries grow faster than others, but rather focus on the alternative question of why a country's growth rate varies over time. To conduct comparisons of growth rates across countries in a given period and comparisons of growth rates over time in a given country, one has to make some rele-

[12] This argument is often taken despite the results of House (2000) and Ventura (1997) that show that diminishing returns are not necessarily associated with conditional convergence.

[13] These shares seem reasonable in the light of the empirical works by, e.g., Denison (1962) and Maddison (1987).

vant assumptions: e.g., international linkages are either nonexistent or unimportant. These considerations show that once we allow for open economy settings, the issue of convergence cannot be used as a criterion for choosing between models of exogenous and endogenous growth.

Two analyses below illustrate the possibility of building endogenous growth models that harmonise with conditional convergence by focusing on open economy issues. Acemoglu and Ventura (2002) suggest that conditional convergence occurs as a result of commodity trade and specialization. In their set-up, there exists a continuum of intermediate products that are produced according to an AK-technology and final goods that are produced with the use of domestic physical capital and the range of intermediates. In this case, international trade in intermediate products implies that countries with an above-average rate of capital accumulation experience declining export prices because the greater supply reduces the relative prices of the intermediates produced in that country. This mimics diminishing returns in the neoclassical model by dampening the rate of return to capital, and discourages further accumulation. Ben-David & Loewy (2000) analyse a version of Lucas' primary model of human capital accumulation in an open economy setting. They include international spillovers in the accumulation of human capital. The extent of these spillovers depend on (i) accessibility to other countries' knowledge (which is facilitated by trade), and (ii) ability to absorb and utilize the accessible knowledge stocks abroad (social capability). Contrary to the closed economy-version of the model, this open economy-version preserves the conditional convergence feature, but extends the conditions for convergence: Countries have to implement the same trade policies in order to converge to the same growth path.[14]

Empirical evidence of club convergence

The hypothesis of conditional convergence is further corroborated by another repeated finding in several studies, namely the existence of convergence clubs or multiple regimes. Hence, the world's countries do not converge toward a common level unconditionally. Instead, differences in initial conditions and endowments cause economies to move in separate directions where the endpoints are determined by different equilibrium conditions. An indication of the existence of different long-term equilibria can be seen in figure 2.

[14] Also, technology transfer may imply conditional convergence in models consistent with endogenous growth – see chapter 7 for details.

Figure 2

Source: Durlauf et. Al. (2004), fig. 1

The diagram shows the "frequency" on the vertical axis and countries' income in terms of GDP per worker on the horizontal axis. The dotted line displays the distribution in the year 2000 and the solid ling the distribution in 1960.

The figure shows a kernel density plot of the distribution of GDP per worker across the countries of the world relative to the 1960 value for the USA. The distribution for the year 2000 values displays two modes, which would be indicative of growth processes with more than one long-run equilibrium. In fact, a number of studies involving a variety of different techniques have provided evidence of the existence of multiple regimes.

Durlauf and Johnson (1995) find using classification methods nonlinearities in the growth process, which is implied by the existence of convergence clubs. They test a null-hypothesis of a single common growth regime against a process of multiple regimes. The common growth process is rejected in favour of convergence clubs. This result is interpreted as being generated by initial conditions.

Papageorgiou and Masanjala (2004) re-examine Durlauf and Johnson's results and find similar evidence for multiple growth regimes. Their method identifies thresholds in the data, which produce four separate growth regimes. Tan (2004) using generalised, unbiased interaction detection and estimation finds statistically significant evidence for the existence of convergence clubs. In this case, the clubs are determined by differences in institutional quality and ethnic fractionalisation.

Factoring methods and clustering procedures have also been applied in the search for growth regimes. Desdoigt (1999) found four clusters with distinct growth processes: the OECD countries, Africa, Southeast Asia and Latin America. In the case of the OECD cluster, the identifying variables are human capital (primary and secondary schooling), initial income differences and the growth of the labour force. The remaining three clusters emphasize the importance of government consumption, human capital and investments in capital goods. These findings are interpreted as accentuating the importance of structural characteristics rather than initial conditions. Kourtellos (2003) likewise applies factoring methods and clustering procedures and finds support for two equilibria discriminated by differences in initial conditions.

Panel data analysis is used by Canova (2004) to identify the existence of several regimes among regions of Europe. Again the ordering variable for the different convergence clubs is initial income.

In conclusion, a substantial body of literature exists that supports the notions of different equilibria, convergence clubs and multiple regimes. The number of different regimes found in the literature varies significantly. Moreover, the causes for the emergence of clubs are disputed with some emphasising the role of initial conditions whereas others advocate the differences in structural characteristics. Nevertheless, the notion dating back from at least Solow of a single universal growth regime applicable to all countries and regions does not seem to be in accordance with the empirical evidence. The search is on for identifying the discriminating features that force economies into specific growth paths.

A successful model incorporating the salient features of growth and the stylised facts deduced from the available empirical data requires incorporating the substantiated evidence of multiple regimes and convergence within the regimes. Thus, on the positive side each economy in the world does not follow its own entirely individual growth path although the empirical evidence points to a number of different steady-states. An all-encompassing model therefore needs to be able to divide countries into the appropriate groups. Furthermore, the question of the distinguishing features whether it may be structural characteristics or initial conditions should be addressed. From a policy oriented point of view finding the dividing factors to be structural characteristics would leave room for policy action and government intervention in order to move an economy from a low growth regime to a higher one. Changing initial conditions, on the other hand, is beyond the scope of government policy.

4. The development process

The observation that an all-encompassing model needs to be able to divide countries into appropriate groups and that the development of a country may be divided into distinct epochs has led some researchers to describe the development process as a series of stages where each stage 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. The original stage theory was formulated by Rostow (1952, 1960) who distinguished five stages of development. More recently, researchers have built formal models where various growth mechanisms vary in importance at different stages of development. The transition from one stage to another is either caused by an exogenous shock to the economy or explained endogenously. These theories are surveyed in chapter 4.1.

The stage theories fail to incorporate the consequences of a country's economic development for the fertility of the population and visa versa. Thereby, these theories do not explain the intricate development of the population size along with the development of income per capita and technology. However, the evolution of the size of the population is an important determinant of income per capita as is technological progress – through most of human history, technological progress has fostered population growth thereby failing to expand income per capita. For this reason, the so-called unified growth theory incorporates a fertility choice by households. It aims at capturing the growth process throughout human history in a single framework where economies take-off from one epoch to another through a gradual process. This theory and other theories that aim at explaining both long-run growth and fertility are surveyed in chapter 4.2.

4.1. Stage theories

Kuznets (1971) c.f. Meier (1995) defined stage-theory as "... a theory of long-term economic change implying: (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 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). He distinguished 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 the 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 process of inter-stage transition. Furthermore, empirical analyses show that some of Rostow’s aggregate measures such as the investment rate that are crucial to characterise different stages fail to explain different observed development paths of nations such as Great Britain, France, Germany, and the USA.

More recent stage theories explain the transition from one stage to another either by exogenous shocks to the economy or as endogenous shifts. Baldwin et al (2001) present a model with two regions (North and South). The authors assume that (i) development emerges from decreasing transaction costs of trading goods and dispersing ideas, and (ii) transition from one stage to another arises from exogenous shocks to transaction costs. The model entails only one accumulating factor, local knowledge capital, implying that knowledge is not dispersed globally. Initial conditions and factor endowments are assumed identical in two regions. In the first stage, trade in goods is low due to high transportation costs. An exogenous decrease in transportation costs renders trade a profitable venture. This induces industry to cluster in the Northern region and decline in the South with the North experiencing a take-off. During the next stage of development, the North reaches an equilibrium where per-capita income levels are higher than in the South. In the third stage, the costs of diffusion of knowledge decreases. The South consequently takes advantage of the knowledge accumulated in the North and converges to the high-income level. Thus, the rate of technology diffusion is determined by the costs of exchanging information. The implication is, therefore, that the substantial decreases in the costs of exchanging information that has occurred in the last two or three decades would induce convergence of all developing countries to the high-income level (that is absolute convergence).

Next, models that incorporate different growth mechanisms in different stages of development are presented. Funke and Strulik's (2000) model encompasses physical capital accumulation, human capital accumulation and product development. Only physical capital is accumulated in the first stage and both physical and human capital accumulate through improvements in the quality of labour in the second stage. Innovation drives growth in the third and final stage. 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 physical capital accumulation ensures that 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, when the amount of human capital increases implying a drop in the wage rate per unit of human capital.[15] Since R&D is conducted only with human capital, this development implies an ultimate equality between the value of an innovation and its costs. At this point, the economy propels to the final development stage. The authors demonstrate that the growth rate during this stage surpasses the growth rate of the second stage. The model predicts that depending on initial endowments and the productivity of knowledge formation, some countries may converge towards a state of stagnation and underdevelopment where neither human capital accumulation nor innovations occur.

Howitt & Mayer-Foulkes (2002) also focus on the role of human capital in a stage-like model of vertical innovation. The authors assume that modern R&D involves highly advanced scientific skills. Three different stages are produced by the model: A stagnation stage where new technologies cannot be applied; an implementation stage where no R&D is carried out domestically, but new technologies developed by R&D-conducting countries are absorbed; and a high-income stage where new technologies are developed. The level of human capital determines a country's capability for ap-

[15] Note that when the wage rate per unit of human capital decreases this does not mean that the wage rate per hour decreases. The implication is rather that the wage differential between workers with a high education and workers with a low education decreases.

plying and developing new technologies. This is not a stage model, in that it does not predict a uni-directional path from one stage to another. Instead it produces three different equilibria. The initial factor endowments are the prime determinants for which of the three equilibria characterises a specific country. Deliberate costly government actions are required in order to move from one stage to a higher stage.

