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Essays on Trade, Growht, and Development

by

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Chapter 1*

Introduction

1 A Short Summary of the Thesis

During the last two decades we have seen great advances in modelling of market imperfections and endogenous growth mechanisms. Thereby it has become possible to study static as well as dynamic effects of international integration in general equilibrium frameworks without restricting the analysis to perfect markets. Beyond this introduction, my thesis consists of four chapters where I study growth and development consequences of trade liberalization in a setting where imperfect competition and externalities are essential. There are basically two 'facts' that have served as motivation for my models. The first 'fact' is that the most successful developing countries in the post World War II period have been relatively open to trade. The second 'fact' is that there seems to be a non-monotonous relationship between trade liberalization and long-term growth for more advanced, industrialized countries.

In chapter 2 I study how trade liberalization can be a means to escape from an underdevelopment trap. The point of departure is an assumption that labour and specialized intermediates are imperfect substitutes in the production process. If the intermediates are produced under increasing returns to scale and exhibit some complementarity, an autarky may become trapped with an unsophisticated and labour intensive technology. What I show is that trade liberalization may lead to a modernization process in the 'underdeveloped' country by increasing saving and investment incentives.

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In chapter 3 I argue that the presence of scale economies in the R&D sector indicates ambiguous growth effects of trade liberalization between industrialized countries that differ in local purchasing power: trade liberalization possibly reduces R&D incentives in 'small' countries, but resource constraints may prevent a parallel increase in R&D efforts in 'large' countries. The explanation for this outcome is found in Krugman's home market effect, which says that small countries tend to have a disadvantage in industries with scale economies. I also demonstrate that the global growth rate may be maximized for some intermediate levels of trade costs if there are imperfect international knowledge spillovers.

Static economic geography models indicate that trade liberalization may be harmful either for rich or for poor countries, depending on the initial level of trade costs. In chapter 4 I use a dynamic framework to argue that it is insufficient only to consider static effects, because trade liberalization may increase the global growth rate to the benefit of both poor and rich countries.

In chapter 5 I show that trade liberalization can make it profitable for a relatively backward country to imitate goods from a more advanced country. This may be advantageous for both rich and poor countries. However, I also show that there may exist an 'imitation trap' where the international wage gap is larger and the global growth rate smaller than in an equilibrium where both poor and rich countries innovate.

In the next four sections I will place my models into a broader framework, and discuss related literature and possible extensions. The perspectives in this introduction may to some extent be considered as complementary to the ones used in the main chapters.

2 On Chapter 2: Trade Liberalization, Saving, and Development

In chapter 2 I study how trade liberalization can be a means to escape from an underdevelopment trap. The point of departure is an assumption that labour and specialized intermediates are imperfect substitutes in the production process. If the intermediates are produced under increasing returns to scale and exhibit some complementarity, an autarky may become trapped with an unsophisticated and labour intensive technology. What I show is that trade liberalization may lead to a modernization process in the 'underdeveloped' country by increasing saving and investment incentives.

2.1 Motivation and previous literature

The economic development in the most successful East Asian countries since the 1960's has been amazing. Purchasing power adjusted real income per capita (PPC) in Taiwan and South Korea, for instance, was equal to \$1753 and \$1163 in 1966, but had reached \$8063 and \$6673 by 1990. For a comparison, during the same period PPC changed from \$653 and \$1198 to \$1264 and \$2096 in India and Sri Lanka, respectively (Summers and Heston 1991). Of the many differences and similarities between these countries, the fact that India and Sri Lanka have been relatively closed economies compared to Taiwan and South Korea has been emphasized in the literature (e.g., Romer 1993).[1]

How can it have been possible for the NICs to achieve such unprecedented economic growth over the last decades? Has openness to trade really been an important factor? And if it has, what is it about openness that can create 'miracles'? These kinds of questions have drawn the attention of numerous economists, and the research motivation has perhaps best been described by Lucas (1988, p. 5): "I do not see how one can look at figures like these without seeing them as representing *possibilities*....The consequences for human welfare .... are simply staggering: Once one starts to think about [this], it is hard to think about anything else."

Empirical evidence

Some of the mystery behind the development in the NICs seems to have disappeared with the highly influential paper of Young (1995). Following his analysis, what is remarkable about these countries is not the productivity growth, but rather an astonishing factor accumulation. In Taiwan, for instance, the investment ratio increased from about five percent in the early 1950s to some 22 percent four decades

[1] India has perhaps been the country that most consistently has followed an import substitution policy (Bruton 1998).

later. For South Korea the picture is even more dramatic; the investment rate increased from five percent to forty percent. There were also significant increases in the labour participation rates in all the NICs, partly because the birth rate declined and partly because a higher proportion of the women joined the labour force. At the same time the quality of the labour force improved - the share of the population with secondary education in Taiwan and South Korea was almost tripled between 1966 and 1990. In addition there was also some reallocation of labour away from sectors with low productivity growth (agriculture, in particular). Thus, although the average GDP growth rate per capita between 1966 and 1990 was equal to some 8.5 % both in Taiwan and South Korea, the average total factor productivity (TFP) growth rates (ex. agriculture) were not higher than 3.5 % and 1.7 %, respectively. Still impressive TFP growth rates, but not mysteriously so - the TFP growth rates in France and Germany during the same period were, for instance, about 1.5 %.[2]

The East Asian miracle in a neoclassical framework

The high East Asian investment rates are striking if we reason within the neoclassical growth theory: the rate of return to capital should decline sharply over the years, and growth should eventually come to a halt - at least if the Inada conditions are fulfilled and we abstract from exogenous technological progress.[3] That does not seem to have happened (at least not prior to the present crisis, which presumably has quite different causes.).

Ventura (1997) challenges this way of reasoning, and argues that diminishing returns need not set in once we open up for international trade. Indeed, a small open economy may be able to achieve *sustained* growth even if the Inada conditions hold. In order to show this, Ventura uses a Ramsey-Cass-Koopmans growth model with a large number of countries and two primary factors; capital and labour. These factors are nontraded, and are used as inputs in production of two costlessly traded

[2] All the figures are taken from Young (1995).

[3] The interesting part of the Inada condition in this connection is the assumption that $\lim_{k\to\infty} f'(k) = 0$, where $f'(k)$ is the marginal product of capital per capita. It has long been known that we may have endogenous growth without technological progress if this assumption is violated, see Arrow et al. (1961).

intermediates that have opposite factor intensities. He allows the countries to differ in labour productivity, but presupposes that trade in intermediates equalizes international factor prices once we adjust for productivity differences (a weak form of the factor-price-equalization theorem).

Consistent with observations from East Asia, Ventura considers a country in which the consumers - for some exogenous reason - have a saving rate above world average. This country is moreover assumed to have a relatively low population growth, and to be too small to affect world market prices. Ventura then demonstrates that even though there are globally diminishing returns to capital for the world as a whole, the same need not be true for each individual (small) country. What happens is instead that the high-saving country produces, and exports, increasingly more of the capital intensive intermediate good; the rate of return to capital will not decline since the world market prices on the intermediates are given.

The essence of Ventura's model is nothing but the Rybczynski effect applied to growth theory, and his model builds on a number of simplifying assumptions (particularly on the production side) that make it questionable how robust the results are. Nonetheless, for two reasons I still think his article is important. First, very few researchers seem to have taken into account the fact that the Solow model does not necessarily predict decreasing returns at a national level in an open world economy. From the point of view of small countries this scale effect indicates possible long-run (dynamic) gains from trade that, to a large extent, seem to have gone unnoticed in the literature. Secondly, Ventura's model casts some doubt on empirical evidence that rejects endogenous growth models and lends support to the conditional convergence hypothesis of the Solow model. (I will not go deeper into this latter point, even though it has relevance for chapters 3, 4, and 5 of this thesis.)

2.2 Focus and main results of the model in chapter 2

Though the model presented in chapter 2 differs from Ventura's in several respects, also I have taken the seemingly positive relationship between trade and growth in the NICs as a point of departure. My focus is, however, somewhat different; what I want to show is that there may be reason to expect a positive relationship between trade liberalization and saving, particularly for a backward economy. Possible growth effects of trade liberalization will, moreover, eventually peter out in my model.

I consider a world consisting of two countries that possibly differ in size and level of development.[4] There are two major production sectors - one 'modern' and one 'traditional' - and one R&D sector. The modern sector uses labour along with a CES composite of intermediate goods, which are invented by R&D firms, in order to manufacture the final output. The CES formulation implies that there is some complementarity between the intermediates. Thus an economy would - other things being equal - be better off the higher the number of differentiated intermediate goods. But development of new kinds of intermediate goods requires some fixed investments: the costs come today and the benefits in the future. Due to the complementarity we have a sort of increasing returns at the level of society that may lead to multiple equilibria and a vicious circle: if demand for intermediates is small, then the scale of production will also be low. And with a low scale of production the average costs will be high, and therefore cost minimizing final goods manufacturers may prefer to use a relatively large share of labour in the production process. Compared to an economy that has inherited a large number of varieties, an economy that inherits a low number of differentiated intermediates may therefore be caught in a trap where it is dependent upon an inferior technology .

Trade liberalization could break the vicious circle. First, intermediate goods producers may improve their profitability because they gain better access to the export market. Second, the complementarity between the intermediates also implies that domestic demand and R&D profitability in the underdeveloped country increase because the price of the composite good relative to labour is reduced. The analysis shows that this second effect may in fact be the most important one. If trade costs are sufficiently reduced, consumers will thus be willing to lend money to

[4] In order to avoid any confusion, I should perhaps stress that in discussion of Ventura's model the term 'small, open economy' refers to a country which is unable to affect world market prices. In the rest of this thesis I use the term 'small' to describe a country with relatively low aggregate purchasing power, but that still can influence equilibrium prices.

entrepreneurs who invest in R&D; new intermediate goods will be introduced. and so final goods producers maximize profit by shifting to a substantially less labour intensive technology. Even after the country has left the underdevelopment trap. trade liberalization may increase savings because it becomes profitable to use labour in an increasingly more indirect way, making the incentives to develop new kinds of intermediates higher.

2.3 Some possible extensions

There is only one type of labour in the model I present in chapter 2, but an interesting extension of the model could be to assume that researchers in developed countries (DC) are more efficient than those in less developed countries (LDC). This modification, which is hardly controversial, allows us to ask a couple of interesting questions.

First, should an LDC principally aim at closer integration with other LDCs or with DCs? Traditional trade theory typically predicts that gains from trade are likely to be largest between dissimilar countries, and this should tend to make integration with DCs preferable. Trade with DCs also allows the LDC to improve its efficiency by importing more advanced production technologies (which in my context means a broader specter of specialized inputs).

However, the more advanced the trading partner, the larger the comparative disadvantage for product developers in the LDC. In isolation, this could increase the likelihood that the country becomes locked in production of traditional low-tech goods, characterized by small learning potentials and slow technological progress. Indeed, this is an old theme within development economics. Static and dynamic economic geography models lend some support to this prediction, but they also indicate that the depth of the trade integration is important. A reasonable conjecture is, perhaps, that the negative aspects of an integration with DCs are most pronounced if the process is only 'half-hearted'.

With international productivity differences we may also study consequences of outsourcing; with outsourcing I mean that entrepreneurs/capitalists in DCs perform research domestically, while actual production is carried out in low-wage LDCs. To study this issue it seems preferable to distinguish between capital owners and labour. and some of the direct effects are likely to be quite clear. First, we should expect outsourcing to result in higher demand for manufacturing workers in LDC's and lower demand in DCs. Thereby outsourcing could make workers in DCs worse off. both in absolute and relative terms. Secondly, outsourcing should be beneficial for capital owners in the DCs by enabling them to employ inexpensive labour. But if the wage level and other factor costs in the LDCs increase as a result of outsourcing, then capital owners in the LDCs are likely to be hurt. Moreover, if outsourcing does not generate knowledge spillovers or other kinds of positive externalities for entrepreneurs in the LDCs, then they are possibly worse off also because the *de facto* competition from the more efficient foreign researchers increases. However, outsourcing should increase global efficiency by better utilization of comparative advantages. A fruitful research strategy would perhaps be to investigate under which circumstances this is not true, and study what determines how gains and losses from outsourcing are split internationally.

3 On Chapter 3: Endogenous Growth and Trade Liberalization between Small and Large Countries

In chapter 3 I argue that the presence of scale economies in the R&D sector indicates ambiguous growth effects of trade liberalization between industrialized countries that differ in local purchasing power: trade liberalization possibly reduces R&D incentives in 'small' countries, but resource constraints may prevent a parallel increase in R&D efforts in 'large' countries. The explanation for this outcome is found in Krugman's home market effect, which says that small countries tend to have a disadvantage in industries with scale economies. I also demonstrate that the global growth rate may be maximized for some intermediate levels of trade costs if there are imperfect international knowledge spillovers.

3.1 Motivation

The evidence that closed economies have slower long-term economic growth than more open economies is quite convincing. In an empirical study, based upon Summers and Heston's (1991) data set, Sachs and Warner (1995) even find some evidence that "a sufficient condition for higher-than-average growth of poorer countries, and therefore convergence, is that poorer countries follow reasonably efficient policies, mainly open trade and protection of property rights.". Grossman and Helpman (1991, ch.1) also refer to several studies that show disappointing long-term growth for relatively closed economies. An example is Syrquin and Chenery (1989) who, in a sample of over 100 countries for the period 1952-83, found that countries with an outward oriented policy achieved a growth in total factor productivity that was almost forty per cent higher than that of those with an inward oriented policy.

Grossman and Helpman (1991, ch.8) discuss several channels through which higher openness and more trade presumably increase international knowledge spillovers and thereby growth in models which build on Romer's (1990b) R&D specification. First, there is reason to believe that if the trade volume increases, so do person-to-person contacts across the countries. This is likely to lead to more exchange of information, better cultural understanding, increased knowledge about new technologies and organizational forms (like the Japanese Just-in-time system) and so on. Secondly, the more widespread the use of imported goods, the more probable it is that domestic researchers actually learn about, and draw knowledge from, foreign products. Third, importers may have suggestions for improvements of the goods they buy - and both imports and exports should thereby increase the knowledge base as trade increases. But Baldwin and Forslid (1996) emphasize that the combination of extensive trade liberalization in the last decades and a somewhat disappointing evolution of productivity indicates that "trade liberalization and technology-led growth cannot be linked by a simple relationship".

3.2 Focus and main results of the model in chapter 3

In chapter 3 I argue that there are strong reasons to expect ambiguous growth effect of trade liberalization between countries that differ in size (i.e., local purchasing power). To show this, I set up a simple model where rational, forward looking entrepreneurs perform R&D whenever it is profitable, and where knowledge spillovers produce growth as in Romer (1990b) and Grossman and Helpman (1990). R&D

requires fixed investments, and the output - knowledge and designs for new kinds of goods - has a very special character since it later becomes a nonrival input. A main point of Romer (1990a) is that this nonrivalry unavoidably generates globally decreasing average cost curves for each R&D firm that has made a successful innovation. My claim is that these scale economies, when coupled with Krugman's home market effect, clearly indicate uncertain growth effects of trade liberalization.

As will be recalled, the home market effect says that large countries (i.e., countries with relatively high local purchasing power) tend to have an overproportional share of industries with scale economies if there are positive trade costs. Krugman and Venables (1990) have, however, demonstrated that the strength of the home market effect is not likely to be a monotonous function of the level of trade costs. The reason is that self-sufficiency is decisive for the international production pattern when trade costs are very high, while the relative size of local markets is more or less irrelevant when trade costs are very low. We may consequently anticipate the home market effect to be strongest at some intermediate levels of trade costs.

Using Krugman's and Krugman and Venables' logic in an endogenous growth framework, it is useful to imagine that we have a world consisting of two countries which are intrinsically symmetric in all respects except for their size. Assume further that we have complete international knowledge spillovers, and that trade costs on innovated goods initially are relatively high. Trade liberalization is then likely to strenghten the home market effect, and resources in the small country may therefore be shifted away from research activities and into sectors without scale economies ('traditional' non-growth generating sectors). This need not affect the global growth rate if there is a parallel increase in research in the large country. However, resource constraints may prevent the reduced research incentives in the small country from being counterbalanced by correspondingly higher incentives in the large country. In that case the net effect of trade liberalization is to reduce the global growth rate, and the relative factor rewards in the large country will have increased due to the higher factor demand. This process then continues until the strength of the home market effect has reached its maximum. Thereafter further trade liberalization increases R&D employment in the small country, and consequently also the global growth rate. The home market effect thus suggests a U-shaped relationship between trade liberalization and growth.

Though empirical studies indicate that international knowledge flows are important, we also have clear evidence that intranational spillovers are stronger than international. I therefore extend the model in order to look at consequences of trade liberalization when we have imperfect international spillovers. With imperfect spillovers the growth rate tends to be higher the more concentrated the research sector is, and therefore the growth rate may increase if trade liberalization strengthens the home market effect. This is, as discussed above, most likely to happen if trade costs are not too low. But if trade is inexpensive, then liberalization may imply that a relatively larger share of the research takes place in the small country (due to its lower factor costs). In that case the global growth rate is likely to be reduced. The analysis shows that the growth rate may in fact be maximized for some intermediate levels of trade costs when we have imperfect international spillovers.