More deterministic explanations for income differences across countries are presented in Kejak (2003) where underdevelopment traps in a model of physical and human capital accumulation occurs when the initial factor endowments are too low. The speed of human capital accumulation is too slow compared to the level of physical capital; hence the country is trapped in underdevelopment.

Acemoglu et al (2006) construct a model where governmental policies play an important role for development. Initially, an economy pursues an investment-based strategy relying on existing firms in order to maximise investment given market imperfections and governments' focus on investments, firms are protected and benefit from the imperfect markets. Monopolistic rents accruing to the existing firms 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 produces 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 undesirable policies may be pursued for too long leading to non-optimal economy-wide outcomes.

Explanations for the income grouping patterns of countries vary with the chosen stage theory: Baldwin et al. focus on the costs of exchanging goods and information, and others view the relative speed of human capital accumulation compared to physical capital accumulation as important determinants (Funke and Strulik, and Kejak). Howitt and Mayer-Foulkes point out the significance of initial conditions in particular the level of human capital. But the ability for government policy to incite economic development and escape underdevelopment traps is common to all surveyed theories.

4.2. Endogenous fertility

In Romer's model of growth through product development, the long-run rate of growth is positively correlated with population (provided that a larger population implies that a larger amount of human capital is devoted to research). In this sense, the growth rate is positively correlated with the scale of the economy. Jones and others contend that there is no empirical evidence of such a correlation. However, Blackburn et. al. (2000) and Dalgaard and Kreiner (2003) demonstrate that it is possible to avoid scale effects and yet the determinants of long-run growth are the same as in Romer's set-up. They combine R&D with human capital accumulation, and shows that scale effects depend exclusively on the existence of human capital externality effects, provided that there is no feedback of R&D on capital accumulation. By excluding externality effect it is possible to avoid scale effects and still obtain an endogenously determined rate of long-run growth. In a related set-up with endogenous fertility, Hansen (1998) shows that there may exist a strong negative relationship between population growth and per capita income, and a weakly negative relationship between population growth and growth in per capita income in accordance with empirical evidence of developed countries.

The unified growth theory aims at explaining not just the correlation between fertility and economic conditions in developed countries but to capture the process of development over the course of human history from Malthusian stagnation to sustained economic growth. Unified growth theorists divide human history into tree sub-periods: The Malthusian epoch, the post-Malthusian epoch and the modern growth regime. During the Malthusian Epoch, population growth and technological progress were insignificant by modern standards. Resources generated by technological progress and land expansion (leading to an increase in the level of income) were channelled primarily towards an increase in the size of the population, resulting in a negligible average growth rate of per capita income. Further, the standards of living across countries did not appreciably differ because differences in technologies or in land productivity across countries resulted in variations in population density rather than in the standard of living.

During the post-Malthusian epoch, the technological progress increased markedly along the process of industrialization, triggering a take-off from Malthusian stagnation. The positive Malthusian effect of per capita income on population growth was still maintained, meaning that the increase in income generated by the industrialization process led to a sizeable increase in population growth, which offset some of the potential gains in income per capita. Countries experienced the take-off from Malthusian stagnation at different points because industrialization did not occur simultaneously across all countries. The developed regions experienced the take-off in the beginning of the 19th century, whereas the take-off in some of the less developed regions was delayed well into the 20th century.

The acceleration in the rate of technological progress in the second phase of the Industrial Revolution led to increasing demand for human capital, reflecting the increasing skill requirements in the process of industrialization. Parents started to give priority to child quality instead of child quantity which resulted in a reallocation of resources towards education. The gradual increase in life expectancy and the wage differential between parental labour and child labour also generated a further inducement for investment in human capital. As the fraction of individuals with high valuation of quality increased, technological progress intensified, thereby raising the rate of return to human capital. This interaction between the acceleration in technological progress and the human capital formation ultimately prompted the demographic transition.

The theory suggests that prior to the demographic transition, population growth increased along with investment in human capital, whereas the demographic transition brought about a decline in population growth along with a further increase in human capital formation. The transition to the modern growth regime which is a state of sustained economic growth was therefore characterized by a gradual increase in the importance of the accumulation of human capital relative to physical capital as well as a sharp decline in fertility rates. The rise in aggregate income has not been counterbalanced by population growth, enabling sustained technological progress and factor accumulation to bring about sustained growth in income per capita. The differential timing of the take-off from the post-Malthusian epoch and the corresponding variations in the timing of the demographic transition increased the gap between the richest regions and the poorest regions, and therefore led to a great divergence in income per capita as well as population growth.

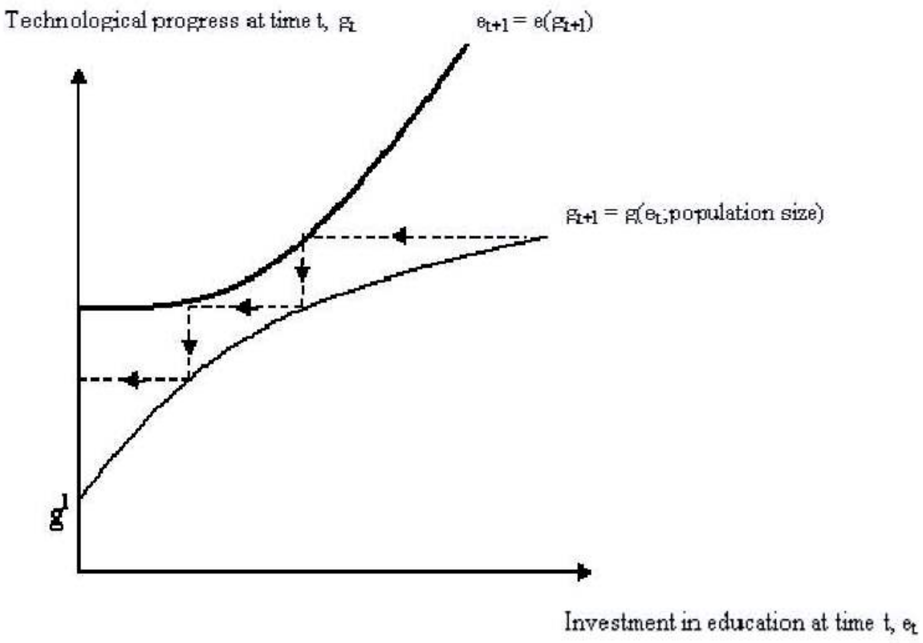
Historical evidence suggests that the take-off from the post-Malthusian epoch to a state of sustained economic growth, rapid as it may appear, was a gradual process not plausibly viewed as the outcome of a major exogenous shock. The challenge to unified growth theorists is therefore to capture the observed gradual and continuous phase transition in a single dynamic system.

Galor and Weil (2000) have developed a unified growth model that explains the evolution of per capita income, technology and population over the course of human history with a dynamic system where the equilibria and their stability are altered qualitatively in the process of development. The model is an overlapping-generations-model where each person lives in two periods – childhood and adulthood. During adulthood a person decides how much to consume, how many children to have, how much time to spend on work and how much time to spend on educating the children.

The authors assume a minimum consumption level, and if the potential income at a certain time is sufficiently high so as to assure that the consumption is above this minimum level, then it will be optimal to spend time on educating children. On the other hand, if potential income is insufficient then an increase in parental potential income raises the number of children but has no effect on their quality. Regardless of whether potential income is sufficiently high or not, increases in the wage rate does not change the division of child-rearing time between quality and quantity. However, the division is affected by the rate of technological progress because it changes the return to education: There is a positive relationship between technological progress and human capital for two reasons. First, technological progress increases the demand for an educated work force and therefore increases the expected return to investment in child quality. Second, skilled individuals have a comparative advantage in adapting new technologies which become more and more important as technology advances. Hence, technological progress reduces the quantity of children but increases their quality.

The theory proposes that in early stages of development the economy is a stable Malthusian equilibrium where the population size is relatively small. Technology advances rather slowly and generates proportional increases in output and population. Due to the fact that the rate of technological progress is slow, there is no incentive to invest in the quality of children. The inherent positive interaction between population and technology in this epoch, however, gradually increases the pace of technological progress. The economy is therefore situated in the only equilibrium in the dynamic system: the Malthusian equilibrium, *g1*, as depicted in figure 3.

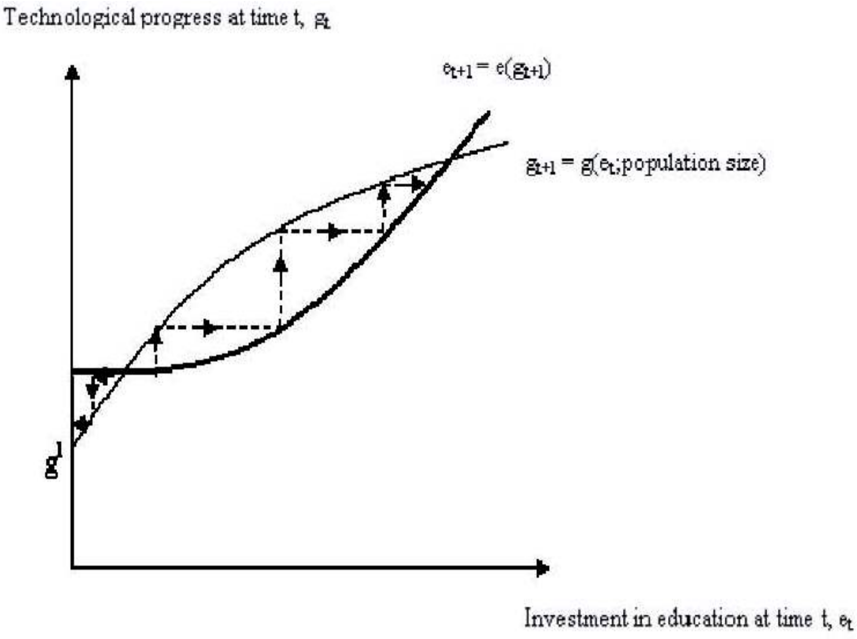
Figure 3



Source: Galor (2005), fig. 4.2, page 67

An increase in the pace of technological progress has two opposing effects on the evolution of the population size. First, it eases households' budget constraints, allowing parents to allocate more resources to having children. Second, it induces a reallocation of resources toward child quality. Due to the limited demand for human capital, the first effect dominates in this stage, and the rise in real income permits households to increase their family size. As population grows slowly in reaction to technological progress, the Malthusian equilibrium gradually shifts reflecting small increments in the rate of technological progress while the level of education remains at a zero level. When population has grown sufficiently it will generate a qualitative change in the dynamic system as depicted in figure 4.

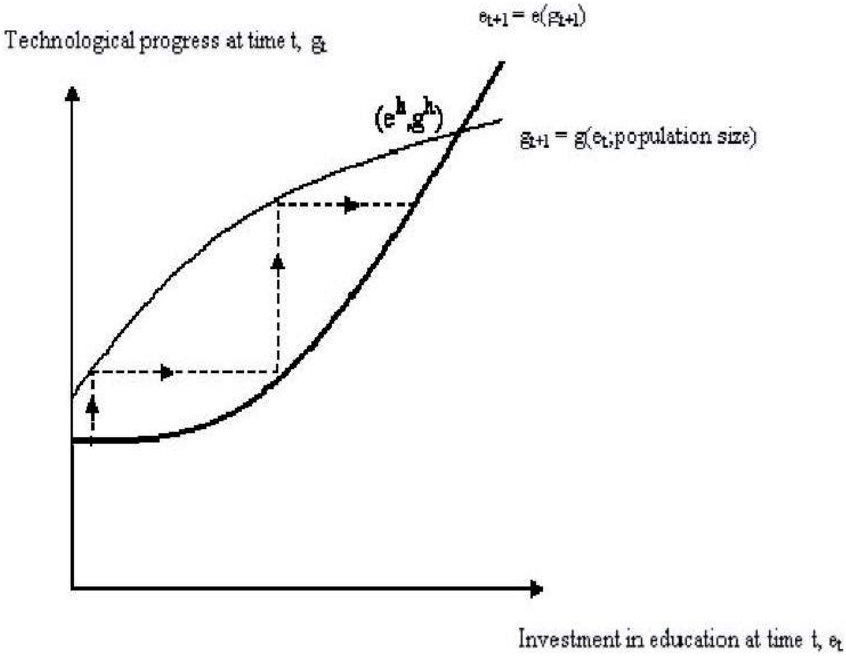
Figure 4



Source: Galor (2005), fig. 4.3, page 67

In the absence of large shocks, the economy remains in the vicinity of the Malthusian equilibrium where education is still zero but now the rate of technological progress is moderate. The population levels still rise and maintain continued increases in the rate of technological progress. As this continues, the dynamic system experiences another qualitative change resulting in the disappearance of the Malthusian equilibrium, see figure 5.

Figure 5



Source: Galor (2005), fig. 4.4, page 68

The resulting equilibrium is the sustained growth regime characterized by high levels of education and technological progress. The intuition behind this is that the increase in the pace of the technological progress increases the demand for human capital and the additional resources from technological progress are reallocated towards child quality. The interaction between investment in human capital and technological progress generates a virtuous circle: human capital formation prompts faster technological progress, which in turn further raises the demand for human capital, inducing further investment in child quality, triggering the demographic transition. The offsetting effect of population growth on the growth rate of per capita income is eliminated and the interaction between technological progress and human capital accumulation permits the economy to converge towards the modern equilibrium characterized by sustained economic growth.

The emergence of human capital formation and its impact on the demographic transition and technological progress is a central element in the transition from the post-

Malthusian regime to the state of sustained economic growth in all unified growth theories. The models differ, however, in explaining the mechanisms that generate or reinforce the rise in human capital formation. Some stress the importance of capital-skill complementarity, i.e., that the accumulation of physical capital enhances the importance of human capital in the production process (Fernandez-Vilaverde (2003) and Galor and Moav (2006)). Others stress the decline in mortality rates and the rise in life expectancy as explanation for the change in the division of child-rearing time from quantity to quality (e.g., Kalemli-Ozcan, Ryder and Weil (2000)). Yet others focus on the adverse effect of the rise in the demand for human capital on child labour (Hazan and Berdugo (2002) and Doepke and Zilibotti (2005)). Galor and Moav (2004) mention cultural or genetic evolution in the attitude of individuals towards human capital formation, while Galor and Mountford (2006) have the rise in demand for human capital via an increased specialization in the production of skill-intensive goods due to international trade. The potential connection between international trade and the emergence of human capital formation is surveyed closer in section 6.2.

5. Empirical evidence on international trade and growth

A major problem in empirical analyses of trade and growth is the choice of measurement for openness. The simple solution of choosing the value of trade relative to GDP yields ambiguous results. As an example, Ghana's trade (imports + exports) comprised 93% of GDP in 2003 whereas South Korea's only comprised 74% even though South Korea's GDP per capita was 17971 $ against Ghana's 2238 $; see World Development Indicators (2005). Thus, on the surface, in this case one could argue for an inverse relationship between trade and income. Furthermore, the causality is not obvious since trade is affected by income and trade might have effects on income. This endogeneity problem implies econometric complications in establishing robust empirical links between trade and income. Therefore, economists have applied a variety of other measures of openness related to an economy's barriers for imports and/or exports aiming at achieving a more direct estimate of the restrictions facing potential trading partners.

Some early noteworthy attempts to empirically analyse the link between trade protection and income/growth for developing countries was carried out by Krueger (1978), Bhagwati (1978) as referenced by Baldwin (2003). They used the effective exchange rates faced by importers/exporters taking into account a variety of macroeconomic policies. They find that trade barriers aiming at import substitution policies generally do not produce sustainable increases in long-run growth rates. The same conclusion is reached by Papageorgiou, Michaely and Choksi (1991) where they employ subjective indices of countries' degrees of trade liberalisation. Balassa (1978) regresses the growth rate of exports on the growth rate of GDP. He finds a positive relationship between exports and growth.

An often cited attempt at a measure of the level of protection was carried out by Dollar (1992). He uses distortions in the real exchange rate where the hypothesis is that in the long run the law of one price holds.[16] Therefore, the contention is that deviations from the law of one price can only be maintained if potential importers/exporters face barriers preventing them from taking advantage of the price differences. Thus, real exchange rate deviations are an aggregate estimate of the level of protections. Dollar (1992) finds a negative correlation between real exchange rate distortions and growth. However, the law of one price may fail to comply for a variety of other reasons as Rodriguez and Rodrik (2001) states. In particular, monetary and nominal exchange

[16] The law of one price says that within a single market identical goods must sell at identical prices.

rate policies have a significant impact on the real exchange rate regardless of trade policies. Moreover, Rogriguez and Rodrik (2001) applies the Dollar procedure to the new updated version of the same data (Heston and Summers (1991)) and finds that the same regressions now yield the wrong sign.

Another attempt to construct a reliable openness measure is done by Sachs and Warner (1995). By combining 5 different indicators a variable for openness is designed. The core statistic analysis of the paper is a multiple regression of growth as the dependent variable on the openness variable and a number of other variables. Sachs & Warner include a handful of explanatory variables in order to partial out their cross-country variations. Explanatory variables include policy variables, initial GDP, educational level, political unrest and investment rates. They find a robust and significant effect of the openness dummy on growth. The authors conclude that the openness indicator has a significant positive relationship with growth between 1970 and 1989 ceteris paribus. Among other conclusions Sachs and Warner find indications of absolute convergence among open economies. Rodriguez and Rodrik (2001) scrutinize their findings and conclude that the openness measure is a result of several different macroeconomic and trade policies. Rodriguez and Rodrik (2001) re-estimate their regressions and find that the only two out of the five indicators account for the bulk of the variation in the data. The first of these measures indicate a state trading enterprise with monopoly over exports. This measure corresponds de facto to a Sub-Saharan Africa dummy thereby making it indistinguishable from other factors specific to this region. Hence, it is doubtful whether this indicator can be said to measure trade barriers solely. The other significant indicator is a black market premium. However, this premium may arise from a host of other policies other than simply trade barriers. In conclusion, it is unlikely that the aggregate measure with five indicators provides a reliable estimate of openness per se. Furthermore, problems of selection bias and other econometric problems raise doubt over the findings.

Several other empirical analyses of the link between trade and growth are reviewed by Rogriguez and Rodrik (2001) and are found not to be entirely convincing in demonstrating a positive linkage. Hence, they conclude that the jury is still out on the question of whether openness is beneficial to growth. Instead, they argue for the importance of considering the effects of various state variables thereby pointing towards contingent relationships rather than look for a general effect of trade on growth. Furthermore, a more promising approach they suggest would be to consider more disaggregated relationships perhaps in the form of micro-econometrics whereby the individual effects of trade on production and productivity can be identified.