3.3 Some possible extensions

In the model I have presupposed that labour is homogenous and freely mobile between the sectors in each country. It would probably be a relatively simple extension of the model to assume that the research sector requires skilled labour, while both skilled and unskilled labour may be used in 'traditional' production. One advantage of such a modification is that it would dampen some effects which become quite exaggerated in my framework. A more ambitious extension would be to study how trade liberalization affects the incentives to accumulate human capital; one attempt in this direction has been made by Dinopolous and Segerstrom (1998).[5]

In future work I should also focus more on the mechanisms and scope of knowledge spillovers. For instance, while there is a large body of empirical literature

[5]In Dinopolous and Segerstrom's model trade liberalization between symmetric countries increases the incentives to perform R&D, and reduces the relative wage of unskilled labour. They further argue that their paper sheds some light on the increasing wage differences between skilled and unskilled labour in the US (and the high unemployment in Europe): the cause may be North-North trade (as opposed to North-South trade).

which looks at the question of whether knowledge spillovers are mainly intraindustrial or interindustrial (see Mohnen 1995 and 1998), and how they evolve over time, very few attempts have been made to model such differences in theoretical trade/growth frameworks. Presumably international economics would benefit from the ideas put forward in papers dealing with urban economics concerning these matters, see Glaeser, Kallal, Scheinkman, and Shleifer (1992) and Henderson, Kuncoro, and Turner (1995).[6]

4 On Chapter 4: Agglomeration and Growth Effects of Trade Liberalization

Static economic geography models indicate that trade liberalization may be harmful either for rich or for poor countries, depending on the initial level of trade costs. In chapter 4 I use a dynamic framework to argue that it is insufficient only to consider static effects, because trade liberalization may increase the global growth rate to the benefit of both poor and rich countries.

4.1 Motivation and previous literature

In the 1950s and 1960s there was wide-spread fear among economists and politicians that gains from trade between industrialized countries and developing countries would come at the expense of the latter group. If anything, the opposite view seems to dominate today: there is fear that higher competitive pressure from low-cost countries like China and India may reduce welfare in the rich countries. The aim of Krugman and Venables (1995) was to show within a single framework that there may be some sense in both these views. Since their paper serves as a building block for both chapters 4 and 5 of this thesis, I will go through its main aspects.

[6] Urban economists carefully distinguish between 'MAR' (Marshall-Arrow-Romer) and 'Jacobs' externalities: with MAR, knowledge spillovers take place only within an industry, and market competition tends to reduce innovation incentives. In models with 'Jacobs' externalities, on the other hand, the most important knowledge transfers come from outside the core industry, and competition tends to increase the growth rate. Somewhere in between these extremes we find 'Porter models', which argue that knowledge spillovers are intraindustrial, but that competition has positive effects on innovation incentives.

There are two sectors and two intrinsically symmetric countries in Krugman and Venables' model. Goods from the 'traditional' sector are produced under constant returns to scale and are traded costlessly. In the modern sector, on the other hand, there are increasing returns to scale and the goods can only be traded at some costs. Krugman and Venables further assume that the modern sector uses some of its output as intermediate inputs, and this feature implies that we have vertical industry linkages which may generate international industry agglomeration. In order to see this, suppose that one country - the North - for some reason has a somewhat larger share of the modern sector than has the other country - the South. Due to trade costs on intermediates, firms in the North then tend to have a cost advantage over those in the South, and therefore we may see a relocation from the latter to the former country (cost linkage). But if the share of the modern sector that is located in the North increases, then, other things being equal, also demand for intermediates will increase in the North (demand linkage). This in turn tends to attract even more firms to the North. However, product market and labour market competition may become unduly high in the North if the country has the larger part of the modern sector. What Krugman and Venables demonstrate is that the combination of increasing returns to scale and input-output linkages creates positive concentration advantages which dominate over the traditional competitive forces for certain levels of trade costs.

There will not be any concentration of economic activity when trade costs are high since in that case the countries basically have to be self-sufficient. This changes for some intermediate levels of trade costs: the centripetal forces then make the symmetric equilibrium unstable, and both countries may possibly become specialized - the North in the modern sector and the South in the traditional sector. Reductions in the level of trade costs have now made the South worse off - the wage level has decreased while at the same time the consumer price index has increased since a larger share of the modern goods must be imported. But with even lower trade costs the importance of the demand and cost linkages decreases, and firms in the modern sector become more sensitive to international wage differences. When trade costs are already 'low', further trade liberalization consequently results in a relocation of firms from the North to the South along with wage increases in the latter country. This is unambiguously positive for the South, but since the North now must import a larger share of the goods from the modern sector, the welfare level in that region will possibly fall.[7]

4.2 Focus and main results of the model in chapter 4

Since Krugman and Venables use a static framework they tell only half the story, and therefore I have modified their model in order to study growth consequences of trade liberalization.[8] The research sector is modelled in much the same manner as in chapter 2, except that I now assume that already invented intermediates are used as inputs in the innovation process (this is what Rivera-Batiz and Romer, 1991a.b. call the lab equipment specification). It turns out that the relationship between trade liberalization and economic growth follows a quite complex pattern, but one that perhaps should be expected on the basis of Krugman and Venables' model. First, the countries remain symmetric when the level of trade costs is high,[9] and a modest trade liberalization increases the growth rate because it reduces innovation cost. However, for some intermediate levels of trade costs the research sector may become completely agglomerated in the North, in which case the wage level in the South falls. The reason for this is basically the same as in Krugman and Venables: if there are many producers of intermediate goods in the North, the presence of trade costs implies that incentives to found new research firms also are highest here. Simultaneously, the more research firms there are in the North, the higher the demand for intermediates in that country. These forces correspond to the cost and demand linkages, respectively, in Krugman and Venables. As in their model, the welfare level in the North has unambiguously increased. The important point, however, is that we cannot say for sure whether trade liberalization has reduced welfare in the South even if that should be the case in a static framework. The

[7] Depending on parameter values, it is also possible that both countries gain, since the direct effect of reducing trade costs is positive.

[8] Independent of my work Baldwin, Martin, and Ottaviano (1998) look at the same issue.

[9] One qualification is needed here: the symmetric equilibrium is never stable if the economies of scale are sufficiently high (see section 1.2.4).

reason is that the concentration of the research sector has led to reduced innovation costs, and thereby the world will see a faster technological progress which is to the benefit of both countries. Both countries will consequently be better off in the long run, even though trade liberalization indeed has created an international welfare gap. The same kind of ambiguity is present for 'low' levels of trade costs as well: even if it should be true that the immediate effect of trade liberalization is to reduce the welfare level in the North, the positive dynamic effects of trade liberalization may dominate in the long run.

4.3 A digression into 'new' endogenous growth theory

I have made no attempt at developing new growth theories either in this or any other chapter. Indeed, I have aimed at something much less ambitious, namely to demonstrate some growth consequences of trade liberalization in two of the most accepted endogenous growth frameworks.[10] I will therefore discuss some of the more recent research in the field of endogenous growth theory, and come up with a conjecture about how my results would be affected if I had used the 'new' endogenous growth theory specification instead of the one by Romer-Grossman-Helpman. The discussion is equally relevant for chapters 3, 4, and 5, but I shall concentrate the debate around Romer's (1990a,b) knowledge driven technology because that is where most of the recent research has been concentrated.

Romer (1990a,b) assumes that the 'production function' for new innovations is equal to

$$\dot{A}(t) = \delta H_A A(t), \tag{1}$$

where δ is a constant, H_A the quantity of skilled labour (researchers) allocated to the research sector, and $A(t)$ is a measure both of the number of innovations made as of time t and of the society's common knowledge base. Equation (1) implies that a given growth rate can be sustained by a constant number of researchers, and in that sense R&D neither becomes easier nor more difficult over time. Like all 'traditional' endogenous growth models, Romer's specification does, however, rest

[10] I use the so-called knowledge driven technology in chapter 3 and the lab equipment technology in chapters 4 and 5.

on a much criticized knife-edge assumption.[11] Equation (1) is namely only a special case of

$$\dot{A} = \delta H_A A^{\phi} \tag{2}$$

with ϕ=1. Growth will eventually peter out if the labour force (population) is constant and $\phi < 1$, but Romer (1990b, p. 84) defends his choice $\phi = 1$ by claiming that "...there is no evidence from recent history to support the belief that opportunities for research are diminishing. Moreover, linearity in A is convenient analytically, and assumptions about what will happen in the far future for values of A that are very large relative to the current level have very little effect on the question of interest.". Solow (1994), however, finds it more interesting to note that the economy will explode within a 'short' time if ϕ is only a bit larger than 1; with reasonable parameter values and $\phi = 1.05$, the days of scarcity will be over in some 200 years. To believe that by some chance $\phi \equiv 1$, neither a touch below nor above, one would "have to believe in the tooth fairy" according to Solow (p.51). Since he further cannot find any strong empirical evidence which supports the knife-edge assumption, he concludes that this branch of growth theory is "unpromising".

Jones (1995a,b) takes the same view as Solow, and states that $\phi = 1$ "represents a completely arbitrary degree of scale economies". Romer's parameter assumption further implies that if resources (H_A) devoted to R&D are doubled, then also the output rate ($\frac{\dot{A}}{A}$) from the R&D sector should double and generate a permanently higher economic growth rate. Jones claims that this prediction easily is shown not to be fulfilled. The number of scientists and engineers who are employed in the R&D sector, for instance, has increased by a factor of five in the USA from 1950 to 1987 (Jones 1995a, p. 760), but we have certainly not seen a similar increase in the growth rate - it may even have declined.[12]

Based on the 'arbitrariness' of $\phi = 1$ and empirical evidence (see Dinopolous and

[11] In this sense endogenous growth models represent a step back compared to neoclassical growth models: arguably the greatest achievement of Solow (1956) was indeed to get rid of knife-edge assumptions in the Harrod-Domar models.

[12] Time lags and other factors certainly make this too simple an observation to discard endogenous growth models, see Jones (1995b) for a short discussion.

Thompson 1998a,b for a discussion), Jones (1995a,b) has proposed an endogenous growth model where it becomes more difficult to make innovations over time because the most obvious ideas are discovered first. In his formal model, which basically is the same as Romer (1990b) except for the removal of the knife-edge, he ends up with the following steady state growth equation for patens and output per capita:

$$g = \frac{n}{1-\phi}. \tag{3}$$

Equation (3) shows that the long-run growth rate is proportional to the population growth rate n and inversely proportional to the degree of external scale economies. To see the intuition for this result, assume that we do not have any externalities ($\phi = 0$). It then follows from equation (2) that $\dot{A} = \delta H_A$. There will consequently be a constant number of new innovations each period if $\dot{H}_A = 0$, and so $\frac{\dot{A}}{A}$ declines over time and eventually reaches zero. R&D employment must therefore increase if we shall have a constant asymptotic growth rate, and $0 = \frac{d}{dt}\left(\frac{\dot{A}}{A}\right) = \frac{d}{dt}\left(\frac{H_A}{A}\right)$ implies $\frac{\dot{H}_A}{H_A} = \frac{\dot{A}}{A}$. By definition the steady state sector division of labour must be constant, and therefore R&D employment must increase by the rate n. That g in turn is increasing in the degree of knowledge spillovers (ϕ) for any given $n > 0$, is hardly surprising.

The beauty of Jones' model is that even though changes in R&D efforts only have level effects in steady state, it is nevertheless intentional research by profit maximizing firms as in Romer-Grossman-Helpman that causes the economy to grow. Jones (1995a) moreover shows that the transitional period between steady states in his model is possibly considerably longer than in the Solow model. Therefore, if trade liberalization should have positive or negative level effect, the temporary growth effect along the transition path may be quite long. My conjecture is consequently that many of the qualitative effects that I discuss in chapters 3, 4, and 5 may still survive in the short and medium run also in Jones' setting.

Short on empirical criticism of the Romer-Grossman-Helpman framework:

Some of the empirical evidence which is said to refute R&D based endogenous growth theory does not seem very convincing (see Dinopolous and Thompson

1998a,b, and Aghion and Howitt 1998 for surveys). Let me give two examples. First, there is at best a very weak positive correlation between country size and growth rates, and Jones, (1995a,b) as well as Barro and Sala-i-Martin (1995), several times argues as though R&D models predict large countries to grow faster than small ones (due to the scale effect). That interpretation is not correct in an open world economy.[13] If anything, the standard models rather predict that all open economies should tend to have the same long-term growth rate. Secondly, empirical research typically does not take changes in product quality into consideration. Thompson and Waldo (1997) have shown that this may seriously bias the time estimates of TFP growth, and Baldwin, Braconnier, and Forslid (1998, p. 3-4) offer an extreme example of how this neglect may completely blur the picture.

In another context Matsuyama (1997) argues that since all economic models are abstractions and simplifications, "the trouble begins when we start taking a particular model literally" (p. 140). Although the knife-edge assumption in endogenous growth models is possibly implausible, it may nonetheless be a good first approximation because it usually reduces the analytical complexity (see also Romer 1990b, and Baldwin, Braconnier, and Forslid 1998).[14] The 'real world' may also have some self correcting devices which prevent the growth rate from approaching zero or infinity, and a hypothesis along these lines has been put forward by Kocherlakota and Yi (1997). Their point of departure is that the growth rate depends positively on public capital and negatively on distortionary taxes. As higher public investments take place, the need for tax income increases. Based on simulations for a period of 100 years for the USA and 160 years for the UK, they submit the view that we should in fact expect the positive and negative effects of these policies to cancel each other over time. Kocherlakota and Yi's point is that "the government budget constraint [implies that] growth-enhancing investments require growth-reducing taxation", and

[13] In a not too diplomatic manner Baldwin, Braconnier, and Forslid (1998, p. 3-3) call it "theoretical illiteracy" to interpret the models as though large countries should grow faster than small ones when there is trade.

[14] However, there may also be a tendency for researchers to dismiss models that do not generate constant growth rates in the long run. This "error" may, e.g., prevent explorations of growth effects of trade liberalization in markets characterized by market segmentation and strategic interaction.

so they maintain that Jones is using a statistical rather than an economic point of view when he argues that it would be "miraculous" if different permanent policy variables are exactly offsetting (see Jones 1995b and his rejection of the $Y = AK$ model).

When all this is said, it should also be emphasized that there is a critical lack of empirical support for the R&D based endogenous growth models. In my growth papers I do only to a very small extent consider level effects of trade liberalization, and this is potentially a serious shortcoming if models à la Jones provide better descriptions of growth determinants than do those in the tradition of Romer-Grossman-Helpman.

5 On Chapter 5: Trade Costs, Innovation, and Imitation

In chapter 5 I show that trade liberalization can make it profitable for a relatively backward country to imitate goods from a more advanced country. This may be advantageous for both rich and poor countries. However, I also show that there may exist an 'imitation trap' where the international wage gap is larger and the global growth rate smaller than in an equilibrium where both poor and rich countries innovate.

5.1 Previous literature on imitation

In his seminal paper "*International Investment and International Trade in the Product Cycle*" Vernon (1966) puts forward a hypothesis whereby goods initially are developed and manufactured in advanced countries, but where process standardization later makes it profitable to relocate the production to less advanced countries which have lower wage levels. Krugman (1979) arguably formalizes Vernon's ideas in a one-sector model with technology spillovers between the North and the South, and what he seeks to explain is the pattern of trade and why wages are highest in the developed North. To this end he builds a simple model where only the North is able to innovate new products, but where firms in either country are able to produce imitated goods after a certain time lag.[15] Both the innovation and imitation rates

[15] Strictly speaking, Vernon studies innovating firms' location decisions, not imitation. Krug-

are exogenous, and there is perfect competition between innovators and imitators. Krugman then shows that unless the imitation rate is 'too high' the countries will become completely specialized; the North in innovation and the South in imitation. In that case the North will have relatively high wages, and will export newly innovated goods to the South in exchange for imitated ones.

Also Grossman and Helpman (1991, ch. 11) postulate that the South is unable to innovate, and assume perfect competition between the original innovator and the imitator. They also follow Krugman in considering horizontal differentiation. The major modification from Krugman's model is that they build a knowledge-driven growth model where both the rates of innovation and imitation are made endogenous through deliberate investments by profit maximizing entrepreneurs. Thereby Grossman and Helpman are able to study how imitation affects the innovation rate which in turn is equal to the common global growth rate in real wages. They find that imitation tends to reduce the innovation incentives because it shortens the monopoly period for the Northern innovator. This negative growth effect is however dominated by a positive growth effect; imitation by the South releases labour from manufacturing to R&D in the North.

In a 'quality ladder' model Grossman and Helpman (1991, ch. 12) still assume that entrepreneurs in the South invest in imitation, but now imitated goods eventually become obsolete because Northern firms develop new and better generations of the goods. In this model the negative effect of imitation may dominate, in which case a higher imitation rate reduces the innovation rate. The result that imitation has beneficial growth effect therefore does not seem to be very robust.