Lee, Ricci and Rigobon (2004) consider the issue of endogeneity – also raised in Rodriguez and Rodrik (2001) – which they argue is a common problem in studies of trade and GDP. By construction the openness measure often implies endogeneity, thus, unless endogeneity is properly addressed in the econometric analyses the resulting estimates are biased and inference is invalid. Moreover, identifying the causal links may be impossible. In Lee, Ricci and Rigobon (2004) they apply an econometric method appropriate with endogeneity and generate robust, although small effects of openness to growth. However, they also find the equivalent reverse causality that growth effects openness.

Another contribution to growth empirics without a foundation in formal modelling is Harrison (1995). She investigates the relationship between trade and growth by applying time series- and panel data analysis. A number of openness variables are used in regressions on the right hand side. She regresses growth on openness after controlling for the effect of variations in application of resources (physical and human capital as well as labour are accounted for). Although the correlation across different types of openness is not always strong, Harrison finds a generally positive association between growth and openness.

Frankel and Romer (1999) employ an instrumental variable estimator in their analysis of growth and trade. They argue that simple OLS regressions of income on exports/imports are plagued by endogeneity problems. Thus, they apply geographical characteristics that are considered uncorrelated with trade policies as instruments. They find that generally there is a positive linkage and that OLS regressions do not overstate the effects, cf. Baldwin (2003).

Dollar and Kray (2001) examine the with-in country differences in growth and trade. In this manner, they state, they avoid country specific differences and geographically related effects. They conclude that there is a strong and significant positive link between the changes in trade and changes in growth.

The numerous attempts to establish a robust general link between trade and growth have not proven to be entirely convincing. Trade is in it self a composite of a variety of different products and services each of which could have different impacts on the growth mechanisms in an economy. Furthermore, the vast differences between countries' economies in terms of factor endowments, education systems, geographical location, degree of market oriented policies, abundance or lack of natural resources, etc.

provide for varying degrees and means of impact from trade. Edwards (1993) states that early cross-country statistical studies are based on overly simplistic theoretical models and are flawed for a number of econometric reasons. Similarly, Srinivasan and Bhagwati (2001) find that the weak theoretical foundations, the poor quality of data and inappropriate econometric techniques employed in many of these studies casts doubt over the validity of the findings.

Thus, the conclusion stated by Rodriguez and Rodrik (2001) that trade/growth analyses need to be more targeted towards disaggregated mechanisms by which trade channels through the economy and effects growth seems warranted.

6. International trade and growth in theory

The conventional trade theory determines the pattern of international trade and the distribution of welfare across countries in a static setting. It relates the pattern of trade to comparative advantage and predicts that if two countries engage in trade, each will have incentives to increase production of goods in which it has a comparative advantage, i.e., the lower relative marginal cost prior to trade than the other country.[17] The result is that each country exports goods in which it has a comparative advantage. Usually, comparative advantage is assumed to stem from either exogenous technological differences (as in the classical Ricardian model) or different factor endowments (as in the Heckscher-Ohlin model).[18] Hence, the conventional trade theory associates international trade with a reallocation of resources determined by exogenous differences across countries.

The second goal of the conventional trade theory is to analyse the effects of international trade in terms of welfare and the distribution of gains and losses. In short, international trade increases aggregate national income through a more efficient allocation of resources. At the same time, it leaves at least some factors with reduced real income. For example, the Heckscher-Ohlin model has the abundant factor gaining from trade, while the scarce factor looses from trade. It is, however, possible to achieve Pareto gains from trade through lump sum taxes and transfers. Dixit and Norman (1980) demonstrate that in the absence of the lump sum possibility, it is possible to reach a situation where everyone gains from trade through a set of commodity and factor taxes and subsidies.

The conventional trade theory is concerned with the level effects of international trade while disregarding growth effects. However, substantial changes to economies are achieved through the aggregate effects of growth over time. Hence, it seems important to analyse the effects of international trade in a dynamic context. Unfortunately, the traditional neoclassical growth model precludes long-run growth effects of international trade. Opening up an economy where the ultimate source of growth is described as exogenous technological progress has level effects and transitory growth effects: International trade in a two-good version of the neoclassical model has each country specializing relatively in producing the good in which it has a comparative advantage. This specialization pattern leads to a more efficient use of the world's resources. Hence, income and welfare improves in both countries but in the long run the

[17] See, e.g., Dixit and Norman (1980).
[18] See, e.g., Feenstra (2004).

growth rate is determined by the exogenously given rate at which technological breakthroughs occur.[19] [20] For this reason, analyses of dynamic effects of openness are scarce until the 1990's - and because the neoclassical growth theory permits analyses of international linkages far simpler than observed patterns between, e.g., developed and developing countries.

The development of the new growth theories that focus on R&D and product development (cf. section 2.2) provides researchers with a tool that enables analyses of a wide range of international linkages in rich dynamic set-ups. Hence, the recent theoretical literature that links international trade and growth is able to concurrently explain, for example, the sources for comparative advantage, and to account for the evolution of these differences over time, and explain effects on trade pattern. In this chapter, we focus on international commodity trade and investigate, first, the determination of comparative advantage in a framework where the state of technology is endogenously determined, and comparative advantage is determined by the historical patterns of technological change (Section 6.1). Then we turn to a model of endogenous population and consider the interaction between population growth and comparative advantage (Section 6.2).

6.1. Endogenous comparative advantage

Comparative advantage usually emerges from exogenous differences in technologies, factor endowments, or in other relevant differences across countries. But when countries engage in technological competition, comparative advantage becomes endogenously determined. Research successes create export opportunities as innovators learn to produce goods that are better than, different from, or less costly than those manu-

[19] The exact degree of specialization and the pattern of trade depend on the dissimilarity of the countries' factor endowments prior to trade and the functioning of the international financial capital markets.

[20] This is not necessarily true in multisector versions of the neoclassical model as shown by Ventura (1997) and House (2000). By adding a second production sector to the model, House demonstrates the possibility of periods of constant marginal returns to capital in a small open economy when production is diversified. The reason is that as capital accumulates, resources are continually reallocated from production of the relatively labour-intensive consumer good to the relatively capital-intensive investment good. As a result, factor prices remain constant as capital accumulates, and the economy may experience a sustained period of constant marginal returns. This implies that level effects of trade liberalisation may be substantially larger than those normally inferred from the neoclassical model. By replacing the standard neoclassical production functions with fixed-proportions technologies, Ventura demonstrates that trade liberalizations can lead to sustained growth in an economy, which has no growth in autarky.

factured abroad. How long-run trade patterns and growth rates are determined in the case of endogenous (or dynamic) comparative advantage depends on the geographical scope of knowledge spillovers. If international knowledge spillovers are costless and instantaneous globally, then the trade patterns are determined by relative factor endowments as in the conventional trade theory. On the other hand, if research projects contribute to general knowledge only in the country where the research is carried out, then initial conditions can matter for the long-run pattern of trade. Reality undoubtedly lies between these extremes, and a plausible specification might include lags in the diffusion of knowledge that are shorter domestically than internationally and that decreases with the degree of openness. See section 7.1 for a further discussion of knowledge spillovers.

In order to analyze dynamic effects of specialization in areas of comparative advantage the model of product development described in section 2.2 is developed to include two consumer goods with different intensities in factor requirements. Often the two goods are described as a high technology good and a traditional (agricultural) good, where it is assumed that production of the traditional good is relatively more intensive in unskilled labour and less intensive in human capital than the production of the high tech good. In this setting countries will be able to specialize in their respective sectors of comparative advantage. While the reallocation of resources from trade liberalization has positive income effects in a static setting, anticipated effects on the dynamic process, say on growth and income, are not so straightforwardly anticipated or clear. First, we analyse the case of international knowledge spillovers, then the case of national knowledge spillovers.

International knowledge spillovers

When international knowledge spillovers are instantaneous, all countries share in a common pool of knowledge capital. Grossman and Helpman (1991, chapter 7) analyse this case and find that comparative advantage, the pattern of specialization and the pattern of trade are uniquely determined by relative factor endowments. Factor prices likely equalize in cases when countries have similar factor endowments. In this case, the economy with a relative abundance of human capital undertakes relatively more research than the other economy and acquires the know-how to invent more blueprints. Hence, with the restriction that each intermediate good must be manufactured in the country where it is developed, the human capital-abundant economy produces a relatively wider range of intermediate goods than the other country. This pattern of specialization implies that firms in each country export the unique intermediate good that has been developed there. The pattern of inter-industry trade depends on assumptions about international trade in financial assets. If there is no international trade in financial assets, then each country's trade account must balance in each period and the human-capital rich country imports the traditional consumer good and exports (on net) the high-tech good, while the unskilled labour-abundant country has the opposite pattern of trade. If, on the other hand, there is assumed to be international trade in financial assets, then a country may run a deficit on the trade account balanced by a surplus on the income/service account in the long run. In this case, a country may become a net importer of both intermediate goods and the traditional consumer good.

Since knowledge spillovers are international, human capital devoted to research is equally productive in the two countries and, therefore, the countries face equal rates of product innovation. However, the pattern of specialization implies that real output grows faster in the human capital-abundant country than in the unskilled labour-abundant country. This result follows from the facts that (i) high-tech manufacturing comprises a larger share of the national economy in the human capital-abundant country, and (ii) productivity growth of high tech manufacturing increases with product development while productivity of the traditional manufacturing sector is constant. Whether international trade is conducive to growth in the human capital-abundant country is, however, ambiguous. The reallocation of resources towards research tends to increase the rate of growth in the economy. However, since the world economy is relatively better endowed with unskilled labour than the human capital-abundant economy, the world economy will devote relatively more resources to unskilled labour-intensive activities. Hence, the common rate of innovation may actually be less than in the human capital-abundant economy prior to trade. This tends to decrease the rate of growth of this economy such that the net effect of international trade on long-run growth of the human capital-abundant economy is ambiguous.