Currie et al. (1996) stress that even though the models of Krugman (1979) and Helpman and Grossman (1991) may be appropriate when we study the traditional relationship between the North and the South, they may be less so in a West-East perspective: the East Asian countries may in a not too distant future become equally important innovators as the Western economies. In order to catch this aspect, Currie et al. modify Grossman and Helpman's (1991, ch. 11) framework in a way such that they do not have to presuppose that the East imitates. They do, however, assume

man's model is nonetheless considered to offer the first formalization of Vernon's ideas.

that the West has an advantage over the East in knowledge assimilation. This may lead the East to imitate goods from the West if the former region lags far behind. In effect Currie et al. further assume increasing returns to knowledge accumulation in the copying sector and show how the East then eventually finds it profitable to innovate. Their primary focus is to discuss global policy implications with respect to, e.g., R&D subsidies.

5.2 Focus and main results of the model in chapter 5

I follow Currie et al. and let it be endogenously determined whether the countries innovate or imitate. The motivation for my paper is that trade liberalization and imitation seem to have been key words for some of the East Asian countries. In my model with two countries and two sectors I ask how imitation affects the global growth rate and the international wage gap; would it have been 'better' if also the East were innovating, or is imitation in fact preferable?

I assume that imitation, other things being equal, requires less resources than do innovation, and that there is Bertrand competition between innovators and imitators. Unlike the papers listed above I do, however, not presuppose any exogenous differences between the West and the East. Instead, I build on the growth model developed in chapter 3, where two initially identical regions endogenously develop into an advanced 'West' and a more backward 'East'. As a simplification I focus on a case where the symmetric equilibrium is never stable, and where wages (endogenously) always are relatively low in the East. I show that imitation is unambiguously preferred when trade costs are relatively high, in which case the global growth rate is higher and the international wage gap smaller than if both countries had to innovate. This changes fundamentally for some intermediate levels of trade costs, where there exist multiple equilibria - one equilibrium where both countries innovate, and one where the East imitates. Economic growth is moreover lower and international wage differences larger in the equilibrium with imitation. For low levels of trade costs innovation is more profitable than imitation also in the East, so then the countries end up in an equilibrium with relatively small wage differences and high growth.[16]

[16]It may be noted that a crucial assumption in Vernon's (1966) product cycle argumentation for

The explanation for why we have multiple equilibria is the presence of pecuniary externalities. Consider first the equilibrium where the East imitates. Despite the low wage level in the region, it is not profitable for a single entrepreneur to deviate and make innovations. Why? The reason is that imitations are sold at low prices, and therefore a potential innovator would face too high price competition from domestic producers of (imperfect) substitutes to be able to cover the relatively high innovation costs. However, by lowering the competitive pressure, innovation does become profitable if a sufficiently high number of entrepreneurs in the East choose to innovate rather than to imitate. This in turn allows higher equilibrium wages in the East. But then, as a result of the higher wage level, imitation is no longer profitable; due to the (latent) price competition from the original innovator in the West the profit margin will be too low to cover imitation costs.

5.3 Some possible extensions

The fact that imitation possibly reduces the global growth rate in my model clearly indicates that it would be interesting to look at possible policy implications. That is, however, not a straightforward matter since it requires an out of steady state analysis which typically are not considered in the innovation-imitation literature (one exception is Walz, 1995). Furthermore, as pointed out by Walz (op. cit), it is rather extreme and unrealistic to assume that we will actually observe Bertrand competition between an innovator and a subsequent imitator in equilibrium (it will typically be a non-credible threat). Neither is it obvious how a less fierce price competition than Bertrand would turn out in my model; on the one hand consumer and input prices to the research sector increases. This obviously has negative effects. On the other hand, the cost of being imitated is also reduced - tending to increase the innovation incentives - while at the same time a higher wage level is sustainable in the

why the rich world innovates and initially produces new goods is that we either have imperfect knowledge spillovers (p. 192) or that innovators are dependent upon a range of specialized inputs (p. 203). Grossman and Helpman and Currie et al catch the first assumption, while I catch the second. Vernon assumed that these specialized inputs were non-traded, but, as stressed by Stiglitz (1992), there are very few inputs which are truly non-traded.

poor region. A non-trivial extension would therefore be to study other price games. This is done in a closed economy by Walz (1995) and Segerstrom (1991), and in an open economy by Jensen and Thursby (1985). In order to find analytical solutions the latter article assumes that there is only a single monopolist in the innovating region and a central planner in the less developed region who participate in the game. Jensen and Thursby moreover had to rely on an open loop Nash equilibrium in order to keep the model tractable.[17] Thus it seems that a game theoretical competition approach would be rather challenging within my framework, which already is quite complex.

Finally, it would clearly have been beneficial to simplify my model. Unfortunately, it is not at all clear how this should be done since the questions I ask hardly can be answered in a partial equilibrium model. Indeed, I do not really see how I can use a much simpler framework and still keep the possibility of multiple equilibria.

6 Some Concluding Remarks

Fujita, Krugman, and Venables (1998, p. 9) write that their book "sometimes looks as if it should be entitled Games You Can Play with CES functions". In that respect I guess a good title for my thesis could be 'Some New CES Games'; I have used the Dixit-Stiglitz monopolistic competition framework in all four chapters. Anyone who has worked with imperfect competition in general equilibrium models, and who likes to do a bit of calculus, will clearly agree that this approach has its virtues. It is equally clear that the framework has its drawbacks, and one sometimes wonders how general the findings are (even though the work of Ottaviano and Thisse (1998), which experiments with other market structures, puts an upper limit on the worries). There are, for instance, some empirical work that indicates a positive correlation between product market competition and productivity growth within a firm or industry (see Aghion and Howitt 1998, ch. 7). This effect, which is possibly important, is not caught within the framework I have used in my growth models.

[17] An open loop Nash equilibrium means that the players do not take into consideration how their actions affect the rival's future decisions. Segerstrom's analysis is greatly simplified because he assumes a cooperative game.

I have also systematically used Samuelson iceberg trade costs in all my models, a modelling trick which makes things much more tractable (for instance, we do not need to model a separate transport sector). To quote Fujita, Krugman, and Venables once more: the combination of a Dixit-Stiglitz economy and iceberg trade costs "causes many potentially nasty technical complications simply to, well, melt away". I do not really think that it is worthwhile to model other kinds of trade costs for the sort of questions that I have been concerned with. However, in my papers I only study mutual trade liberalization. Presumably, it would have been interesting to look at unilateral liberalization as well, particularly in chapters where I am concerned with trade liberalization between industrialized and developing countries. There is, for instance, reason to believe that real trade costs for many developing countries can be significantly reduced by simplifications of trade procedures. By allowing both unilateral and mutual trade liberalization we are likely to come closer to 'reality', and better be able to study policy implications.

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Chapter 2*

Trade Liberalization, Saving, and Development

Abstract

Why is there apparently a positive correlation between saving and trade liberalization, in particular for the most successful developing countries? Despite tremendous research effort this puzzle is to a large extent still unresolved. In this general equilibrium model we show one channel which may shed some light on the issue. The basic idea is that trade liberalization may lead firms to use labour in a more indirect way, and thereby increase the incentives to save in order to develop new kinds of intermediate goods. For a backward economy this effect may be particularly strong, in which case trade liberalization possibly initiates a qualitative shift from a labour intensive to a more sophisticated production technology. Possible increases in the export to GDP ratio are then a side effect of the domestic investment and modernization process.

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1 Introduction

The import substitution policy (ISP) that a number of poor countries followed in some decades after World-War II did not work very well despite its many theoretical justifications (see, e.g., Krueger, 1984, and Balassa, 1989). Rather than raising welfare, quite the opposite seemed to happen - not the least in the long run.[1] On the other hand, several countries with relatively open trade regimes have fared quite well. Important examples for the purpose of the present paper are South Korea and Taiwan with their impressive growth rates. Yet, the belief in so-called export-led growth is less wide-spread than it used to be. One reason for the scepticism is that improved resource allocations and other efficiency improvements which frequently are claimed to result from outward orientation typically should have level effects and not influence long-term growth. Against this it could be objected that what we observe in South Korea and Taiwan is really level effects, appearing as transitional dynamics from one steady state to another, and that the NICs will grow no faster in the new steady state than the traditional industrialized countries do. This, indeed, seems very likely. Several of the Asian countries started on low income levels that presumably were well below their full potentials. Such was probably also the situation for Japan, who experienced 'miraculous' growth rates for some decades after the second world war, but who no longer seems to grow faster than nations like the USA and Germany. Nonetheless, even if what we observe is transitional dynamics, the magnitudes are still difficult to explain from traditional trade theory. Besides, Rodrik (1995) has given some evidence which shows that the relative profitability of exports were not particularly high in South Korea and Taiwan at the time of their

[1] In principle, one should distinguish carefully between ISP and various degrees of de-linking. ISP commonly hinges on learning-by-doing and infant-industry arguments, and import protection is only meant to be temporary (e.g., Bruton, 1989). De-linking, on the other hand, is intended to be more permanent. Proponents of the latter policy have to a large extent relied on arguments put forward by Prebisch (1950) and Singer (1950), who claimed that developing countries have experienced a terms-of-trade loss (Balassa, 1989, maintains that this impression may be an artefact of the arbitrary chosen time periods in Prebisch' and Singer's studies). In practice, however, also ISP tended to take on a more permanent character.

take-off.

So perhaps the growth experiences of these countries were more the result of successful government market interventions than of export orientation? Rodrik (op. cit.) argues forcefully that this was the case. His basic presumptions are that both countries were relatively well endowed with skilled labour, but that a modern industry sector requires a range of complementary non-traded intermediates that are produced under increasing returns to scale. He formalizes his view in a model where pecuniary externalities may imply that large-scale industrialization is profitable even though individual entrepreneurs are unable to cover development costs for new kinds of inputs. The role of the governments of Taiwan and South Korea, then, was to coordinate investments.[2] The contribution of the export orientation was to give domestic producers access to a large market, and to open up for imports of state-of-the-art capital goods. Rodrik thus denies the idea of export-led growth; rather, he says, it was investment-led - made possible by government coordination.

There are certain similarities between South Korea and Taiwan in the 1950s on the one hand, and some of the Eastern European countries today on the other. The quality of the labour force is very important in this respect. Hungary, for instance, probably has a labour stock that is well able to compete in manufacturing of advanced products. Wang and Winters (1994:139) argue that "....the quality of scientific education in Poland compares with that in several industrial countries while that in Hungary is among the best in the world." At the same time there can be little doubt that countries like the Czech Republic, Hungary, and Poland are capable of manufacturing products that are more skill-intensive than the products that they manufacture today. Much of the production is labour intensive, using rather old-fashioned technologies. There is a need for specialized inputs that were

[2]Murphy, Shleifer, and Vishny (1989) and Matsuyama (1995) offer careful discussions of coordination problems in the presence of pecuniary externalities. For a more theoretical discussion of the *nature* of complementarities, see Matsuyama (1997) who also argues that the view that coordination problems call for government intervention is "fundamentally misguided". Interestingly, however, World Bank (1993) - which typically has been seen as a rather market-oriented and non-interventionist institution - maintains that the governments of South Korea and Taiwan did play a positive role in solving coordination problems.

never produced under the old regimes, in some cases because of system failures during the communist period, in others because market economies require different skills and inputs. Should Eastern Europe repeat the successful, if we are to believe Rodrik's story, government interventions of Korea and Taiwan?

That could, of course, be a possibility, and it is certainly important to understand the East Asian experiences. But a pure blueprint of Asian 'miracle-policies' would hardly work. As Lucas (1993:252) puts it: "[S]imply advising a society to "follow the Korean model" is a little like advising an aspiring basketball player to "follow the Michael Jordan model"". Besides, we have the more fundamental questions about how important non-traded intermediate goods really are, and whether the Korean and Taiwanese policies really were that successful or, in any case, necessary for growth to take off. And even if interventions were necessary then, would the same be true today?

Rodrik argued for intervention because of assumed pecuniary externalities and scale effects in production of non-traded intermediate goods. Ethier (1979) stresses the importance of scale economies in production of intermediate goods, but further claims that an ever increasing share of these goods is becoming tradable. Particularly in the service industry there has been an almost revolutionary development, and services in general have become much more mobile than they used to be. World Bank (1995) gives several examples on how modern communication technology has made it less expensive to separate the geographic location of service production and service consumption, and asserts that this could raise the welfare level in poor countries. Also Grossman (1995), in a comment to Rodrik's paper, questions the assumption about a non-traded sector that is dependent upon a large local market. Likewise, neither Grossman nor Norman (in the same issue) find the story of successful government intervention and coordination too convincing. Norman further questions (p.102) why Rodrik "argues for a complex intervention story (direct intervention to overcome a coordination failure) when a simple one - a high saving and investment rate - suffices." Norman then underlines that investment credits and tax incentives, which were used by the governments in both South Korea and Taiwan, contributed to higher private saving. This could be sufficient for take-off also in Rodrik's model, .but it is unclear whether the saving incentives were - and are - sufficiently large to explain the increases that actually took place. Moreover. Lewis (1954: 155) maintains that "the central problem" in development theory is to understand why *voluntary* saving increases significantly as countries are successfully transformed.[3] A main objective of the present paper is precisely to show one channel through which trade liberalization may contribute to increasing the saving ratio.[4]

There are two countries and two main production sectors in the formal dynamic model presented below. In the so-called modern sector the final consumer good is manufactured by using labour and a CES composite of intermediate goods. The CES formulation implies that there is some complementarity between the intermediates. Thus an economy would - other things being equal - be better off the higher the number of differentiated intermediate goods. But development of new kinds of intermediate goods requires some fixed investments; the costs come today and the benefits in the future. In an autarky model Ciccone and Matsuyama (1993) have shown that due to pecuniary externalities a country may be caught in an underdevelopment trap if the intermediate goods exhibit a sufficient degree of complementarity: if demand for intermediate goods is low, then the incentive to develop and produce intermediate goods is low too. And if the supply of intermediate goods is low, then the fact that there are scale economies in the intermediate goods sector imply that intermediates are relatively expensive (high average costs). Therefore the final goods industry may respond by using a labour intensive technology. In Rodrik's model the government could easily break this vicious circle by coordinating investments, but in a dynamic framework consumer impatience may make any autarky industrialization unattainable even for a benevolent social planner.

Now assume - in accordance with the discussion above - that intermediate goods are in fact tradeable, though only at some cost. Suppose further that one of the countries initially is caught in an underdevelopment trap and that trade costs are

[3]The term 'voluntary' is important; it may well be argued that the tremendous investment rates in socialist countries like the former Soviet Union under Stalin and in Rumania under Causescu were feasible as a result of *de facto* forced savings. This is discussed in several works by Janus Kornai, see, e.g., Kornai (1992).

[4]The terms 'trade liberalization' and 'reduction of trade costs' will be used interchangeably.

reduced. This may break the vicious circle. First, intermediate goods producers may improve their profitability because they gain better access to the export market. Second, the complementarity between the intermediates also implies that domestic demand and profitability in the underdeveloped country increase because the price of the composite good relative to labour is reduced (the analysis shows that this second effect may in fact be the most important one). If trade costs are sufficiently reduced it may thus become profitable for entrepreneurs to invest in development of new kinds of intermediates and for final goods producers to shift to a technology which is substantially more intensive in intermediate goods.[5] This is understood also by domestic consumers, who are therefore willing to lend money to entrepreneurs or buy shares in their firms. We shall then see a period with a large increase in savings and a massive entry of new firms in the intermediate goods sector.[6]

The model we present indicates that the likelihood of escaping from an underdevelopment trap is higher the larger the set of differentiated intermediate goods produced by the trading partner. Other things being equal, this set is in turn increasing in country size (due to scale economies). The analysis may therefore leave an impression that firms in the modern sector would prefer trade liberalization with a large country rather than with a small one, but this is not necessarily true. Indeed, the opposite may be the case if only a part of the economy is subject to increasing returns to scale. We therefore also include a sector which operates under constant returns to scale with labour as the only input, and assume that this sector produces a good which is traded costlessly. It is then shown that unless trade liberalization

[5]The importance of increased industrial specialization and more indirect use of labour can be traced back to Young (1928). See also Ethier (1982) for an early formal discussion of static welfare gains of international trade in intermediate goods, and Evans, Hokapohja and Romer (1998) for an application to endogenous growth theory.

[6]We have quite clear empirical evidence of a strong correlation between a country's saving and investment. This is not necessarily caused by formal and informal barriers, see, e.g., Obstfeld (1986) for a discussion. Also Collins and Rodrik (1991) maintain that the modernization process in Eastern Europe, like the one that took place in the NICs, for the most part must be financed from domestic sources. Therefore we have chosen not to allow international capital flow in the model.

leads to a 'large' increase in the use of intermediates, firms in the modern sector may be worse off if the country has become developed and thereafter liberalizes trade with a large country. This market size effect was first shown by Krugman and Venables (1990), and has later come to play an important role in economic geography research.

The rest of this paper is organized as follows. The formal model is presented in section 2. Some general profitability effects of trade liberalization are discussed in section 3.1, while section 3.2 focuses on the channels through which trade liberalization may bring a country out of an underdeveloped trap. Section 4 offers some concluding remarks.

2 The model

There are two countries, h (home) and f (foreign), with population sizes equal to L_j $(j = h, f)$. Each inhabitant supplies one unit of labour and is internationally immobile. The consumers have identical preferences, and demand goods from a modern (m) and a traditional (z) sector.

The demand side

A representative household has an instantaneous Cobb-Douglas utility function given by $u_j(s) = \ln\left[k_0 m_j(s)^\eta z_j(s)^{1-\eta}\right]$, where k_0 is some positive constant and $\eta \in (0,1)$. Let $p_{mj}(s)$ and $p_{zj}(s)$ denote consumer prices on goods from the modern and traditional sector, respectively. By choosing $k_0 = \eta^{-\eta}(1-\eta)^{-(1-\eta)}$, the ideal consumer price index equals

$$q_j(s) = p_{mj}(s)^\eta p_{zj}(s)^{1-\eta}. \tag{1}$$

By defining consumer expenditure as $E_j(s) \equiv [p_{zj}(s)z_j(s) + p_{mj}(s)m_j(s)]\, L_j$ we can write indirect utility as $\ln \frac{E_j(s)}{L_j q_j(s)}$. Utility is assumed to be additively separable over time, so the household's intertemporal utility function can be expressed as

$$V_j(t) = \int_t^\infty \ln\left[\frac{E_j(s)}{L_j q_j(s)}\right] e^{-\rho(s-t)} ds, \tag{2}$$

where $\rho > 0$ is the subjective discount rate.

Each household supplies inelastically one unit of labour, receives wages $w_j(s)$, and is free to borrow or lend at a market determined interest rate $r_j(s)$. We therefore have an accounting identity which says that

$$\frac{E_j(s)}{L_j} = w_j(s) + r_j(s)\Omega_j(s) - \dot{\Omega}_j(s), \tag{3}$$

where $\Omega_j(s)$ is family net financial wealth at time s, and $\dot{\Omega}_j(s) = \frac{d\Omega_j(s)}{ds}$.

Equations like (3) are typically described as dynamic budget constraints in the literature, but this is not quite correct. It must hold almost by definition, and imposes no constraint as such. There is, e.g., nothing in (3) which hinders households from borrowing an infinite amount one period, and taking up new loans in subsequent periods in order to pay interest on their debts. Therefore we need some restrictions on consumer behaviour. One possibility is to impose the no-Ponzi-game condition, $\lim_{T\to\infty}\Omega_j(T)e^{-\int_t^T r_j(v)dv} \geq 0$, which says that asymptotically a family's debt cannot rise faster than the interest rate - the family must be able to repay its debt 'in the end'. Let $R_j(s) = e^{-\int_t^s [r_j(v)-r_j(t)]dv}$ be the discount factor. Given (3) and the no-Ponzi-game condition, Appendix A1 shows that households simply maximize (2) subject to the intertemporal budget constraint

$$\int_t^\infty \frac{E_j(s)R_j(s)ds}{L_j} = \int_t^\infty w_j(s)R_j(s)ds + \Omega_j(t), \tag{4}$$

so that the Lagrangian can be formulated as

$$\mathfrak{L} = \int_t^\infty \ln\left[\frac{E_j(s)}{L_j q_j(s)}\right] e^{-\rho(s-t)}ds + \lambda(t)\left[\int_t^\infty w_j(s)R_j(s)ds + \Omega(t) - \int_t^\infty \frac{E_j(s)R_j(s)ds}{L_j}\right].$$

Differentiating with respect to $E_j(s)$, we find the first order condition

$$\frac{1}{E_j(s)}e^{-\rho(s-t)} = \lambda(t)R_j(s) \tag{5}$$

which describes the household's optimal saving and consumption path. The shape of the utility function further implies that consumers will allocate a share η of their expenditures each period to goods from the modern sector.

Time differentiation of (5) gives us $\frac{\dot{E}_j(s)}{E_j(s)} = r_j(s) - \rho$. Without loss of generality we shall assume that it is country f which is possibly small ($L_f \leq L_h$) and 'under-developed' (to be defined later), and it proves advantageous to choose $w_h \equiv 1$. This choice of numeraire implies that $E_j(s)$ is constant in steady state, in which case the nominal interest rate equals the subjective discount rate;

$$r_j(s) \equiv r = \rho. \tag{6}$$

In the following we will omit time subscripts when no confusion can arise.

The supply side

There is free entry in both the traditional and the modern sector. We abstract from differences in relative factor endowments between the countries, and in our context it is therefore convenient to assume that labour is the only primary factor of production.

The traditional good is produced with a simple constant returns to scale technology, and by choice of measurement we assume that one unit of labour produces one unit of output. Since we further presuppose that this good is traded costlessly, it follows that $p_z \equiv p_{zh} = p_{zf}$ and

$$w_j \geq p_z, \tag{7}$$

with equality in at least one country.

The production function for the modern good, which is non-traded, is given by

$$M_j = F\left(L_{mj}, X_j\right) = \left[L_{mj}^{\frac{\theta-1}{\theta}} + X_j^{\frac{\theta-1}{\theta}}\right]^{\frac{\theta}{\theta-1}}, \qquad (\theta > 0, \theta \neq 1) \tag{8}$$

where L_{mj} is labour, and $X_j = \left[\int_0^n \left[x_\omega(s)\right]^{\frac{\sigma-1}{\sigma}} d\omega\right]^{\frac{\sigma}{\sigma-1}}$ is a composite of differentiated intermediate goods.[7] We require that the elasticity of substitution between the intermediate goods is greater than one ($\sigma > 1$) so that no variants are essential in production.

It takes κ units of labour to develop a design for a new intermediate good, and thereafter β units of labour for each unit of output. All producers in a given

[7] As is well known, the CES function (8) collapses into a Cobb-Douglas function when $\theta = 1$.

country will charge the same price since the goods are symmetric in (8) and produced with the same technology. The perceived elasticity of demand is equal to σ if each producer assumes that his behaviour neither affects the wage level nor the price of the composite good. Profit maximization consequently implies that the producer price of a representative intermediate good from country j is $p_j = \beta\frac{\sigma}{(\sigma-1)}w_j$. By choice of scale, let $\beta = \frac{(\sigma-1)}{\sigma}$ such that the *f.o.b.* price equals

$$p_j = w_j. \tag{9}$$

Intermediates may be traded internationally, but only at a cost. We model these costs to be of the Samuelson iceberg type, and assume that only $\left(\frac{1}{\tau}\right)$ of each unit shipped actually reaches its destination $(\tau \geq 1)$. This implies that the *c.i.f.* price of an imported good is τ times higher than the *f.o.b.* price, so the price index for the composite good is

$$P_j = \left[n_j p_j^{1-\sigma} + n_i \left(p_i \tau\right)^{1-\sigma}\right]^{\frac{1}{1-\sigma}} \tag{10}$$

for $i \neq j$. By taking the dual of (8), and noting that the m-good is perfectly competitive, we further find

$$p_{mj} = \left[w_j^{1-\theta} + P_j^{1-\theta}\right]^{\frac{1}{1-\theta}}. \tag{11}$$

From equation (11) it follows that the share of intermediates in the m-good is

$$\alpha_j = \alpha\left(\frac{P_j}{w_j}\right) = \frac{P_j^{1-\theta}}{w_j^{1-\theta} + P_j^{1-\theta}}. \tag{12}$$

By using (12) we can express the value of (indirect) consumer demand for intermediates in country j as $\alpha_j \eta E_j$ (recall that the consumers use a share η of their income on the modern good). We further know that with the CES price index P_j the aggregate market shares in X_k $(k = i, j)$ for intermediate goods producers in country j equal $s_{jj} = n_j\left(\frac{p_j}{P_j}\right)^{1-\sigma}$ and $s_{ji} = n_j\left(\frac{\tau p_j}{P_i}\right)^{1-\sigma}$, respectively. Demand in market $k = i, j$ for a good produced in country j is thus given by

$$x_{jk} = \frac{s_{jk}\alpha_k \eta E_k}{n_j p_j}. \tag{13}$$

Equilibrium conditions

The instantaneous profit flow for an intermediate good producer equals $\pi_j = (p_j - \beta w_j)(x_{jj} + x_{ji})$, or

$$\pi_j = \frac{p_j (x_{jj} + x_{ji})}{\sigma}. \tag{14}$$

We shall assume that a firm receives an international patent with infinite life when it developes a new kind of intermediate good, and the present value of a representative firm is thus $v_j(t) = \int_t^{\infty} \pi_j(s) R_j(s) ds$.[8] Time differentiation gives us

$$\dot{v}_j(t) = \rho v_j(t) - \pi_j(t), \tag{15}$$

where we have used $r = \rho$. There is no uncertainty in our model. Equation (15) can therefore be interpreted as a no-arbitrage condition which says that during a short time period dt a consumer is indifferent between receiving $\rho v_j dt$ from a bank deposit or owning a share in a firm which gives a profit flow $\pi_j dt$ plus a change in firm value $\dot{v} dt$.[9]

Technically it is often assumed in growth models that capital goods costlessly can be transformed into consumption goods. But it would seem quite artificial to assume that an invention can be transformed back to labour, and therefore it is always the case that $\dot{n}_j \geq 0$. The cost of a new invention is $w_j \kappa$. If this cost is greater than the value v_j of producing a new variant of intermediate good, then entry cannot be profitable and we must have $\dot{n}_j = 0$. Otherwise, free entry ensures that $v_j = w_j \kappa$ in equilibrium. The free entry condition therefore implies

$$\begin{aligned} v_j &= w_j \kappa \ \text{ when } \dot{n}_j > 0, \text{ and} \\ v_j &\leq w_j \kappa \ \text{ when } \dot{n}_j = 0. \end{aligned} \tag{16}$$

The firms are owned by domestic shareholders, and the ownership is evenly spread among the country's consumers (who do not have any other financial assets).

[8]It hardly makes sense to talk about international patents when we consider autarkies. Technically we can still neglect the possibility that any brand is produced in both h and f, since the probability measure of an overlap is equal to zero (there is an infinite number of potential goods to produce). We shall therefore assume that no good is produced in both countries. It should, nonetheless, be noted that it may be interesting to study integration also when we allow an overlap; see Rivera-Batiz and Romer (1991) for an example in an endogenous growth context.

[9]This interpretation is due to Grossman and Helpman (1991).

Consumer expenditure in steady state must therefore be equal to

$$E_j = [w_j + \rho\Omega_j] L_j, \tag{17}$$

where $\Omega_j = \frac{n_j v_j}{L_j}$.

It takes $n_j\beta(x_{jj} + x_{ji})$ and $\frac{(1-\alpha_j)\eta E_j}{p_j}$ workers to manufacture intermediate goods and the final M-good, respectively, while $\dot{n}_j\kappa$ workers are needed to develop new designs. Let L_{zj} denote employment in the traditional sector. Labour market equilibrium thus requires (with $\dot{n}_j \geq 0$)

$$L_j = n_j\beta(x_{jj} + x_{ji}) + \frac{(1-\alpha_j)\eta E_j}{p_j} + \dot{n}_j\kappa + L_{zj}, \tag{18}$$

where $L_{zj} = 0$ if $w_j > p_z$ and $L_{zh} + L_{zf} = \frac{(1-\eta)(E_h + E_f)}{p_z}$.

Autarky

To show the existence of a possible underdevelopment trap it is useful to draw a phase diagram for an autarky, c.f. Figure 1. To this end we first note that innovation costs are equal to the present value of an intermediate good if $v_j = w_j\kappa$ from equation (16). In that case no firm has any incentive to enter the market, and we can set $\dot{n}_j = 0$ in the labour market equation (18). Due to the shape of the utility function we know that $L_{zj} = \frac{(1-\eta)E_j}{w_j}$ since $p_{zj} = w_j$ for an autarky, and equation (13) tells us that $x_{jj} = \frac{\alpha_j\eta E_j}{n_j p_j}$ ($x_{ji} = 0$ and $s_{jj} = 1$ in absence of trade). Using that $\beta = \frac{\sigma-1}{\sigma}$ and $p_j = w_j = w_j\kappa$ we can thus write equation (18) as

$$v_j = \frac{\kappa}{L_j}\left[\frac{\sigma - \eta\alpha_j}{\sigma}\right] E_j = w_j\kappa \tag{19}$$

when $\dot{n}_j = 0$. Since we have chosen $w_h \equiv 1$ when there is trade, it is natural to let $w_j \equiv 1$ for an autarky. Equation (19) therefore describes the horizontal line $v_j = w_j\kappa = \kappa$ in Figure 1. There will be new entry if the firm value is greater than the one given by $\dot{n}_j = 0$, and so the arrows above this curve point from the left to the right. The arrow lines below the curve, which consequently point leftwards, are dotted since n_j cannot decrease. The curve is shifted upwards if the fixed costs κ increase.

The firm value is constant if $\dot{v}_j = 0$. Then equation (15) tells us that $\rho v_j = \pi_j = \frac{p_j x_{jj}}{\sigma} = \frac{\alpha_j \eta E_j}{\sigma n_j}$, or

$$v_j = \frac{\alpha_j \eta E_j}{\rho \sigma n_j}. \tag{20}$$

The value v_j of a firm must be expected to increase (decrease) in the future if the share price is higher (lower) than the one corresponding to (20). This explains the vertical arrows. To find the slope of the curve we differentiate v_j with respect to n_j, and Appendix A2 shows that $\frac{dv_j}{dn_j} = g(n_j, \eta)\left[\frac{\eta-\sigma}{\sigma} n_j^{\frac{\theta-1}{\sigma-1}} + \frac{\theta-\sigma}{\sigma-1}\right]$ where $g(n_j, \eta) > 0$. Provided $\theta > \sigma$ the curve is thus upward sloping until it reaches a maximum at $n_j^* = \left[\left(\frac{\theta-\sigma}{\sigma-1}\right)\left(\frac{\sigma}{\sigma-\eta}\right)\right]^{\frac{\sigma-1}{\theta-1}}$ and thereafter downward sloping. We also see that $\frac{dv_j}{dn_j} < 0$ if $\theta < \sigma$, in which case the curve $\dot{v}_j = 0$ is always downward sloping.

Note that the $\dot{v}_j = 0$ locus is shifted downwards if demand for modern goods decreases (η lower), the labour force is smaller (which reduces E_j) or the subjective discount rate ρ is higher (it is therefore possible that the curves $\dot{n}_j = 0$ and $\dot{v}_j = 0$ will never cross).

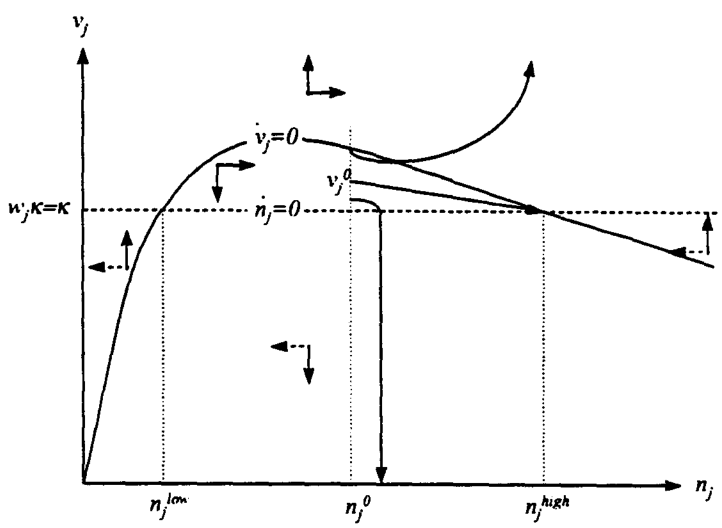

Figure 1: *Phase diagram, autarky.*

Suppose that the initial number of firms is equal to n_j^0 as in Figure 1. In that case the share value v_j must be equal to $v_j^0 > w_j \kappa$ and the number of firms converge to n_j^{high}. A start value higher than v_j^0 would imply an ever increasing share value and thus a violation of the transversatility condition $\lim_{s \to \infty} \Omega_j(s) R_j(s) = 0$ (see

Appendix A1). A value lower than v_j^0 cannot be possible either, because that would finally lead to a negative v_j if the no-arbitrage condition in equation (15) is to hold. With rational expectations, and given n_j^0, we therefore have a unique saddle point trajectory that starts at the value v_j^0 and converges to $(n_j^{high}, w_j\kappa)$.[10] Using similar arguments we find that the present value of an intermediate good is greater than the innovation costs for any initial $n_j \in (n_j^{low}, n_j^{high})$, and that we will reach the point $(n_j^{high}, w_j\kappa)$ in steady state.

The steady state value of an intermediate good is increasing in the number of existing varieties along the upward sloping part of $\dot{v}_j = 0$, but with $v_j < w_j\kappa$ if $n_j < n_j^{low}$. In that case there will be no new entry, and the modern sector must use a labour intensive and unsophisticated production technology - the country is, in some sense, caught in an underdevelopment trap.[11] At the other end of the scale, it is easy to verify that $v_j < w_j\kappa$ to the right of n_j^{high}. There will thus be no new entry if n_j^0 is greater than n_j^{high}.

To see why $\frac{dv_j}{dn_j}$ is possibly positive, we differentiate equations (13) and (14) with respect to n_j and hold consumer expenditure fixed. Letting $\varepsilon(y, z)$ denote the partial elasticity of y with respect to z, we have

$$\varepsilon(\pi_j, n_j) = \varepsilon(\alpha_j, n_j) - 1.$$

The first term reflects that the share of intermediates in the final good possibly changes because the ratio $\frac{P_j}{w_j}$ is reduced, and from equation (12) we find $\varepsilon(\alpha_j, n_j) = \frac{(\theta-1)(1-\alpha_j)}{\sigma-1}$. With a Cobb-Douglas production function ($\theta = 1$) the share of intermediate goods is constant, while it increases (decreases) if the elasticity of substitution between X_j and L_{mj} is greater (smaller) than one. The second term shows that,

[10] See also Blanchard and Fischer (1989, ch. 5) and Grossman and Helpman (1991, c. 3).