When the countries' resource compositions adequately vary to preclude equalization of factor prices, at least one of the countries must find itself uncompetitive in the long run either in conducting R&D or in producing the traditional consumer good. Hence, the human capital-abundant country may specialize in R&D and high-tech manufacturing while the other country may specialize in traditional manufacturing implying faster GDP growth in the human capital-abundant country than in the other country. When factor prices are not identical across countries, it is interesting to relax the restriction that firms must manufacture intermediate goods in the same country as they have been invented. As explained in section 7.3.2, in this case, multinational corporations may form, which may alter the long-run pattern of trade such that the human capital-abundant country exchanges blueprints for commodities.

National knowledge spillovers

When knowledge spillovers are confined to the national level, then the accumulated wisdom in a country can influence the cost of innovation there. Hence, prior experience may influence the allocation of resources to R&D and govern long-run outcomes. In a framework where endogenously derived differences in general knowledge is the only basis for international trade, Grossman and Helpman (1991, chapter 8) show that initial stocks of general knowledge govern long-run outcomes. The country with a greater initial stock of general knowledge enjoys an initial advantage in the research lab. Often, this country accumulates knowledge more quickly than other countries implying a more rapid increase in real wages, leading to a lower real interest rate. In turn this will stimulate higher investment and more rapid creation of ideas, leading to faster growth. The country will systematically increase its share, and the end result is that all R&D is done in the country with the initial advantage. This dynamic reduces growth in the country with the lower initial stock of general knowledge.

Young (1991) sets up a learning-by-doing model, where initial conditions govern the long-run outcome: A lack of technology diffusion gives the developed countries a comparative advantage in sectors with more potential of learning by doing. The least developed countries (LDCs) that begin with a lower level of general knowledge will specialize in production of relatively unsophisticated goods with less potential for learning by doing. As a result, the LDCs may experience a reduction in the rate of growth, which might translate into dynamic welfare losses from trade. In contrast, the developed countries enjoy faster growth and dynamic welfare gains. In the model, current comparative advantage is determined by the past history of technological change, while current patterns of comparative advantage play an important role in determining the rate of future technological progress. This gives a potential rationale for policy intervention in order to promote local research activity or to induce the LDCs to specialize in goods with greater potential for learning by doing. Grossman and Helpman stress policy hysteresis - that a temporary subsidy to R&D activity can have permanent positive effect on the growth rate.

6.2. Comparative advantage and the development process

In a unified growth model, Galor and Mountford (2006) focus on the interaction between population growth and comparative advantage. The description of the individuals of the economy is similar to the unified growth model surveyed in section 3.2: individuals live for two periods, and in the second period they decide how many children to have, whether they shall be trained to be skilled or unskilled workers and how much time to spend on work. It takes more resources to train a child to be skilled worker than unskilled worker. There are two consumer goods in the economy - an agricultural good and a manufactured good. Production of either good may take place with either old or new technology. All technologies use unskilled labour but only the new technology for producing the manufactured good uses human capital. In the early stages of development, production is conducted using the old technologies. However, it is assumed that technological progress depends positively on population size and skill intensity, so that productivity of all technologies rises with population. Moreover, it is assumed that the new technologies advances more rapidly than the old ones so at some point in time, first, the new technology for producing agricultural goods become economically viable and, second, the new technology for producing manufactured goods becomes profitable. When the agricultural sector starts to use the new technology, the economy escapes the Mathusian trap where wages fall as population increases. When the manufacturing sector begins using the new technology, there is a demand for skilled labour and parents start to substitute quantity of children for quality of children. In this stage, there is a self-reinforcing relationship between technological progress and the human capital intensity of the economy which causes both the rate of technological progress and the level of human capital to rise.

International trade between countries at different technological stages may affect the timing of the demographic transition across countries, and may thereby explain the great divergence in income levels across countries in the last two centuries. The intuition is as follows. The technologically advanced country has a comparative advantage in the production of the manufactured good since technological progress in the manufacturing sector is faster than in the agricultural sector. Hence, international trade increases the demand for skilled labour in the advanced country and decreases it in the other country. Therefore, parents in the advanced country have fewer children but train more of them to be skilled workers, while parents in the other country have more children but less incentive to train them to be skilled workers. Hence, the demographic transition of the technologically advanced country is accelerated while the transition of the less advanced country is delayed as a result of international trade.

Also, the gains from trade are distributed unequally across countries since the less advanced country's output growth is generated primarily by population growth such that output per capita is lower than in the advanced country (even in the case when trade affects output growth of the trading countries at the same rate).

In conclusion, the dynamic effects of international trade are not as straightforward as the static effects. Grossman and Helpman demonstrate that the geographic scope of knowledge spillovers is crucial for the distribution of dynamic gains across countries: When knowledge spillovers are international, the country with the lower initial stock of general knowledge may experience lower growth as a result of international trade. When knowledge spillovers are national in scope, Young and Galor and Mountford also point to the danger that poor countries do not experience dynamic gains from trade due to uncompetitiveness in production lines with large growth potential. Despite these results, the positive static effects raise the level of welfare across countries. But in order for poor countries to reap the dynamic gains it may be necessary to subsidise human capital accumulation or R&D.

7. International diffusion of knowledge and technology

The industrial research laboratory produces two types of output: specific technical information that allows a firm to engage in a particular product or to engage in a particular production process, and general knowledge with wider applicability. Imports, education and information channels are some of the mechanisms with which knowledge and technology shifts diffuse throughout countries. Consider the models of product development described in section 2.2, where the outcome of R&D depends positively on the amount of general knowledge generated by previous research activity. International diffusion of general knowledge takes place when the knowledge spillover is, to some extent, international in scope. Also, international technology diffusion can be explained in terms of these models. Technology shifts take place when either new intermediate goods or intermediate goods of a better quality are being used in manufacturing. International technology diffusion ensures that intermediate goods from the technology frontier become available for use internationally.

International trade is not necessarily a prerequisite for international knowledge or technology diffusion to take place. For example, international knowledge spillovers may happen through communication and cooperation at an informal level. However, international trade may facilitate the international diffusion of especially technology because follower countries get access to productive inputs from the technology frontier or inputs with embodied technological progress. Comin and Hobijn (2004) distinguish between a push and a pull effect of international trade on technology diffusion.

The push effect is the mechanism with which countries that import goods from more technological advanced countries get more exposed to new technological developments. These countries are likely to adopt the technologies that they are exposed to whereas countries that do not import goods from advanced economies are less likely to adopt new technologies. The pull effect works through the competition effect of international trade: trade promotes competition which increases the incentives to innovate and adopt new technologies by individual firms in order to sustain their international competitiveness.

The transfer of technology from developed countries to LDCs often happens through imitation efforts or establishment of multinational corporations.[21] For imitation to be

[21] It is implicitly assumed that domestic technology diffusion is perfect. This assumption might be inappropriate, for example if a country's population is scattered geographically in heterogeneous regions, and trade between these domestic regions is sparse.

profitable, a succesful imitator must be able to earn positive profits in competition with the inventor. This is often the case in an open world economy where imitation arises from cost differentials between developed countries and LDCs. Hence, some degree of specialization may happen such that R&D takes place in human-capital-rich countries while manufacturing primarily is done in countries with low manufacturing costs.[22] There are, however, barriers to the international transfer of technology from developed countries to LDCs. One branch of the theoretical literature focuses on the existence of appropriate technologies. That is, a lack of complementary inputs and human capital that may prevent a country from obtaining productivity gains from technological innovations.

International diffusion of knowledge and/or technology is perhaps the most important mechanism by which integration into the world economy can promote innovation and growth. Coe et al. (1997) show that foreign R&D appears to have beneficial effect on domestic productivity, and that this effect increases with the degree of openness. Nadiri & Kim (1996) show that the relative importance of domestic R&D to foreign R&D varies across countries. Domestic R&D activity is highly important in the USA, while foreign R&D seems more important in countries like Italy and Canada. These empirical findings might be a result of either knowledge or technology diffusion since they cannot easily be separated from each other in practice. A few studies are more directly concerned with technology diffusion. Comin & Hobijn (2004) examine the diffusion of more than 20 technologies across 23 of the world's leading industrial economies. Their results suggest a pattern of trickle-down diffusion. The rich technological leaders tend to be the ones that innovate and adopt new technologies the earliest. After adoption by the leading countries, the laggards follow suit and partially catch up with the leaders. Income per capita, human capital, openness, and strength of the judicial and legislature systems have a positive effect on the level of technology adoption. Comin & Hobijn's results harmonize with a focus on appropriate technologies. The importance of the theory of appropriate technologies in describing technology diffusion as an explanation for growth is also supported by Jerzmanovski (2002). He shows that the bulk of cross-country total factor productivity (TFP) differences are due to inefficient use or delayed adoption of new technologies by trailing countries. Some studies find imitation to be an important means of technology adoption. For example, in a study of 48 product innovations Mansfield et al. (1981) found that 34 new products had been imitated during the sample period (between 5 and 20 years).

[22] If it is costly for firms to establish production facilities offshore then an innovator may consider patent licensing, that is, the innovator extends manufacturing rights to a producer in a foreign country in exchange for a royalty payment.