[11] Self-fulfilling prophecies about an expected future industrialization or active government policy to coordinate investments might bring the country out of an underdevelopment trap if n_j is slightly below n_j^{low}. The requirements for this to be possible will not be studied here, see Ciccone and Matsuyama for a discussion. Possibilities for self-fulfilling prophecies in the presence of pecuniary externalities have also been studied earlier by Matsuyama (1991) and Krugman (1991). (The latter paper contains an error, but the mistake does not really affect the qualitative picture, see Fukao and Benabou, 1993.)

holding $P_j X_j$ fixed, the value of demand for existing brands decreases by one percent if the number of varieties increases by one percent. Thus

$$\varepsilon(\pi_j, n_j) = \frac{(\theta - 1)(1 - \alpha_j)}{\sigma - 1} - 1, \tag{21}$$

and $\frac{dv_j}{dn_j}$ is positive if $\varepsilon(\pi_j, n_j) > 0$.

The economic idea behind the existence of a possible underdevelopment trap is that complementarities between specialized inputs generate increasing returns at the level of society: the average costs will be high if the scale of production is low. Final goods producers may consequently find it profitable to use a relatively labour intensive production technology if there is only a small supply of intermediates. The subsequent low demand for intermediates in turn reduces the incentives to develop new varieties. The economy may thus end up in a vicious circle; as we have seen, this may happen if $\theta > \sigma$. Though this inequality will be assumed to hold in all the subsequent simulations, we will also discuss other cases in detail.[12]

If we take a literal interpretation of the model, it would perhaps seem most natural to assume $\theta < \sigma$ because the elasticity of substitution would then be higher the finer the level of aggregation we look at. As usual there is a trade-off between tractability and 'realism'. In particular we have assumed that there is only one group of intermediates, and that these moreover are symmetric. An obvious extension of the model would be to have varying degrees of substitutability and complementarity between different intermediates. Then the requirement for an underdevelopment trap to exist would possibly seem less strict, but the drawback would be a considerably more complex algebra.

3 Consequences of trade and trade liberalization

This section consists of two parts. Section 3.1 discusses some general positive and negative effects of trade liberalization for the firms' profitability, and shows the

[12]Ciccone and Matsuyama use the notion of Hicks-Allen substitutes and complements to explain the presence of an underdevelopment trap. They also offer a more general discussion than we do.

importance of the relative size of the trading partner. In section 3.2 the main focus is on how trade affects an underdeveloped country.

3.1 Profitability effects of trade liberalization

Below we will study how reductions in the level of trade costs affect the profitability of firms in the modern sector. It will be shown that whether trade liberalization ($d\tau < 0$) has a beneficial effect depends on two factors. First, lower trade costs imply a reduced protection of the domestic market as well as improved market access to the foreign country. Profitability tends to increase if the latter effect dominates, and we shall then possibly see higher innovation and saving incentives. Secondly, trade liberalization reduces the cost of the composite good X_j relative to labour. This has a positive profitability effect if the share of intermediates in the m-good increases.

Differentiation of equation (13) gives $\varepsilon(x_{jj}, -\tau) = \varepsilon(\alpha_j, -\tau) + \varepsilon(s_{jj}, -\tau)$ when we hold wages and consumer expenditure fixed. For the first term we have $\varepsilon(\alpha_{jj}, -\tau) = (\theta - 1)(1 - \alpha_j) s_{ij} \gtreqless 0$ if $\theta \gtreqless 1$, and so the absolute value is higher the larger the market share of foreign firms (s_{ij}) (reflecting the significance of import for the country). Otherwise the interpretation is similar to the one we gave when we derived equation (21) for $\varepsilon(\pi_j, n_j)$. The second term illustrates that import competition increases when trade is liberalized, and the absolute value of this negative effect is also larger the higher the number of foreign firms. More concretely, one percent reduction of the trade costs reduces demand for domestic goods by σs_{ij} percent (since the elasticity of substitution equals σ), and thus the market share decreases by $(\sigma - 1) s_{ij}$ percent; $\varepsilon(s_{jj}, -\tau) = -(\sigma - 1) s_{ij} < 0$. We may thus write

$$\varepsilon(x_{jj}, -\tau) = [(\theta - 1)(1 - \alpha_j) - (\sigma - 1)] s_{ij} \gtreqless 0, \tag{22}$$

and, analogously,

$$\varepsilon(x_{ji}, -\tau) = [(\theta - 1)(1 - \alpha_i) s_{ji} + (\sigma - 1) s_{ii}] \gtreqless 0. \tag{23}$$

Let μ be the share of a firm's operating profits that is earned on the home market. From equation (14) we then have

$$\varepsilon(\pi_j, -\tau) = \mu_j \varepsilon(x_{jj}, -\tau) + (1 - \mu_j) \varepsilon(x_{ji}, -\tau) \gtreqless 0. \tag{24}$$

It turns out to be convenient also to separate $\varepsilon(\pi_j, -\tau)$ into two effects which have somewhat different origins. First, we have what we shall label *the net competitive effect*, $\varepsilon(\pi_j, -\tau)_{comp}$, namely that trade liberalization reduces the protection of the home market as well as improving the export market access to the foreign country. The former reduces the profit flow by $(\sigma - 1)\mu_j s_{ij}$ percent while the latter increases the profit flow by $(\sigma - 1)(1 - \mu_j) s_{ii}$ percent for each percent reduction of trade costs. We therefore have

$$\varepsilon(\pi_j, -\tau)_{comp} = (\sigma - 1)\left[-\mu_j s_{ij} + (1 - \mu_j) s_{ii}\right] \gtreqless 0 \text{ if } \frac{s_{ii}}{s_{ij}} \gtreqless \frac{\mu_j}{1 - \mu_j}. \tag{25}$$

We shall discuss the significance of (25) in more detail in the next two subsections.

The second effect of trade liberalization is that the price of the composite good is reduced, and this leads to a higher (lower) share of intermediates in the final m-good if $\theta > 1$ ($\theta < 1$). We may therefore define a *substitution effect*, $\varepsilon(\pi_j, -\tau)_{subst}$, which is equal to

$$\varepsilon(\pi_j, -\tau)_{subst} = (\theta - 1)\left[\mu_j (1 - \alpha_j) s_{ij} + (1 - \mu_j)(1 - \alpha_i) s_{ji}\right] \gtreqless 0 \text{ if } \theta \gtreqless 1. \tag{26}$$

We then have $\varepsilon(\pi_j, -\tau) = \varepsilon(\pi_j, -\tau)_{comp} + \varepsilon(\pi_j, -\tau)_{subst}$.

The countries are basically self-sufficient when trade is expensive, in which case both of them must produce intermediates as well as the traditional good. The latter implies that $w_h = w_f$ when τ is high (because we have assumed that there are constant returns to labour in the traditional sector, and z is traded costlessly). Appendix A3 shows that we then have $\mu_h = \mu_f \equiv \mu = \frac{1}{1+\tau^{1-\sigma}} \geq \frac{1}{2}$ if $v_j = w_j \kappa$.

3.1.1 Trade between symmetric countries

To see whether trade liberalization has a positive effect on the profitability of intermediate goods producers, and thus contributes to increase saving and investment incentives, we will start with the simple case where the countries are symmetric. It is then easy to show that $s_{jj} = \frac{1}{1+\tau^{1-\sigma}} = \mu$, and inserting this into equation (25) we find $\varepsilon(\pi_j, -\tau)_{comp} = 0$. This reflects that the increased export income generated by trade liberalization is exactly matched by the loss from higher import competition unless the share of intermediates in the final good changes. Equation (24) therefore reduces to

$$\varepsilon\left(\pi_j,-\tau\right)=\varepsilon\left(\pi_j,-\tau\right)_{subst}=s_{ij}\left(\theta-1\right)\left(1-\alpha_j\right)\gtreqless 0 \text{ if } \theta\gtreqless 1. \tag{27}$$

Equation (27) thus reveals that whether closer integration leads to higher or lower profitability for the firms depends on the sign of the substitution effect: the profitability increases if $\theta > 1$. Put another way, the possible gains from trade liberalization for intermediate goods producers in this case is the fact that they observe higher demand because it becomes profitable for the modern sector to use an increasingly more indirect method of production.[13] If that happens, savings and investments to develop new intermediates increase.

3.1.2 Trade between countries of different size

Next suppose that $L_h > L_f$. We shall initially assume that both countries have diversified production structures and that $v_j = \kappa w_j$ holds, while other cases are discussed in the next section. With these assumptions it is still true that $\mu_j = \mu$, but the effect of trade liberalization is asymmetric when the countries differ in size. This can be seen by defining $\Delta_{subst} \equiv \varepsilon\left(\pi_f,-\tau\right)_{subst} - \varepsilon\left(\pi_h,-\tau\right)_{subst}$ and $\Delta_{comp} \equiv \varepsilon\left(\pi_f,-\tau\right)_{comp} - \varepsilon\left(\pi_h,-\tau\right)_{comp}$, and using equations (25) and (26) to get

$$\Delta_{subst}=\left(2\mu-1\right)\left(\theta-1\right)\left[\left(1-\alpha_f\right)s_{hf}-\left(1-\alpha_h\right)s_{fh}\right]>0 \text{ if } \theta>1, \tag{28}$$

and

$$\Delta_{comp}=-\left(2\mu-1\right)\left(\sigma-1\right)\left(s_{hh}-s_{ff}\right)<0. \tag{29}$$

The signs of Δ_{comp} and Δ_{subst} follow from the fact that $\mu > 0.5$ (the larger share of the firms' profit comes from the home market) and because $n_h > n_f$ implies $s_{hh} > s_{ff}$, $s_{hf} > s_{fh}$, and $\alpha_h > \alpha_f$ (this is straightforward to show).

[13] Trade liberalization would imply that both n_h and n_f decrease monotonically if $\theta < 1$ and we disregard the constraint $\frac{dn_j}{-d\tau} \geq 0$. We will not consider the case $\theta \leq 1$ in this paper, since we have quite clear evidence that intermediates become increasingly important (e.g., Ethier 1982).

The reason why the substitution effect tends to be stronger for the small country than for the large country, is both that import is relatively more important for the former ($s_{hf} > s_{fh}$) and that the share of intermediates in the final modern good is already 'high' in the latter $(\alpha_h > \alpha_f)$. In this respect the positive effect of trade liberalization is larger in f than in h if $\theta > 1$; $\Delta_{subst} > 0$.

Equation (29) does, however, illustrate that the net competition effect is biased in favour of country h; the relative importance of the home market is the same for the firms in h and f when trade costs are high (as shown by μ), but liberalization implies that firms in the large (small) country face increased competition from a small (large) number of foreign competitors. Indeed, trade liberalization increases the profitability in h and decreases the profitability in f as far as this effect is concerned (see appendix A4).[14] Since the substitution effect is positive in h as well as in f if $\theta > 1$ we therefore have $\varepsilon(\pi_h, -\tau) > 0$. The sign on $\varepsilon(\pi_f, -\tau)$ is, however, uncertain. This sign ambiguity will be carefully studied in the next section, where we shall also discuss what happens in absence of international wage equalization.

3.2 Underdevelopment traps and trade

Innovation costs are equal to the present value of an intermediate good if $v_f = w_f\kappa$, c.f. equation (16). Using equation (18) together with (13) we thus find that the $\dot{n}_f = 0$ locus in a trade regime is described by

$$v_f = \frac{\kappa}{L_f - L_{zf}}\eta\left[\beta\left(s_{ff}\alpha_f E_f + s_{fh}\alpha_h E_h\right) + (1-\alpha_f)E_f\right]. \tag{30}$$

From equation (15) we likewise find that $\dot{v}_f = 0$ when

$$n_f = \frac{\eta}{\sigma\rho v_f}\left[s_{ff}\alpha_f E_f + s_{fh}\alpha_h E_h\right]. \tag{31}$$

In the simulations that follow we have assumed $\kappa = 1.25$ such that the curve $\dot{n}_f = 0$ is horizontal at $v_f = 1.25$ if international wages are equalized.[15]

[14] We have already seen that the net competitive effect equals zero if the countries are identical, c.f. equations (25) and (27).

[15] See Appendix A0 for other parameter values.

Case (i): $L_h = L_f$. .

We shall first consider the consequences of trade for f if $L_h = L_f$. Let the initial number of firms in f be $\tilde{n}_f = \varphi_f n_f^{high}$, where φ_j is some positive constant. Throughout the paper it is assumed that country h is fully developed, with $\varphi_h = 1.0$ in absence of trade. The solid curve in the left hand panel of Figure 2 shows the locus $\dot{v}_f = 0$ under autarky, and the dotted curve with an inverted U-shape shows the locus if there is trade and $\tau = 2.5$. The value v_f is possibly different from $w_f\kappa$ along $\dot{v}_f = 0$, while $\dot{v}_f$ is likely to differ from zero along the horizontal curve where $\dot{n}_f = 0$. All other markets are assumed to clear.[16] The figure shows that trade shifts the locus $\dot{v}_f = 0$ upwards for any given φ_f, and consequently the limit corresponding to n_f^{low} has decreased while the one for n_f^{high} has increased (c.f. Figure 1).

The fact that the lower limit has decreased illustrates the positive consequences of trade liberalization for an underdeveloped country. While, as an autarky f was caught in an underdevelopment trap for $\varphi_f < 0.6$, the critical value is now reduced to $\varphi_f = 0.42$. Assume that φ_f were indeed equal to 0.42, in which case we know that equation (21) must be positive; $\varepsilon(\pi_f, n_f) = \frac{(\theta-1)(1-\alpha_f)}{\sigma-1} - 1 > 0$. Then we also see from (22) that $\varepsilon\left(x_{ff}, -\tau\right) = (\sigma-1)\left[\frac{(\theta-1)(1-\alpha_f)}{\sigma-1} - 1\right] s_{hf} > 0$, and thus trade liberalization also increases domestic profitability in country f. This is illustrated in the right hand panel of Figure 2, which shows that liberalization increases the profitability for intermediate goods producers in f in the home market until $\tau = 2.5$. At this point the country leaves the underdevelopment trap because trade liberalization has increased the share value such that $v_f > w_f\kappa$.[17]

The right hand panel of Figure 2 also makes it clear that for all levels of trade costs the larger share of the gains from trade liberalization comes from increased export income. This happens even though the foreign market is relatively unimportant

[16]Note that Figure 2 is not really a phase diagram since it is assumed that all markets in h are in equilibrium. This is done to simplify the figure analysis because otherwise we would have to operate under higher dimensions. We have used a similar approach also for figures 3 and 4.

[17]The countries are symmetric when $\tau < 2.5$, and further trade liberalization increases the profitability for intermediate goods producers in both countries. The reason for this is that the substitution effect is positive, c.f. equation (26). With our parameter values the substitution effect is, nonetheless, too small to avoid that *domestic* profitability falls when trade costs are reduced.

measured as a share of total operative profits.[18] Nonetheless, it would not be quite correct to interpret this as though the country leaves the underdevelopment trap due to profitable export. Indeed, export profitability increases only marginally as trade is liberalized. The fundamental problem of the economy was the complementarity between the intermediate goods; trade liberalization causes final good manufacturers to change to a technology which is increasingly more intensive in intermediate goods. At $\tau = 2.5$ this has caused the stock dividends to rise sufficiently high to increase the consumers' saving ratio, and in the new steady state equilibrium we have $\varphi_f = 1.2$.

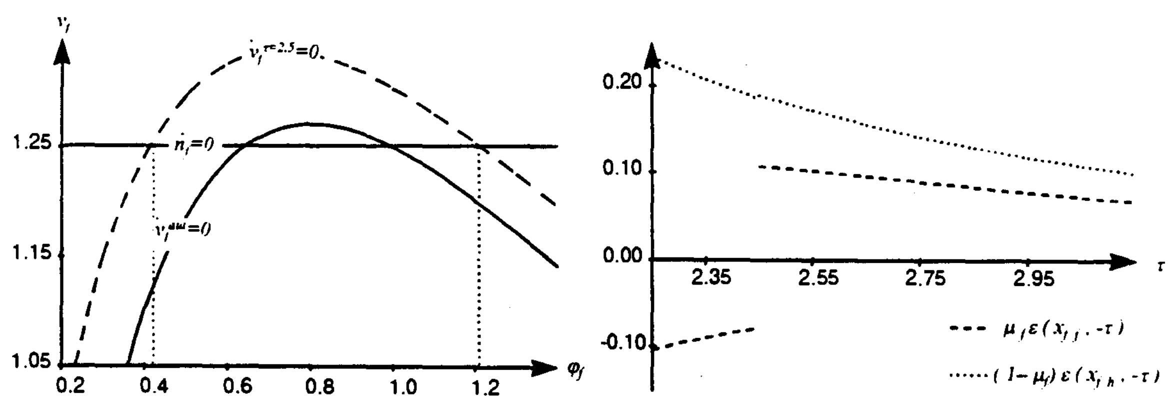

Figure 2: *Trade with an equally sized country. (Left hand panel: τ=2.5.)*

Independent of the initial number of firms in f the possibility of an underdevelopment trap may vanish as the countries become sufficiently integrated, in which case the upward sloping part of the curve $\dot{v}_f = 0$ ceases to exist. Trade liberalization moreover implies that the downward sloping part of $\dot{v}_f = 0$ crosses $\dot{n}_f = 0$ for an increasingly higher value of φ_f: This is clear from equation (27) which showed that n_j is inversely related to the level of trade costs when both countries are developed.[19] Trade liberalization moreover implies that intraindustry trade increases, as

[18]Recall, however, that $\mu_j = \mu = \frac{1}{1-\tau^{1-\sigma}}$ only holds if $v_j = w_j\kappa_j$ in both countries. It is easy to show that $\mu_h > \mu > \mu_f$ when $v_f < w_f\kappa_f$.