Even though the international transmission of general knowledge cannot easily be separated from diffusion of concrete technology know-how in practice, the dynamic effects of knowledge and technology diffusion are conceptually distinct. Therefore, in section 7.1 we focus on the dynamic effects of international knowledge diffusion, while international technology diffusion is described in section 7.2. In both sections, the effects are analyzed with the use of a model of growth through product development where the countries are at the same developmental stage. Next, we turn to the transfer of technology from developed countries to LDCs: Section 7.3 presents potential growth effects of imitation and multinational corporations, while section 7.4 is concerned with the notion of appropriate technologies. Table 1 indicates which frameworks are surveyed.

Table 1

Authors	Main characteristics of the framework	Surveyed in section
Romer (1990)	Horizontal product development, international knowledge spillovers	7.1
Howitt (2000)	Vertical product development, international knowledge spillovers	7.1
Rivera-Batiz and Romer (1991)	R&D uses human capital and general knowledge, technology diffusion through trade in intermediate goods	7.2
Rivera-Batiz and Romer (1991)	R&D uses the same technology as manufacturing, technology diffusion through trade in intermediate goods	7.2
Grossman and Helpman (1991, chap. 9.3)	Countries with different amounts of general knowledge, technology diffusion through trade in intermediate goods	7.2
Feenstra (1996)	Countries with different sizes of the effective labour force, technology diffusion through trade in intermediate goods	7.2
Grossman and Helpman (1991, chap. 11)	Horizontal product development, imitation	7.3
Grossman and Helpman (1991, chap. 12)	Vertical product development, imitation	7.3
Barro and Sala-i-Martin (1997)	The cost of imitation is an increasing function of the ratio between the number of intermediate goods invented in the North and the number of intermediate goods imitated in the South	7.3
Grossman and Helpman (1991, chap. 7.3)	Countries with different endowments of human capital and labour, multinational corporations	7.3
Feenstra (1996)	Countries with different initial amounts of general knowledge, multinational corporations	7.3
Basu and Weil (1998)	Countries with different savings rates, appropriate technologies	7.4
Acemoglu and Zilibotti (2001)	Countries with different skill levels, appropriate technologies	7.4

7.1. International knowledge spillovers

Consider the framework of Romer (1990) and assume that there is no international trade in goods or factors. Instead, we analyse the effects of opening up for communication and cooperation at an informal level – an openness that give researchers access to the international pool of general knowledge.[23] In this case, the total amount of general knowledge increases and so does the production of designs in the research sector which promotes growth.[24] Access to the international pool of general knowledge also gives rise to a reallocation of resources: The larger amount of general knowledge increases the productivity of labour in the research sector while it has no effect on the productivity of labour in manufacturing (there is no international trade in intermediate goods). Therefore, labour is allocated away from manufacturing towards research activity – a reallocation that also promotes growth. Hence, in this setting, the growth rate increases because the production of designs does and because labour is reallocated towards research activity.

In a model of rising product quality, Howitt (2000) shows that international knowledge spillovers may give rise to conditional convergence. He assumes that as the gap between a country's average productivity and the global leading-edge technology narrows, innovations will raise average productivity by less and less. As a consequence, all countries' growth rates will converge to the same value but their average productivity levels and income levels will not: Countries with a larger rate of innovation will also have permanently higher average productivity and a higher relative per capita income. Howitt shows that both the productivity and the income level depend positively on the country's investment rate, the productivity of its R&D, and the R&D subsidy rate and negatively on the world growth rate.

In reality, the geographical scope of knowledge spillovers may depend on the degree of international trade that a country engages in: It might be the case that international trade in tangible commodities facilitates the exchange of intangible ideas. Caselli and Wilson (2004) find empirical evidence that capital imports from technological leaders may embody knowledge. Grossman & Helpman (1991b, chapter 6) use these considerations to develop a functional form where the extent of the spillovers between two countries increases with the volume of their bilateral trade. Feenstra (1996) considers two alternative specifications. First, he supposes that general knowledge in a country

[23] This analysis is carried out in Rivera-Batiz and Romer (1991). A similar analysis with the same result can be found in Grossman and Helpman (1991), chapter 9.1.

[24] The international pool of ideas increases only if there is not total overlap between the set of blueprints invented in each country. This is assumed to be the case.

reflects its own past innovation and an exogenous fraction of the innovation abroad. Second, he supposes that intermediate goods are traded and that a country learns from the foreign goods in proportion to their actual use.

7.2. Technology diffusion between developed countries

It is also possible to analyse the long-run effects of specific technological knowledge diffusion with the use of Romer's (1990) framework. Rivera-Batiz and Romer (1991) analyse effects of international trade in intermediate goods between two countries. The countries are similar in all respects except that trade induces researchers in the two countries to specialize in the production of different types of designs and avoid redundancy. The knowledge spillover may be either national or international in scope – the important assumption is that openness does not affect the geographical scope of it. In this setting, the authors demonstrate that international trade in intermediate goods has no long-run growth effects because trade raises the productivity of human capital in the manufacturing sector as well as in the research sector equally. The explanation for this result is as follows. When researchers in the two countries specialize in the production of different types of designs the worldwide stock of designs will ultimately be twice as large as the stock that has been produced in either country under autarky. This doubles the marginal product of human capital in the manufacturing sector. For the research sector, opening of trade implies that the market for any newly designed good is twice as large as it was in the absence of trade. This doubles the price of the patents and the return to investing in human capital in research. Since the return to human capital doubles in both the competing sectors, trade does not affect the split of human capital between manufacturing and research. Hence, it does not change the long-run rate of growth of the countries. Even so there are positive level effects on output and welfare: The access to a wider range of intermediate goods increases manufacturing output and, thereby, the level of welfare across countries.

Rivera-Batiz and Romer demonstrate that the lack of correlation between technology diffusion and long-run growth is not a robust feature of the class of models that focus on product development. In an alternative version of the model where general knowledge has no productive value and there are no externality effects, they find a positive correlation between trade in intermediate goods and long-run growth. Here, the research technology is identical to the manufacturing technology implying that intermediates, human capital, and unskilled labour are used as inputs in research. In this model with an unchanged interest rate, trade in intermediate goods enlarges the market which causes the same kind of increase in profit earned by the holder of a patent as in the previous model. However, since the price of a patent is determined by technology, the only way that the larger market can be reconciled with a fixed price for the patent is through an increase in the interest rate. A higher interest rate reduces the demand for intermediates, thereby lowering the profit earned by the monopolist at each date. The higher interest rate leads to higher savings and faster growth in both countries. Hence, international trade in intermediate goods generates dynamic welfare gains in this set-up because the rate of growth is too low under autarky (compared with the rate that would be selected by a social planner). In conclusion, the analyses show that the growth effects of international trade are very sensitive to the specification of the research technology: When research activity requires only general knowledge and human capital, international trade in intermediate goods has no long-run growth effects while it causes a permanent increase in the rate of growth when R&D uses the same technology as manufacturing.

Grossman and Helpman (1991) and Feenstra (1996) demonstrate that technology diffusion may lead to uneven growth when the knowledge externality is national in scope and the countries differ in terms of either the amount of general knowledge that has been generated in the past (Grossman and Helpman) or the effective labour force (Feenstra). In both analyses product development is the ultimate source of growth, and it requires labour and general knowledge to invent designs for new intermediate goods. It is assumed that the knowledge externality is national in scope. There exist two types of final goods that are imperfect substitutes in consumption. When free trade in final goods exists, the analyses show temporary positive effects of trade in intermediate goods on the growth rate of product development in the larger country, but in the long run it approaches its autarky rate of growth. In the smaller country the long-run growth rate of product development is less than in autarky. Hence, the authors demonstrate that trade can lead to uneven growth when the knowledge externality is national in scope. In this case, the relatively larger amount of general knowledge generated in the past or greater effective labour force allows the larger country to introduce new products at a faster rate such that it captures a growing share of the total number of differentiated intermediate goods and a growing share of world aggregate demand. This puts an upward pressure on wages in the larger country which offers the prospect of capital gains, giving entrepreneurs a greater incentive to introduce new intermediate goods. The opposite happens in the smaller country such that product development takes place at different long-run rates in the two countries. Feenstra notes that if the countries are of identical size, there would be no growth effects of trade in intermediate goods – as in the first model of Rivera-Batiz and Romer. Likewise, it is conjectured that the countries will grow at different long-run rates when the knowledge externality is national and the countries differ in terms of either the amount of general knowledge generated in the past or the amount of human capital in Rivera Batiz and Romer's first model. This may explain why developing countries with low amounts of human capital experience lower growth rates than rich countries even when there are no barriers to the international diffusion of technology. This issue is further explored in section 7.4.

The lower growth rate of product development in the smaller country in Grossman and Helpman's and Feenstra's analyses does not necessarily mean that the smaller country experiences welfare losses due to trade. Since the growth rate of product development in the larger country is temporarily higher with trade than in autarky, the price of the final good produced in this country is lower under free trade than in autarky. Even though the price of the final good produced in the smaller country is higher under free trade than in autarky, the price index of the smaller country decreases as a result of trade in intermediate goods provided that the initial market share of the smaller country is not too high. This reduction in the price index leads to utility gains in the smaller country even though its growth rate of product development decreases as a result of international trade in intermediate goods.

In conclusion, the theoretical literature points to the existence of positive static or dynamic welfare gains from international technology diffusion between countries at the same developmental stage. However, when it comes to the question of a correlation between international technology diffusion and long-run growth, the answer seems to be "it depends". When research activity does not use the specific technology that diffuses across countries as a result of international trade, then trade liberalisation does not affect countries' long-run growth performances unless the countries are of different sizes in terms of the effective labour force or the amount of general knowledge that has been generated in the past – in which cases the smaller country may experience lower long-run growth as a result of international trade in intermediate goods. However, when the technology that diffuses is used in research activity then trade liberalisation promotes long-run growth across countries.

7.3. Imitation

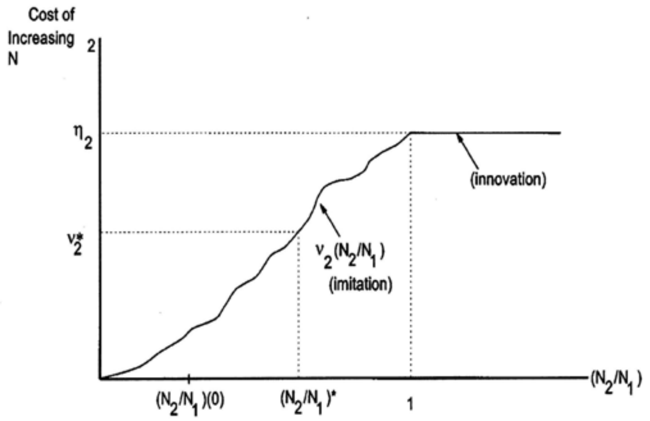
Leaving aside trade between similar countries or trade between countries that only differ in terms of relative endowments and looking at technology diffusion between developed countries and LDCs, it is more likely to take place through imitation than through mutual adaption of technologies invented abroad. In this case, trade in intermediate products combined with weak international patent laws make it possible for firms in LDCs to imitate a product that was initially invented in a developed country and capture market-share and quasi-rents by under-pricing the original innovator. Grossman and Helpman's (1991, chapters 11 and 12 analyse the long-run effects of imitation in models of vertical and horizontal product development, respectively. It turns out that the two models may yield different predictions about the relationships between imitation and the long-run rate of growth.

First, we consider the effects of imitation in a simple model of horizontal product development. There exist two countries or regions: an innovating North and an imitating South. Innovation in the North takes place with the use of labour and general knowledge. It is assumed that the South does not innovate at all – here imitation is the vehicle for technological progress. An entrepreneur in the South can gain the ability to produce an existing variety invented in the North by devoting labour to the task of imitation. Moreover, there is assumed to be a knowledge externality in imitation like the knowledge externality that exists in research. Grossman and Helpman assume that it is proportional to the number of technologies that the South has already acquired. When international trade in intermediate goods is allowed, there are two contradicting effects of imitation on the long-run rate of growth in the North. On the negative side, the exposure to imitation shortens the expected duration of monopoly rents which tends to reduce growth. On the positive side, Northern producers enjoy higher rates of profits during their tenure as monopolists. This is because each surviving Northern firm benefits when a Southern producer takes over manufacturing from a rival Northern brand, as it is then able to hire some of the laid-off workers and thereby expand its sales and profits. This effect tends to increase the growth rate of the North. It turns out that the positive effect outweighs the negative effect in equilibrium, such that imitation is conducive to growth in the North. Obviously, imitation also increases growth in the South since it has little or no capacity to invent new products on its own. But even if the South could develop new varieties from scratch, it is more likely to grow faster when imitation is possible since more labour is needed to invent a new good than to copy an existing one.

When horizontal product development takes place, innovators in the North look ahead to their ultimate displacement from the market by imitators in the South. When vertical product development takes place, Southern imitators too must foresee their own eventual demise in the wake of further technological advances in the North. It turns out that if the South is relatively efficient at innovation, though still less so than the North, then both the North and the South undertake R&D. Hence, the history of any product line may be complex because at any moment the position of leadership in the market may pass from one Northern firm to another or from North to South. In this case it is not possible to determine whether the positive or the negative effect of imitation on Northern growth dominates. The net effect of imitation on Northern growth is ambiguous.

While Grossman and Helpman considers only long-run effects, Barro and Sala-i-Martin (1997) analyse both transitory and permanent growth effects of imitation in a version of Romer's (1990) model of expanding product variety. In a two-country setting they assume that to begin with, the number of intermediate goods available in the North exceeds the number available in the South, and that all of the varieties of goods known in the South are also known in the North. They assume no international trade in intermediate goods. Hence, agents in the North have no incentive to imitate since there does not exist a pool of foreign goods to copy. On the other hand, agents in the South imitate since the cost of imitation is assumed to be lower than the cost of innovating. Fig. 6 illustrates the cost of imitation function where N_1 is the number of types of intermediates available in the North, and N_2 is the number of intermediates available in the South, $N_2 \leq N_1$, η_2 is the innovation cost in the South, and ν_2 the cost of imitation in the South. It is seen that the cost of imitation is assumed to be an increasing function of the ratio between the number of intermediate goods invented in the North and the number of intermediate goods imitated in the South.

Figure 6: The Cost of Imitation in the South



Source: Barro and Sala-i-Martin (1997), fig. 1, page 6

Barro and Sala-i-Martin show that if the South is intrinsically inferior to the North in terms of a combination of productivity parameters, labour endowments and cost of innovation, then the South never has an incentive to conduct R&D and the North never has an incentive to imitate. In this case, the North is the perpetual leader and the South is the perpetual follower. On the other hand, if the South has been inferior to the North for a long time, but an improvement in government policy renders the South intrinsically inferior, then, when all of the North's discoveries have been copied, Southern firms find it advantageous to start innovating. Then the inventions in the South create a pool of products that will be imitated in the North, and since the cost of imitation is lower than the cost of invention, agents in the North now find imitation preferable to invention. The North's role thereby shifts from leader to follower.

In the analysis by both Grossman and Helpman and by Barro and Sala-i-Martin, the imitating and the innovating region converge towards the same long-run rate of growth of product development. According to Barro and Sala-i-Martin's interpretation "the rate of discoveries plays the role in this model that the exogenous rate of technical change plays in the neoclassical model".[25] Contrary to the findings by

[25] Page 2.

Grossman and Helpman, imitation does not affect the growth rate of the North in the analysis by Barro and Sala-i-Martin. This is because there is assumed to be no international trade in intermediate goods such that imitation does not affect the expected duration of monopoly rents and the possibility of hiring laid-off workers from rival Northern production that has been taken over by the South.

Models of product development that incorporate technology diffusion tend to give rise to patterns of conditional convergence in income per capita. In the analysis by Barro and Sala-i-Martin, the relatively low cost of imitation implies that the South grows faster than the North and tends to catch up with this region (for given government policies and other variables that affect the return from the introduction of new technologies). However, as the pool of copiable material decreases, the cost of imitation rises and the growth rate of the South falls. Thus the increase in the cost of imitation represents a form of diminishing returns (in this case to imitation) that is analogous to the diminishing returns to capital accumulation in the neoclassical model. In this sense, models of product development are consistent with the notion of conditional convergence but convergence takes place not through diminishing returns to capital but through technology transfer.

Multinational corporations

When international trade is liberalised, imitation may promote an international split between R&D activity and manufacturing activity. Establishment of multinational corporations is another channel through which this split may happen. Cost and skill differentials between developed countries and LDCs may induce profit-maximizing firms to establish multinational corporations as analysed by Grossman and Helpman (1991), chapter 7.3. The model consists of two countries, a human capital-abundant and a labour-abundant country, and two consumer goods, a traditional good that is produced with human capital and labour, and a high technology good that is manufactured from differentiated intermediate inputs. A necessary condition for establishment of international corporations to be interesting is that when firms must manufacture their innovative products in the same country where their research facilities are located, factor price equalization between the two countries does not happen. In this case, when the trade equilibrium is characterised by higher costs of manufacturing innovative products in the human capital rich country then innovators in the human capital rich country have an incentive to move their production activities offshore. It is demonstrated that there exists many trade equilibria with multinational corporations characterised by factor price equalization. This equalization emerges as a result of the separation of research and manufacturing activities by at least some entrepreneurs that abate the pressures of labour demand that otherwise cause the wage rate in the human capital rich country to exceed that in the labour-rich country. In these equilibria, the human capital rich country may import the traditional good and a greater volume of innovative goods than it exports.

In a related set-up with national knowledge spillovers and free trade, Feenstra (1996) demonstrates that multinational production will stop R&D activity in the country with the lowest initial amount of general knowledge since firms operating here have higher fixed costs but earn the same profits from sale of intermediate goods as firms located in the other country. Feenstra shows that despite the fact the R&D stops in one country, the growth rate of final output in both countries may be higher, and the rate of decline in consumer prices greater due to the multinational activity. This suggests long-run welfare gains for both countries.

7.4. Appropriate technologies

One branch of the endogenous growth literature emphasizes the lack of appropriate technologies as an important source for cross-country differences in total factor productivity. The idea is that countries need a sufficient amount of complementary inputs to gain productivity from technological advances. Hence, LDCs may refrain from using a new technology designed to make optimal use of the prevailing factors and conditions in richer countries because the technology is inappropriate for LDCs. There are many dimensions in which technological needs of LDCs differ from those of developed countries, including climate, geography, culture and skill levels. For whatever reason, the result is that technologies designed for optimal productivity in developed countries may incite little or no productivity growth in LDCs, even though there are no barriers to the technology diffusion. This may account for the LDC technology frontier capital (e.g. computing and accounting machinery, electrical and communication equipment) being less than that of richer countries (Caselli & Wilson (2004)).