[19]More precisely, we know that $\varepsilon(\pi_j, -\tau) > 0$ when $\theta > 1$ because trade liberalization increases the share of intermediates in the m-good. With free entry this is reflected in an increasing number of firms.

do investment and saving during the transition to the new steady state.

Case (ii): $L_h > L_f$.

Figure 3 considers trade liberalization with a larger country $(L_h > L_f)$, and this size difference potentially affects the industrial structure in f in two different ways. First, equation (22) indicates that the possible positive effects on the home market of trade liberalization are larger the larger the trading partner (the import share s_{ij} increases). Therefore a less extensive trade liberalization should be required in order to bring f out of an underdevelopment trap. Equation (29), on the other hand, showed that there is possibly a negative competitive effect of integration with a larger country. These two opposing forces explain why the curve $\dot{v}_f = 0$ is shifted up and to the left in the left hand panel of Figure 3.

The size of the export market offered to intermediate goods producers in country f is, other things being equal, increasing in L_h. Perhaps a bit surprisingly, the right hand panel of Figure 3 nonetheless shows that the greater part of the gains from trade liberalization now appears in the home market when τ is high (contrary to what we saw when $L_h = L_f$). The reason for this is to be found in equation (22); $\varepsilon(x_{ff}, -\tau) > 0$ and an increasing function of s_{hf} when country f is caught in an underdevelopment trap (and s_{hf} is in turn increasing in L_h, other things being equal). This further underscores the importance of increased profitability of trade liberalization on the home market for an underdeveloped country - indeed, equations (22) and (23) suggest that $\mu_f \varepsilon(x_{ff}, -\tau) > (1 - \mu_f)\, \varepsilon(x_{fh}, -\tau)$ also if $L_h = L_f$ if φ_f in autarky is sufficiently small. This is confirmed by simulations.[20]

[20]Suppose $\varphi_f = 0.3$ and $L_h = L_f = 1$ (and the other parameter values unchanged). Then the positive home market effect dominates for $\tau > 2.42$ (and f leaves the underdevelopment trap at $\tau = 2.12$).

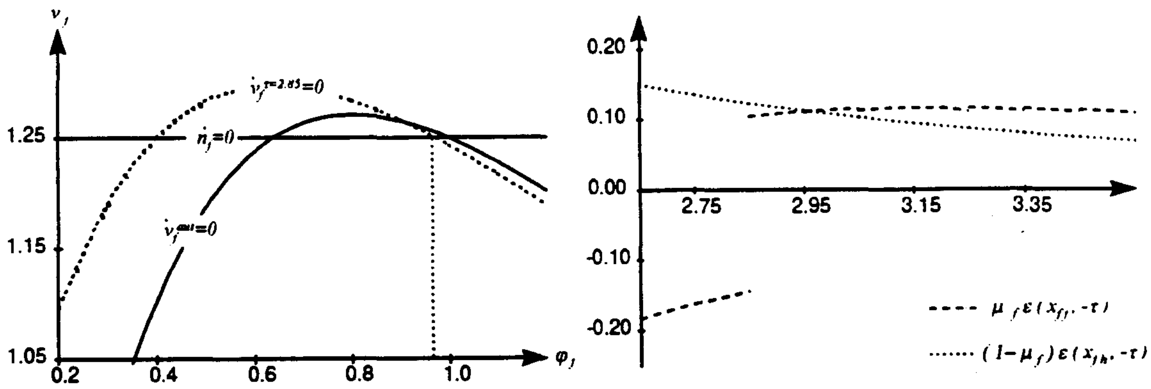

Figure 3: *Trade with a larger country. (Left hand panel: τ=2.85.)*

We shall assume that $L_h > L_f$ also for the rest of this paper. In Figure 3 we chose parameter values such that both countries produce both modern and traditional goods. As should be clear from equation (29), firms in f are increasingly hurt by trade liberalization with a larger country as long as this production structure remains (unless the substitution effect should dominate). This is also a major insight from Krugman and Venables (1990) who have shown that, other things being equal, the competitiveness of firms in a small country is monotonically reduced as trade is liberalized. However, the low competitiveness is also reflected in reduced labour demand in f, and so we should expect the wage level there to be reduced. With our simple technology specification in the traditional sector this requires that f is able to produce world wide demand for the traditional good, in other words that η is 'large'. We shall assume that this is the case.[21] When trade costs are sufficiently reduced we thus reach a level of trade costs where $w_f < w_h$. This in turn generates a tilt in the free entry locus $\dot{n}_f = 0$ as shown in Figure 4.

The wage level in f is now endogenous (recall that we chose $w_h \equiv 1$) and therefore the $\dot{n}_f = 0$ curve is upward-sloping; the lower the number of firms in f, the lower the labour demand and therefore the lower the start-up costs $w_f \kappa$. The $\dot{\nu}_f = 0$ locus is likewise shifted up and back to the right because the handicap of a small

[21] This is not a very restrictive assumption. In a richer model we could have assumed that there are decreasing returns to scale in the traditional sector. In that case we would always have $w_f < w_h$, but such an extension would make the algebra much more complex.

home market is reduced when f can offer inexpensive labour.[22] Further trade liberalization implies that the export market becomes increasingly important for f (with $\lim_{\tau \to 1}\left(1-\mu_f\right) = \lim_{\tau \to 1}\mu_h = \frac{L_h}{L_h+L_f} > \frac{1}{2}$, so that $\mu_f < \frac{1}{2}$). The subsequent curve shifts will be somewhat different: the curve $\dot{v}_f = 0$ still shifts to the right because the market access to the large h market improves, but exactly because international location matters increasingly less we shall also see a process where trade liberalization tends to equalize international wages. Therefore the curve $\dot{n}_f = 0$ will be tilted upwards again (and once more be horizontal at $v_f = 1.25$ when $\tau = 1.0$). In fact, both the substitution effect (provided $\theta > 1$) and the net competitive effect are positive for country f for 'low' levels of trade costs. To see the latter, recall that equation (25) told us that $\varepsilon(\pi_f, -\tau)_{comp} = (\sigma-1)\left[-\mu_f s_{hf} + \left(1-\mu_f\right) s_{hh}\right] \gtreqless 0$ if $\frac{s_{hh}}{s_{hf}} \gtreqless \frac{\mu_f}{1-\mu_f}$. Since the firms have approximately the same market share domestically and abroad when τ is close to 1.0, it follows that we then have $\frac{s_{hh}}{s_{hf}} \approx 1$. Therefore $\frac{s_{hh}}{s_{hf}} > \frac{\mu_f}{1-\mu_f}$ and $\varepsilon(\pi_f, -\tau)_{comp} > 0$ if $\mu_f < \frac{1}{2}$, which we know is true for sufficiently low levels of trade costs.

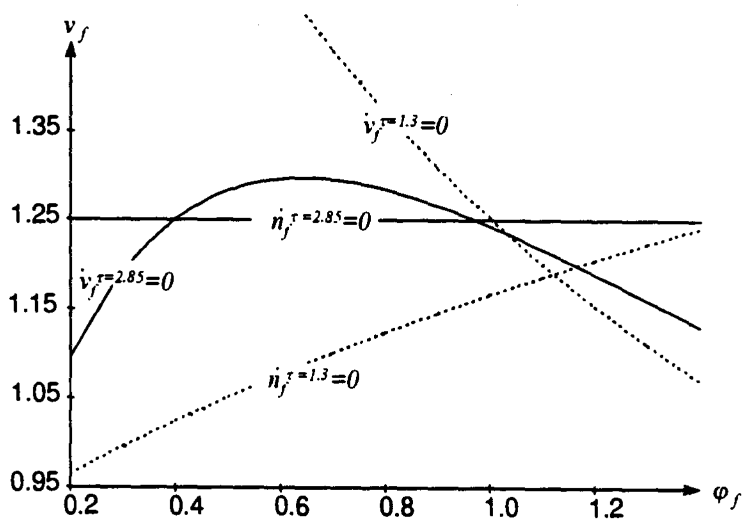

Figure 4: *Factor price effects.*

We have chosen parameter values such that $\varphi_f = 0.4$ under autarky, in which case trade must be liberalized down to $\tau = 2.85$ before the country leaves the

[22] The curve $\dot{v}_f = 0$ is here always downward sloping because the countries are too closely integrated for any underdevelopment trap to exist.

underdevelopment trap. This is illustrated by the sudden jump in α_f in the left hand panel of Figure 5.

Since inventions cannot be 'uninvented', and all research and development costs are sunk costs, we must always have $\frac{dn_j}{-d\tau} \geq 0$.[23] Therefore the relationship between trade liberalization and the entry process of new firms, which is illustrated in the right hand panel of Figure 5, is quite complex. Trade liberalization increases the firm values in both h and f in region A. Thus n_h is steadily increasing, but - as we have seen - n_f stays unchanged until $\tau = 2.85$. At this critical level of trade costs $v_f > w_f \kappa$ and there will be a positive jump in n_f. In region B, however, there will be no new entry in either country; f is disadvantaged by its small home market, while $v_h < w_h \kappa$ as an indirect consequence of the initial jump in n_f. Therefore the firm value is lower than the start-up costs in both countries for some range of trade costs. But the market size effect also implies that further trade liberalization increases the market value of firms in h such that we have $\frac{dn_h}{-d\tau} > 0$ and $\frac{dn_f}{-d\tau} = 0$ in region C. Finally, n_f is rising more than n_h in region D because of country f's factor cost advantage for low levels of trade costs.

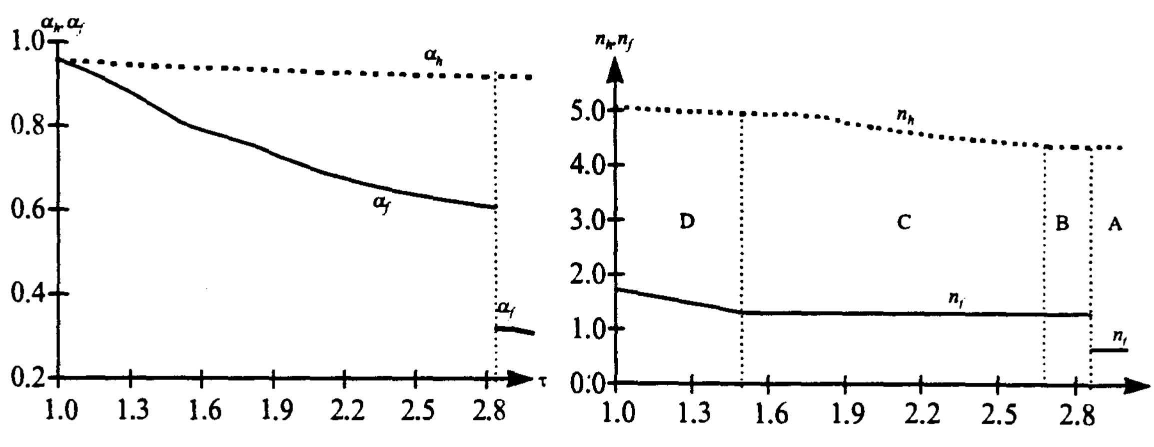

Figure 5: *The share of intermediates and the number of firms.*

[23]This means that a country j may experience a relative de-industrialization as a consequence of trade liberalization ($dn_j = 0$, $dn_i > 0$), but not an absolute de-industrialization ($dn_j < 0$) as is typically the case in economic geography models. Whether one or the other is a better description, is partly an empirical question.

There is an unambiguous and positive jump in the steady state welfare level $\left(\frac{E_j}{L_j q_j}\right)$ in f as we reach the critical level of trade costs where the country changes production technology. In our case trade liberalization does indeed monotonically increase the welfare level in both countries, but this is a result that is somewhat sensitive to our choice of parameter values. In particular, we cannot disregard the possibility that trade liberalization reduces welfare in f if the share value v_f and/or the wage level w_f fall due to market size effects.

4 Some concluding remarks

Hardly any country has been able to achieve satisfactory development over longer time periods following an import substitution policy. On the other hand, several outward oriented countries have fared remarkably well. Yet the belief in export oriented growth has diminished over the years, partly because empirical studies indicate too small increases in actual export profitability. In a model with trade in intermediate goods we have shown one channel through which trade liberalization may induce a shift to a more sophisticated production technology and to increases in the savings and investment rates for an underdeveloped country. Depending on the relative country sizes and the level of trade costs, further trade liberalization may continue to increase saving and exports if it leads to higher shares of intermediates in manufactured goods.

Appendix

A0 Parameter values

In all the simulations $w_h = 1$, $L_f = 1$, $\rho = 0.1$, $\sigma = 4$, $\kappa = 1.25$, and $\eta = 0.9$. Moreover, $L_h = 1$ in Figure 2 while $L_h = 2$ in Figures 3, 4, and 5.

A1 Deduction of equation (4) and the transversatility condition.[24]

Multiplying each term of equation (3) with $e^{\int_s^T r(v)dv}$ and integrating from time t to T we get

$$\frac{1}{L_j}\int_t^T E_j(s)e^{\int_s^T r(v)dv}ds = \int_t^T w_j(s)e^{\int_s^T r(v)dv}ds - \Omega_j(T) + \Omega_j(t)e^{\int_s^T r(v)dv}$$

since $\int_t^T r_j(s)\Omega_j(s)e^{\int_s^T r(v)dv}ds =_s^T |(- e^{\int_s^T r(v)dv})(\Omega_j(s)) + \int_t^T \dot{\Omega}_j(s)e^{\int_s^T r(v)dv}ds$.

Discounting back from time T to time t we have

$$\frac{1}{L_j}\int_t^T E_j(s)e^{-\int_t^s r(v)dv}ds = \int_t^T w_j(s)e^{-\int_s^t r(v)dv}ds + \Omega(t) - \Omega(T)e^{-\int_t^T r(v)dv}. \quad (32)$$

Taking the limit at $T \to \infty$ and using that $\lim_{T\to\infty}\Omega_j(T)e^{-\int_t^T r_j(v)dv} \geq 0$ from the No-Ponzi condition, we find equation (4) except that it only holds with an inequality so far (l.h.s. $\leq$ r.h.s). To verify that it must hold with equality, we note that the Hamiltonian for our problem may be stated as $H = \ln\left[\frac{E_j(s)}{L_j q_j(s)}\right] + \zeta_j(s)\left[w_j(s) + r_j(s)\Omega_j(s) - \frac{E_j(s)}{L_j}\right]$ where $\zeta_j(s)$ is the costate variable. Solving this we find $\zeta_j(s) = k_1 R_j(s)$ (where the constant $k_1 > 0$ since the marginal utility of consumption is always positive). The transversatility condition thus says that $\lim_{s\to\infty} k_1 R_j(s)\left[\Omega_j(s) - \Omega_{\min}(s)\right] = 0$. This can be simplified to

$$\lim_{s\to\infty}\Omega_j(s)R_j(s) = 0 \quad (33)$$

since $\Omega_{\min}(s) = 0$ from the No-Ponzi-game condition.

Using (32) and (33) we find equation (4).

[24] This proof builds partly on Blanchard & Fisher (1989) and Chiang (1992).

A2 The slope of the $\dot{v}_j = 0$ locus for an autarky

From equation (20) we have $\frac{dv_j}{v_j} = \frac{d\alpha_j}{\alpha_j} + \frac{dE_j}{E_j} - \frac{dn_j}{n_j}$, where $dE_j = \rho d(n_j v_j)$. Using (10) and (12) we therefore have

$$\frac{dv_j}{dn_j}\left[1 - \frac{\rho v_j n_j}{E_j}\right] = \left[\frac{1-\theta}{1-\sigma}(1-\alpha_j) + \frac{\rho v_j n_j}{E_j} - 1\right]\frac{v_j}{n_j}. \tag{34}$$

Inserting $\rho v_j n_j = \frac{\alpha_j \eta E_j}{\sigma}$ from equation (20) into (34) and using the definition of α_j we find

$$\frac{dv_j}{dn_j} = \left(\frac{\sigma}{\sigma - \alpha_j \eta}\right)(1-\alpha_j)\left[\frac{\eta-\sigma}{\sigma} n_j^{\frac{\theta-1}{\sigma-1}} + \frac{\theta-\sigma}{\sigma-1}\right]\frac{v_j}{n_j}. \tag{35}$$

Since $0 < \eta < 1$, $0 < \alpha_j < 1$, and $\sigma > 1$ we thus see that $\frac{dv_j}{dn_j} \gtreqless 0$ when $n_j \lesseqgtr \left[\left(\frac{\theta-\sigma}{\sigma-1}\right)\left(\frac{\sigma}{\sigma-\eta}\right)\right]^{\frac{\sigma-1}{\theta-1}}$ as claimed in the main text. Equation (35) also shows that $\frac{dv_j}{dn_j}$ is always negative if $\theta \leq \sigma$.

A3 Market and profit shares domestically and abroad

From equations (14), (15), and (16) we find that the equilibrium quantity of each variety equals $\rho\sigma\kappa$ when $v_j = w_j\kappa$. Since gross demand is τ times greater than net demand, and the elasticity of substitution is equal to σ, it follows that $x_{ij} = (x_{jj}\tau)\tau^{-\sigma}$ when $w_h = w_f$. We therefore have $x_{hh} + \tau^{-\sigma}(x_{ff}\tau) = \rho\sigma\kappa$ and $x_{ff} + \tau^{-\sigma}(x_{hh}\tau) = \rho\sigma\kappa$ which implies that $x_{jj} = \frac{1-\tau^{1-\sigma}}{1-\tau^{2(1-\sigma)}}\rho\sigma\kappa$ and $x_{ji} = \tau^{1-\sigma}x_{jj}$. Due to markup pricing and Samuelson iceberg trade costs we have $\mu_j = \frac{x_{jj}}{x_{jj}+x_{ji}}$, and thus

$$\mu = \frac{1}{1+\tau^{1-\sigma}} \tag{36}$$

in both countries when we have wage equalization and both countries produce intermediate goods.

A4 Relative country size and the sign on the net competitive effect

Assume that both h and f have diversified production structures, and consider the net competitive effect of trade liberalization from the point of view of firms in country j for different magnitudes of the ratio $N \equiv \frac{n_j}{n_i}$. On the one hand, a higher N implies that the negative domestic effect of trade liberalization is lower (because s_{ij} is reduced), and this tends to make it more profitable to integrate with a small than with a large country. On the other hand, the size of the increased export income resulting from trade liberalization is reduced when N increases because s_{ii} is then smaller (firms in j already have a high market share). These two opposing effects are shown by equations (22) and (23), respectively. To see that the first effect dominates, let $\Delta(N)$ denote $\varepsilon(\pi_j, -\tau)$ as a function of N when we disregard the substitution effect. From equation (24) it then follows that

$$\Delta(N) = (\sigma - 1)\left[-\mu\frac{\tau^{1-\sigma}}{N + \tau^{1-\sigma}} + (1-\mu)\frac{1}{N\tau^{1-\sigma} + 1}\right] \tag{37}$$

Differentiation of (37) w.r.t. N gives us

$$\frac{d\Delta(N)}{dN} = (\sigma - 1)\left[\mu\frac{\tau^{1-\sigma}}{(N + \tau^{1-\sigma})^2} - (1-\mu)\frac{\tau^{1-\sigma}}{(N\tau^{1-\sigma} + 1)^2}\right] \tag{38}$$

From (37) and (38) we have $\Delta(1.0) = 0.0$ and $\frac{d\Delta(N)}{dN}\big|_{N=1.0} = \frac{\tau^{1-\sigma}(\sigma-1)}{(1+\tau^{1-\sigma})^2}(2\mu - 1) > 0$. It thus follows that the net competitive effect of liberalization is positive if the trading partner is marginally smaller. But we can say more; $\Delta(N)$ is a continues function and reaches a maximum for $N^* = \frac{\tau^{1-\sigma} - \tau^{-\frac{1-\sigma}{2}}}{\tau^{\frac{1-\sigma}{2}} - 1} > 1.0$ with $(N^*, \Delta(N^*))$ as the only interior extreme point. Since we further have $\lim_{N\to\infty}\varepsilon(\pi_h, -\tau) = 0$ and $\lim_{N\to 0}\varepsilon(\pi_h, -\tau) = -(\sigma - 1)(2\mu - 1) < 0$ it follows that $\Delta(N) > 0$ if $N > 1$ while it is negative if $N < 1$. We therefore have a relationship as shown in Figure 6.

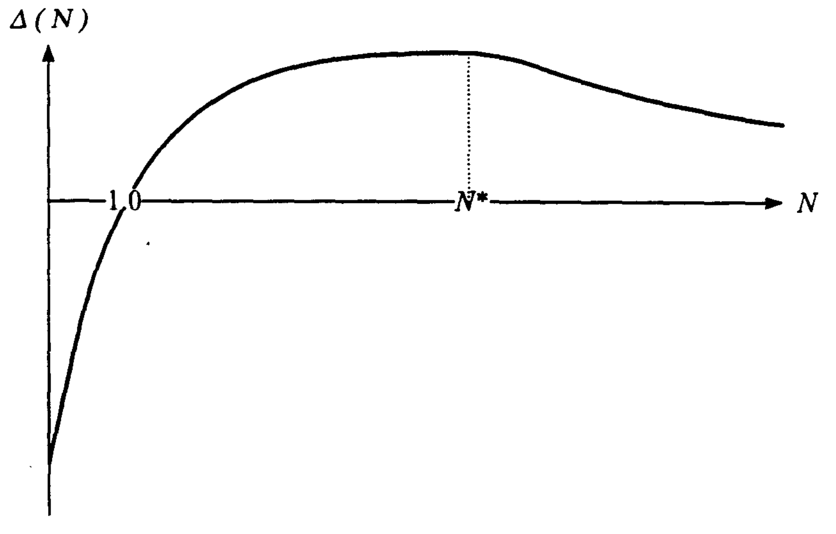

Figure 6: *Relative country size and the pure competitive effect.*

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Chapter 3*

Endogenous Growth and Trade Liberalization between Small and Large Countries

Abstract

In this paper we combine insight from the new trade theory and R&D-based endogenous growth models to argue that there are ambiguous growth effects of trade liberalization between countries that differ in size: trade liberalization possibly reduces R&D incentives in small countries, but resource constraints may prevent a parallel increase in R&D efforts in large countries. The explanation for this outcome is found in Krugman's home market effect, which says that small countries tend to have a disadvantage in industries with scale economies. We also demonstrate that the global growth rate may be maximized for some intermediate levels of trade costs if there are imperfect international knowledge spillovers.

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1 Introduction

In this paper we set up a simple model with rational, forward looking entrepreneurs who perform R&D whenever it is profitable, and where knowledge spillovers produce growth as in Romer (1990b) and Grossman and Helpman (1990). R&D requires fixed investments, and the output - knowledge and designs for new kinds of goods - has a very special character since it later becomes a nonrival input. A main point of Romer (1990a) is that this nonrivalry unavoidably generates globally decreasing average cost curves for each R&D firm that has made a successful innovation. What we want to stress in this paper is that scale economies in the research sector coupled with Krugman's (1980) home market effect indicate ambiguous growth effects of trade liberalization between countries which differ in size.[1] The model we present is made as simple as possible in order to illustrate this point, and no attempt is made at being 'realistic'.

As will be recalled, Krugman's home market effect says that large countries (i.e., countries with relatively high local purchasing power) tend to have an overproportional share of monopolistic industries with scale economies if there are positive trade costs. Moreover, the factor rewards may also be highest in large countries. To see the intuition for this result, suppose, on the contrary, that factor prices are equal and that the number of monopolistic firms in each country is proportional to local purchasing power. Then firms in large countries will have a relative cost advantage since, other things being equal, a relatively small share of their output is exported. In a general equilibrium without any entry barriers this advantage may be offset through higher product market competition (overproportional entry of firms) and higher factor costs. Krugman and Venables (1990) have demonstrated, however, that the strength of the home market effect is not likely to be a monotonous function of the level of trade costs. The reason is that self-sufficiency is decisive for the international production pattern when trade costs are very high (and export income nearly negligible), while the relative size of local markets is more or less irrelevant

[1] Throughout the paper we will use the terms *reductions of trade costs* and *trade liberalization* interchangeably.

when trade costs are very low. We may consequently anticipate the home market effect to be strongest at some intermediate levels of trade costs (see also Ottaviano and Puga 1997).

Using the same logic as above in an endogenous growth framework, it is useful to imagine that we have a world consisting of two countries which are intrinsically symmetric in all respects except for their size. Assume further that we have perfect international knowledge spillovers, and that trade costs on innovated goods initially are relatively high. Trade liberalization is then likely to strenghten the home market effect, and resources in the small country may therefore be shifted away from research activities and into sectors without scale economies. This need not affect the global growth rate if there is a parallel increase in R&D in the large country. However, resource constraints may prevent the reduced research incentives in the small country from being counterbalanced by correspondingly higher incentives in the large country. In that case trade liberalization has had a net growth reducing sector allocation effect, and the relative factor rewards in the large country have increased due to higher domestic factor demand. This process then continues until the strength of the home market effect has reached its maximum, but thereafter further trade liberalization increases the global growth rate because the small country reallocates labour to the R&D sector. The home market effect thus suggests a U-shaped relationship between trade liberalization and growth.

Several empirical studies have demonstrated that international knowledge flows indeed are important, particularly for the research efficiency in smaller countries (e.g., Coe and Helpman 1995, and Bayoumi, Coe, and Helpman 1996). However, as shown by Branstetter (1996) and Eaton and Kortum (1996), intranational knowledge spillovers generally seem to be stronger than international spillovers. In a theoretical framework Grossman and Helpman (1991a, 1991b ch. 8) discuss several channels through which more openness and more international trade presumably increase knowledge spillovers between countries, for instance through improved person-to-person contacts and more frequent communication between seller and buyer. Other studies, like Baldwin, Braconnier, and Forslid (1998) and Keller (1998), emphasize the role of foreign direct investments.

Even though we shall open up for the possibility that trade liberalization increases international knowledge spillovers, our focus is more on the consequences of imperfect spillovers than on how knowledge is transmitted. Again it turns out that the home market effect generates uncertain growth consequences of trade liberalization. With imperfect spillovers the growth rate tends to be higher the more concentrated the research sector, and therefore the growth rate may increase if trade liberalization strengthens the home market effect. As discussed above, this is most likely to happen if trade costs are not too low. But if trade is inexpensive, then liberalization may imply that a relatively larger share of the research takes place in the small country (due to its lower factor costs). In that case the global growth rate is likely to be reduced. Indeed, we show that the growth rate may be highest for some intermediate levels of trade costs when we have imperfect knowledge spillovers.

Arguably the recent interest for the relationship between growth and trade started with the seminal works of Romer (1986) and Lucas (1988), and in an influential paper Rivera-Batiz and Romer (1991a) seek to explain why two symmetric countries possibly grow faster if they are integrated than if they operate as autarkies. They show that the nature of scale effects in the R&D sector is decisive in this respect; integration may have a beneficial growth effect either through knowledge spillovers, trade in goods, or both. The main lesson from Rivera-Batiz and Romer's paper is perhaps somewhat disappointing; until we know more about the engine of growth, we do not really know if, and how, long-term growth and integration are connected (we shall briefly come back to this point in the final section of this paper). Their companion article (Rivera-Batiz and Romer 1991b) is closer to the spirit of the present paper. The focus is still on symmetric countries, but they now allow gradual reductions of tariffs.[2] One of their most interesting results is that trade restrictions may affect the allocation of human capital between research and

[2]It should be noted that Rivera-Batiz and Romer consider income generating tariffs, while we focus on trade barriers that are intrinsically wasteful. The reason for our choice is the fact that tariffs have become relatively unimportant for industrialized countries, and are therefore no longer the primary target of, e.g., the European integration process. We shall clarify the kind of trade costs we have in mind later.

manufacturing (and thus the growth rate) even when we consider identical countries. This result does not appear in our model because we use a simpler production structure - an extension along the lines of Rivera-Batiz and Romer would blur the forces we try to highlight.

A significant share of the research concerning growth effects of trade liberalization has been conducted by Grossman and Helpman, and several of the tools used in this paper have been borrowed from their works. In many respects this paper may be seen as a complement to Grossman and Helpman (1990); our subject is the interaction between the new trade theory and growth, while Grossman and Helpman study the interaction between comparative advantages and growth.

The rest of this paper is organized as follows. The formal model is presented in section 2. In section 3 we derive the growth equations and show formally why trade liberalization may reduce the profitability of performing R&D in small countries. Section 4 offers a discussion of the model and some concluding remarks. A few mathematical derivations are relegated to the appendix, which also shows the parameter values used in the simulations.

2 The model

We are looking at a world consisting of two countries, h and f. In addition to an innovation sector, there are two production sectors; one 'traditional' and one 'modern'. At times the denotation 'research sector' will be used for the modern sector and the innovation sector together. The only basic input is labour, which is homogenous, skilled and intersectorally - but not internationally - mobile. We abstract from population growth, and assume that the consumers in the two countries are identical.

2.1 The demand side

Denote the consumer goods from the modern and the traditional sector by m and z, respectively, and let the corresponding consumer prices be $p_{mj}(s)$ and $p_{zj}(s)$ at time s in country j ($j = h, f$). A representative household supplies one unit of labour inelastically, and at any moment chooses consumption so as to maximize the homothetic and time separable utility function

$$U_j(t) = \int_t^\infty \ln\left[m_j(s)^\eta z_j(s)^{1-\eta}\right] e^{-\rho(s-t)} ds,$$

where $\rho > 0$ is the subjective discount rate (and $0 < \eta < 1$), subject to an intertemporal budget constraint

$$\int_t^\infty \left[p_{mj}(s)m_j(s) + p_{zj}(s)z_j(s)\right] D_j(s)ds \leq \int_t^\infty w_j(s)D_j(s)ds + \Omega_j(t)/L_j.$$

$D_j(s) = e^{-\int_t^s [r_j(v)-r_j(t)]dv}$ is the discount factor, $r(s)$ the market determined interest rate, $\Omega_j(t)$ the share value of domestic firms in the modern sector, and L_j the population - which equals the labour force - in country j. Let $E_j(s) = \left[p_{mj}(s)m_j(s) + p_{zj}(s)z_j(s)\right] L_j$ denote aggregate expenditure on consumer goods in country j at time s. It can then be shown (see chapter 2 of this thesis) that utility maximization yields the Euler equation

$$\dot{E}_j(s)/E_j(s) = r_j(s) - \rho.$$

Let $\bar{E}$ denote aggregate spending in the two countries;

$$\bar{E} \equiv E_h + E_f. \tag{1}$$

The choice of nominal values does not affect the real side of the economy, and it turns out to be convenient to choose numeraire such that $\bar{E}$ is constant (independent of time and state). We shall confine ourselves to steady state analysis. The chosen normalization then implies $\dot{E}_j = 0$, whereby the nominal interest rate equals the subjective discount rate, $r(s) \equiv \rho$.[3]

Time subscripts are hereafter omitted when no confusion can arise.

[3]The method of holding $\bar{E}$ constant is used in a number of papers by Grossman and Helpman in order to simplify out-of-steady-state analysis. The reason why we use this method is quite different; as will become clear later, this normalization makes it easier to use insight from the new trade theory to interpret the growth equations. It should also be noted that we do not require E_j to be independent of trade policy. In fact, as we shall see, E_j must in general change after a trade liberalization if $\bar{E}$ is to stay constant.

2.2 The supply side

2.2.1 Specification of the production technologies

There are two major production sectors in the economy. The traditional sector produces a homogenous good, and the production function is given by $z_j = f^z(L_{zj}) = L_{zj}$, where L_{zj} is employment. The good is costlessly exchanged between the countries, so in a trade equilibrium we must have $p_z \equiv p_{zj} = \min\{w_h, w_f\}$. From the Cobb-Douglas utility function it thus follows that

$$L_{zh} + L_{zf} = \frac{(1-\eta)\bar{E}}{p_z}. \tag{2}$$

Entrepreneurs in the modern sector invent and produce differentiated intermediate goods which are costlessly assembled in a CES-manner into the composite consumer good m_j. Intermediate goods are tradeable, and to simplify the algebra we shall assume that all intermediate goods are symmetric with an elasticity of substitution between any pair equal to $\sigma > 1$. Suppose $n = n_h + n_f$ different goods have been invented by time s. The production function for the modern good can then be written as

$$m_j = f^m(y) = \left[\sum_{i=1}^{n} y_i^{\sigma/(\sigma-1)}\right]^{(\sigma-1)/\sigma}, \tag{3}$$

where y_i is the quantity of intermediate i. We interpret the production function for m_j as in Ethier (1982): an increase in n means that the inputs become more specialized, and the formulation implies that the total factor productivity is increasing in the number of varieties.[4] (This last point is most easily seen if we assume that each variety is used in the same quantity, in which case we have $m_j = n^{(\sigma-1)/\sigma} y_i$ and thus $dm_j/m_j = [(\sigma-1)/\sigma](dn/n) > 0$). There is free entry in production of m_j, and perfect competition prevails since the production function is linearly homogenous for any given n.