Basu and Weil (1998) assume that each technology is appropriate for one unique capital-labour ratio, and that technological change takes the form of learning-by-doing: Firms learn over time to improve the productivity of the specific capital-labour mix that they are using and of similar techniques. This means that when a country is producing at some level of capital per worker, the level of technology appropriate for capital-labour ratios within a neighbourhood of that country's current capital-labour ratio increases. Hence, a country uniformly improves technologies within a given range of the technology it is currently using. Basu and Weil use a simple AK-production function (see section 2.1) and assume that technology is freely mobile across countries. However, technology transfer is not immediate because technologies are indexed by capital intensity: Time is needed for countries to achieve a development level that can fully utilize technologies developed by the technology leaders. The model assumes a maximum level of learning-by-doing bounded to any given capital-labour ratio, and that this maximum level increases with the capital-labour ratio. This implies that technologies have increasingly high potential at higher levels of development.

In the model's two-country version, where the savings rate of the countries differ, Basu and Weil find two possible equilibria – one where the two countries experience different growth rates, and one where the income levels differ but the countries share a common growth rate. Which equilibrium is observed depends on the parameters of the model, and not on initial conditions. If the countries grow at similar rates, the country with the highest savings rate must have a lower level of technology at each capital-labour ratio. This happens only when the high-saving country is always in the lead. As a result, this leaves an improved level of technology for the other country to use, thereby allowing it to grow at the same rate despite its lower savings rate. This equilibrium will be observed if the two countries' capital-labour ratios are not too dissimilar. In this case, the learning-by-doing experienced in one country contributes to the level of technology being used in the other country. When the distance in the countries' capital-labour ratio is sufficiently large for the leader not to profit of the learning-by-doing experienced in the follower country, the two countries will have different growth rates in the long run.

There exists a possibility of convergence clubs among various countries because of spillovers. In a multi-country setting, countries with small differences in their savings rate tend towards a common growth rate, whereas the opposite occurs with countries with substantially variant savings rates within each club, countries share the same growth rate but have different levels of income.

Acemoglu and Zilibotti (2001) focus on differences in skill levels as the main reason why LDCs' technological needs differ from those of developed countries. All the results in this model originate from the fact that the relative abundance of skills in the North induces "skill-biased" innovations.

They consider a world economy consisting of a large advanced Northern country, and a set of small less developed Southern countries. To simplify the analysis, all Southern countries are assumed to be identical. The North and South are distinguished by relative size and relative endowments of skills. The North employs skilled workers in tasks performed by unskilled workers in the South. A number of final goods can be produced with two alternative technologies. The first uses unskilled labour and a set of differentiated intermediate goods, whereas the second technology uses skilled labour and a different set of intermediate goods. The key assumption is that some intermediate goods (machines) can only be used by unskilled workers, while some other intermediate goods (computers) can only be used by skilled workers. When LDCs are forced to use unskilled workers, they will use the "machinery" technology rather than the computer technology and be less productive as a result.

The authors show that in equilibrium, only the North innovates while Southern producers copy the technologies developed in the North. In the absence of international trade, intermediate producers located in one country cannot sell their products to firms located in the other countries, so the relevant market for technologies is the local market. Because the South consists of a set of small economies, intermediate firms will have an infinitesimal market, and the South will not invest in R&D. Hence, R&D firms target their innovations towards the needs of the North, and Southern producers copy technologies from the North.

In equilibrium, all Northern sectors have the same TFP, while Southern sectors that use skilled technologies have higher TFP than Southern sectors using unskilled technologies. Moreover, the TFP will be larger in the North in sectors that use unskilled technologies in the South, and will be larger in the South in sectors that use skilled technologies in the South. The intuition for this result is that the South has access to the same set of technologies and are relatively scarce in skilled workers, so their price and value of production in the skill-intensive sectors will be relatively high.

When R&D firms direct their research towards the needs of the North, both output per worker and output per efficiency unit of labour are higher in the North than in the South. The reason for this difference is a technology-skill mismatch. A larger supply of skills in the North implies that new technologies are relatively skill-complementary, whereas the South, which employs unskilled workers in most tasks and sectors, needs more labour-complementary technologies. Furthermore, both productivity and output per worker in the North relative to the South are strictly increasing in the relative productivities of skilled and unskilled workers. Therefore, as technologies become more skill-biased, the output gap between the North and the South widens. It is important to note that if R&D firms could sell to Southern producers, they would invest more resources in unskilled technologies. This would result in a smaller productivity-gap between the North and the South.

Acemoglu and Zilibotti generalize their model to include international trade in final goods and this causes further divergence in output per worker. Since no international trade in intermediate goods is assumed, inventors continue to sell intermediate goods to only Northern producers, so the relevant market size for inventors do not change. But trade causes the relative price of skill-intensive goods to increase, making skill-complementary innovations more profitable, i.e. technologies are now more skill-biased. This reduces the productivity of unskilled workers both in the South and the North, and because the South is more abundant in unskilled workers, its relative income compared to the North deteriorates. Trade therefore amplifies income differences between the North and the South. Despite causing divergence in output per worker, trade leads to convergence in output per efficiency unit of labour and in TFP. The reason for TFP equalization is factor price equalization. TFP is low in the South when unskilled workers perform tasks that skilled labour could do better. Commodity trade, however, ensures factor price equalization and induces firms in the South to employ unskilled workers only in the tasks performed by unskilled workers in the South, and likewise for skilled workers i.e. TFP differences disappear.

8. Conclusions and discussion

This final chapter concludes the literature survey by briefly summarizing the main findings regarding the core issues mentioned in the introduction.

Mechanisms that may give rise to a correlation between openness and growth

The neoclassical growth theory associated with Solow (1956) and Swan (1956) focus on physical capital accumulation and exogenous technological progress, and predicts that countries' economic growth rate is exogenous in the long run. Contrary to this, the growth theory developed in the late 1980's and 1990's focus on human capital accumulation, and research and development of new or better technologies, and determines countries' growth rate endogenously (e.g., Lucas (1988), Romer (1990), Aghion and Howitt (1992)). This theory incorporates real-life market imperfections, e.g., externality effects and monopolistic competition. Since the long-run rate of growth is endogenously determined in these frameworks, various types of openness – international trade, international knowledge spillovers, international technology diffusion, imitation, foreign direct investment – may affect countries' rates of growth in the long run.

While a framework focussing on one single source of growth may provide an adequate description of an economy at a given developmental stage, it is hardly an appropriate description of the development of an economy from stagnation to self-sustained growth, or of countries at different developmental stages. Therefore, the stage theories combine different growth mechanisms that vary in importance at different stages of development (e.g., Baldwin et al (2001), Funke and Strulik (2000), Howitt and Mayer-Foulkes (2002), Acemoglu et al (2006)). The unified growth theory goes a step further and explains the development of the population size along with the economic and technological development (Galor and Weil (2000)).

Conditions under which openness (does not) promotes growth

The theoretical literature analyses a variety of international linkages and find mixed results regarding the correlation between openness and growth. Taking a broad overview, the majority of the literature suggests that openness is either conducive to growth or has no effect on countries' long-run rate of growth. First of all, opening up for communication and cooperation at an informal level may facilitate the international diffusion of general knowledge which promotes growth across countries because the production of new ideas increases and because more labour is allocated towards research activity (Romer (1990)). Second, international commodity trade may promote growth across countries because it induces a more efficient allocation of resources between manufacturing and research. Hence, the country with a comparative advantage in R&D specializes relatively in research activity while the other country specializes relatively in manufacturing. As a result the growth rate of the world economy increases compared to autarky (Grossman and Helpman (1991), chapter 7).

However, the dynamic gains from trade may be unequally distributed across countries and in some cases countries may actually lose. Countries can differ in terms of human capital abundance (Grossman and Helpman (1991), chapter 7), initial stock of general knowledge (Grossman and Helpman (1991), chapter 8, Young (1991), Feenstra (1996)) and technological stage (Galor and Mountford (2006), Barro and Sala-i-Martin (1997)). The majority of the analyses predict that the rich country experiences higher growth as a result of international trade. The reason is that the rich country has an initial comparative advantage in producing the good with the largest growth potential, and this initial advantage gives rise to a dynamic process that extend the advantage over time.

Even though the theoretical contributions incorporating trade into economic models have progressed steadily, the empirical analyses have not been equally numerous. One major problem is lack of sufficient and reliable data for many countries. Specifically, for developing countries - the countries for which the question of the link between trade and income probably has the greatest importance - data are scarce. Another problem stems from the fact that trade can effect an economy in many ways. Thus, simple measures of a country's barriers to trade may not be able to capture the full extent of the impacts - country specifics play a major role. In conclusion, the literature of empirical studies of the links between openness and growth call for targeted and rigorous econometric analyses that employ appropriate theoretical specifications.

Specific conditions/problems to take account of when considering developing countries

For poor countries there seems to be more uncertainty about the dynamic effects of opening up for international trade: Along with the rich countries extending their comparative advantages in producing goods with large growth potential, the poor countries may find themselves specializing in production activities with low growth potentials (Grossman and Helpman (1991), chapter 8, Young (1991), Galor and Mountford (2006)).

The main potential source of dynamic gains from openness to poor countries seems to be international technology diffusion taking the form of either imitation or multinational corporations. Lower costs of production enable producers in developing countries to capture market shares and quasi-rents by under-pricing the original innovator (Grossman and Helpman (1991), chapter 11, 12, Barro and Sala-i-Martin (1997), Feenstra (1996)). However, when it comes to international technology diffusion, there is also a danger of poor countries not reaping the dynamic gains: If use of technologies developed in rich countries requires the existence of complementary inputs which are not present in developing countries, this may refrain these from using the new technology and gain productivity growth (Basu and Weil (1998) and Acemoglu and Zilibotti (2001)). Hence, it may be necessary to develop certain structural characteristics of developing economies in order to reap the dynamic benefits of openness.

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