β units of labour are required in order to produce one unit of an intermediate good, and all varieties from a given country will have the same price since they

[4]The restriction $\sigma > 1$ is necessary, because otherwise all goods would be essential in production (and the production function not well defined if some goods were not invented).

are symmetric and produced with the same technology. With Chamberlinian large-group monopolistic competition between firms in the intermediate goods sector, it follows that the producer price of a representative intermediate good from country j is $p_j = w_j\beta\sigma/(\sigma-1)$. By choice of scale, let $\beta = (\sigma-1)/\sigma$ such that the *f.o.b.* price equals

$$p_j = w_j. \tag{4}$$

Though international trade in intermediate goods is possible, we shall assume that it involves some costs that are intrinsically wasteful. As in the economic geography literature these costs are interpreted as everything which, other things being equal, makes it more expensive to buy foreign than domestic goods. This includes factors such as pure communication and transportation costs, but not tariffs. The reason why we do not consider tariff barriers is the fact that these no longer seem to be very important between industrialized countries.

Trade costs are technically assumed to be of the Samuelson iceberg type: of each unit shipped, only $(1/\tau)$ arrives at its destination $(\tau \geq 1)$. The rest 'melts away', and such iceberg costs are convenient because they imply that we do not need to specify any transport sector even in general equilibrium models (see, e.g., Samuelson 1952, Krugman 1980). Since intermediate goods producers use mark-up pricing, the *c.i.f.* price of imported goods is τ times higher than the *f.o.b.* export price. Because there is perfect competition in the modern sector, and the intermediates are costlessly assembled, the consumer price p_{mj} for the modern good is equal to the dual of m_j:

$$p_{mj} = \left[n_j p_j^{1-\sigma} + n_i \left(p_i\tau\right)^{1-\sigma}\right]^{\frac{1}{1-\sigma}}. \tag{5}$$

It is well known that with the CES price index in equation (5) the aggregate market shares domestically and abroad are equal to $s_{jj} = n_j \left(p_j/p_{mj}\right)^{1-\sigma}$ and $s_{ji} = n_j \left(p_j\tau/p_{mi}\right)^{1-\sigma}$, respectively. Since there are n_j firms in country j, and consumers use a share η of their income E_j on the modern good, it follows that gross sales volumes of each variety equal

$$x_{jj} = \frac{s_{jj}\eta E_j}{p_j n_j}, \text{ and } x_{ji} = \frac{s_{ji}\eta E_i}{p_j n_j}. \tag{6}$$

Demand for a domestically produced input factor is consequently $y_{jj} = x_{jj}$, while net demand for an exported factor is $y_{ji} = x_{ji}/\tau$.

2.2.2 Specification of the innovation technology

We shall to a large extent follow Grossman and Helpman (1990) when we specify the innovation technology, and presuppose that labour and general knowledge are the only inputs in innovation process. More specifically, it takes $\kappa_j(s)$ units of labour to make one innovation. The variable $\kappa_j(s)$ may be considered as an inverse measure of country j's knowledge stock, and output of designs for new varieties is then given by $\dot{n}_j = L_{nj}/\kappa_j(s)$. As in Romer (1990a,b) and Grossman and Helpman we treat knowledge as nonrival and only partly excludable:[5] when a research firm has made an innovation, it obtains a patent that applies in both countries. Thus the firm will have some market power, possibly making it profitable to invest in research. But the knowledge that has been created through making the new design spills out to the rest of the society, and each new domestic innovation increases the country's public knowledge capital stock, k_j, by one unit. We abstract from depreciation of knowledge and write $n_j = k_j$ for the accumulated knowledge stock that has been developed by domestic firms. Consequently, n_j is a measure both of the knowledge capital stock and of the total number of innovations (varieties) if we consider an autarky. On this background Grossman and Helpman assume that for an autarky $\kappa_j(s) = \bar{\kappa}/n_j$, where $\bar{\kappa}$ is some constant. They further study consequences of completely free trade between two countries, in which case they let $\kappa_j(s) = \bar{\kappa}/(n_j + n_i)$.[6] A similar approach is taken by Rivera-Batiz and Romer (1991a,b). But is it reasonable simply to assume that $\kappa_j(s) = \bar{\kappa}/(n_j + n_i)$ in a world with, e.g., cultural and linguistic barriers (which in our framework means that $\tau > 1$)?

[5]This characterization of knowledge is well known from the endogenous growth literature, and will not be the subject of a detailed treatment here. See Romer (1990a,b) for a careful discussion.

[6]In an extension of the basic model Grossman and Helpman introduce time lags in international knowledge spillover, and an empirical justification for this is found in Jaffe, Trajtenberg, and Henderson (1993). A combination of Grossman and Helpman's approach and the one that we use below would probably be preferable.

The presumption that knowledge does not flow equally well between as within countries has played a central role in many fields of theoretical economics, see for instance Vernon's (1966) seminal paper about product cycles and his explanation for why firms may choose to locate in countries with high factor costs. On the empirical side Coe and Helpman (1995) have found that for small countries the knowledge stock of their trading partners may be more important than the country's own when it comes to productivity improvements over time. This clearly suggests that international spillovers are important, but Branstetter (1996) and others have nonetheless found clear evidence that intranational knowledge spillovers are stronger than international spillovers.

Nadiri (1993) includes a literature study of the magnitude of spillover effects and transmission vehicles, but it is beyond the scope of the present paper to investigate the exact workings of international knowledge spillovers. Instead we aim at getting some insight into the relationship between trade liberalization and growth when the spillovers are imperfect. Since, e.g., political harmonization and improvements in international communication channels should tend to reduce the kind of trade costs we have in mind ($d\tau < 0$) as well as to increase international knowledge spillovers, we shall further assume that trade liberalization may have a positive effect on the flow of knowledge. Somewhat *ad hoc* it will therefore be assumed that the general knowledge stock in country j equals $n_j + S(\tau)n_i$, where $S(\tau) \in (0, 1]$ may be considered as a spillover function with $S'(\tau) \leq 0$.[7] Hence, assume that former research experience and knowledge accumulation increase the efficiency of the country's researchers in such a manner that we have

$$\kappa_j(s) = \frac{\bar{\kappa}}{n_j(s) + S(\tau)n_i(s)}. \tag{7}$$

2.2.3 Free entry and labour market equilibrium

We are now ready to specify when it is actually profitable to invest in R&D. Without loss of generality we can assume that each firm produces only one good, and the

[7] Note that we require S to be strictly greater than zero. The reason for this will become clear later.

value of this firm will then be equal to the present value v_j of the profit flow π_j from an intermediate good; $v_j(s) = \int_t^{\infty} \pi_j(s)D_j(s)ds$. Differentiating - and using $r = \rho$ - we find

$$\dot{v}_j(s) = \rho v_j(s) - \pi_j(s).^{8} \tag{8}$$

As in Grossman and Helpman (1990) we assume that patents are non-tradeable, so that innovation and production must take place in the same country. New entry of research firms takes place until the development cost of a new patent equals the discounted profit flow it generates. In a free entry equilibrium we must thus have

$$\begin{aligned} v_j &= w_j\kappa_j \text{ when } \dot{n}_j > 0, \text{and} \\ v_j &< w_j\kappa_j \text{ when } \dot{n}_j = 0. \end{aligned} \tag{9}$$

Let $g_j \equiv \dot{n}_j/n_j$ be the growth rate of innovations, and define $x_j \equiv x_{jj} + x_{ji}$. At each moment of time $\dot{n}_j\kappa_j = g_j n_j \kappa_j$ units of labour are used in the research sector and $\beta n_j x_j$ in production of intermediate goods. Labour market equilibrium thus requires

$$L_j = g_j n_j \kappa_j(s) + \beta n_j x_j + L_{zj}. \tag{10}$$

3 Balanced growth

To find long-term growth effects of trade liberalization, it is useful first to take a closer look at the labour market equations. We are searching for a steady state (or, more precisely, balanced growth) equilibrium where the sector division of labour is constant and where both countries perform research (g_h, g_f>0).[9] From equations (2) and (10) it is clear that the former requires $\dot{w}_j = 0$ since $p_z = \min\{w_h, w_f\}$. It must

[8]This can be viewed as a no-arbitrage condition (see Grossman and Helpman, 1991b): The return on a share, $(\pi + \dot{v})/v$, must equal the interest rate $r = \rho$ on a bank deposit.

[9]There are two other possible equilibria. In one of these both countries are completely specialized, f in production of the traditional good and h in intermediates. This equilibrium is not very interesting, because it occurs only if there are no international knowledge spillovers; $S \equiv 0$. In the other equilibrium f is specialized in production of the traditional good, while h has a diversified production structure. Both of these cases are briefly discussed in Appendix A5.

also be true that $g_h = g_f$ in steady state. Suppose, namely, that $g_h > g_f$. Equation (10) tells us that $g_j = \dot{n}_j/n_j = -\dot{x}_j/x_j$ - otherwise the sector division of labour cannot stay constant. Therefore $g_h > g_f$ would imply $-\dot{x}_h/x_h > -\dot{x}_f/x_f > 0$. i.e., a slower reduction of the sales quantity of each variety in f than in h. But from equation (3) we see that there is decreasing marginal productivity on each intermediate good, and a higher growth rate in h than in f would thus require $\dot{p}_f < 0$ if $\dot{p}_h = 0$. This cannot be true since $\dot{w}_j = 0$ in steady state. It likewise follows that $g_h < g_f$ cannot hold, and consequently $g_h = g_f = g$.[10]

Consumer expenditure in each period equals wage income plus profit flow minus new investments, $E_j = w_jL_j + \pi_jn_j - v_j\dot{n}_j = w_jL_j + \rho v_jn_j - v_jn_j(\dot{v}_j/v_j + \dot{n}_j/n_j)$, c.f. equation (8). The term in the bracket must be equal to zero since the free entry condition $v_j = w_j\kappa_j(s)$ implies $\dot{v}_j/v_j = \dot{\kappa}_j/\kappa_j$, and $\dot{\kappa}_j/\kappa_j = -g$ from equation (7). This shows that the value of each firm decreases at the same rate as the positive rate of new entries, such that aggregate firm value, v_jn_j, is constant. We therefore have

$$E_j = w_jL_j + \rho n_jv_j. \tag{11}$$

Instantaneous profit flow for an intermediate good producer equals $\pi_j = (p_j - \beta w_j)x_j = p_jx_j/\sigma$. Equations (8) and (9) thus imply that in a steady state growth equilibrium

$$x_j = (\rho + g)\sigma\kappa_j(s). \tag{12}$$

Inserting for the CES market shares (s_{jj} and s_{ji}) and demand (x_{jj} and x_{ji}) for both countries, and using that $g_h = g_f$, general equilibrium can now be found by simultaneously solving equations (1), (2), (4), (5), (7), (10), (11), and (12) for the unknowns E_j, w_j, p_j, L_{zj}, v_j, κ_j, n_h, and g for any positive number n_f.[11]

[10] Grossman and Helpman (1990), who also discuss dynamic behaviour outside steady state in a more complex framework, offer a formal proof of why $g_h = g_f$ along a balanced growth path. See also Grossman and Helpman (1991b, ch. 9) for a simpler treatment than in the former article.

[11] We are free to choose an arbitrary positive number for either n_h or n_f since we have $\dot{n}_h/n_h = \dot{n}_f/n_f$ in the steady state. Alternatively, we could have expressed all the equations in terms of the ratio n_h/n_f, which technically is the same as choosing $n_f = 1$.

3.1 Research incentives, trade, and the home market effect

In this general equilibrium model both countries are able to affect world market prices, but we shall assume that country f is small in the sense that $L_f < L_h$. This assumption naturally implies that $n_f < n_h$ along a balanced growth path. In the presence of imperfect knowledge spillovers ($S < 1$) we thus see from equation (7) that research productivity will be lower in f than in h; $\kappa_f(s) > \kappa_h(s)$. Suppose this inequality holds, and that trade is liberalized. Other things being equal (inclusive of factor costs), we should then expect innovation incentives in f to decline since the country has relatively unproductive researchers. More surprisingly, perhaps, the same may be true even if there are perfect international knowledge spillovers. This is proved in Appendix A2.

To see the intuition, we first note that - other things being equal - a smaller share of each variety developed and produced in h is traded than is the case for f. Research firms in the former country consequently have an advantage over those in the latter country even when $S = 1$ (given that $\tau > 1$). To offset this advantage when $w_h = w_f$ the product market competition for intermediate goods must be higher in the large than in the small country, otherwise the free entry condition is violated. Therefore n_h must be relatively higher than n_f; $n_h/L_h > n_f/L_f$ (which in turn implies that h is a net exporter of differentiated goods). This is nothing but the home market effect that was pointed out by Krugman (1980). Since lower international trade costs imply that firms in the small (large) country face increased competition from a large (small) number of foreign firms, trade liberalization means that the innovation incentives become relatively lower in f than in h. This negative consequence of trade liberalization from a small country's point of view has been labelled 'the market size effect' by Krugman and Venables (1990).

Both countries must be active in both sectors when trade costs are sufficiently high (because trade then plays only a minor role). In that case it also follows that $w \equiv w_h = w_f = p_z$ since there is costless trade in the traditional good z. Wages will remain equalized even for arbitrary low levels of trade costs if consumer demand for z is 'high', and when trade is sufficiently liberalized country f becomes specialized in production of z (while h still is active in both sectors). But what happens if we allow wages to differ, which in our context means that country f potentially must be able to satisfy world-wide demand for the traditional good? The answer to this question is given in the left-hand panel of Figure 1. Starting from high values on τ, trade liberalization reduces the incentives to perform research and produce intermediates in f. The lower labour demand in the small country thus implies that wages begin to diverge at $\tau = 1.75$ (in which case all production of z takes place in f). Trade liberalization continues to increase international wage differences, reflecting a stronger home market effect, until $\tau = \tau^*$. Further liberalization does, however, turn this picture upside-down. The reason for this qualitative change is simple: trade has now become so inexpensive that the low wage level in f makes it increasingly attractive for entrepreneurs in f to invest in research and produce new kinds of intermediate goods. Indeed, at $\tau = 1.0$ the relative market size is irrelevant so that we must have international wage equalization (provided $S = 1$). This so-called factor cost effect was first demonstrated by Krugman and Venables (1990).[12]

The right-hand panel of Figure 1 shows that country h imports the traditional good and is a net exporter of intermediate goods. This is a mirror of the home market effect.[13]

[12] It should be noted that consumption real wages (CRW), which may be defined as $\omega_j = w_j / \left(p_{mj}^{\eta} p_z^{1-\eta}\right)$, are higher in country h than in country f even when $w_h = w_f$ (provided τ>1.0). The reason is that consumers in h pay trade costs on a relatively low share of the intermediates. Therefore it is production costs, and not CRW, that are equalized when trade is expensive.

[13] Simulation parameter values for all figures are given in Appendix A1.

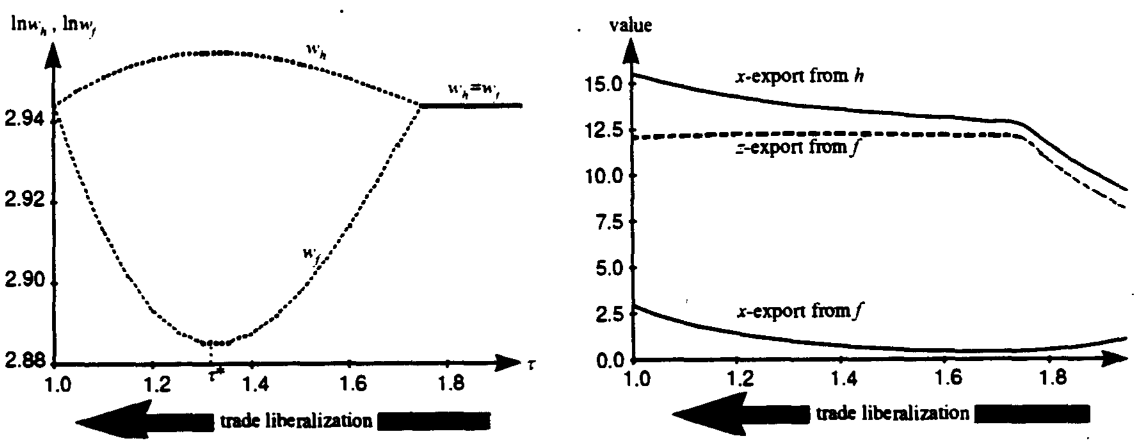

Figure 1: *Wages and trade patterns.*

3.2 Growth rates with a general spillover function

Denote by L_{nj} the number of researchers in each country, and let $N \equiv [n_h(s)/n_f(s)]$. From the condition for labour market equilibrium, equation (10), we have $L_{nh} + L_{nf} = [n_h(s)\kappa_h(s) + n_f(s)\kappa_f(s)]\, g = \bar{\kappa}\left[\frac{N}{N+S(\tau)} + \frac{1}{1+NS(\tau)}\right] g$ since $g_h = g_f$ if both countries innovate in steady state. In order to simplify the subsequent notation it proves useful to define an R-function given by

$$R(\tau) = R\left[N(\tau, S(\tau)), S(\tau)\right] = \left\{\frac{N}{N+S} + \frac{1}{1+SN}\right\}^{-1}. \tag{13}$$

Since $L_{nh} + L_{nf} = \bar{\kappa}g/R$ the variable R is inversely proportional to the number of researchers that is needed to maintain a given growth rate g of new inventions. An increase in R thus makes a higher growth rate admissible. Equation (13) is discussed in detail in section 3.3.2, and we shall see that it is ambiguous whether $R'(\tau)$ is positive or negative.

3.2.1 Production of the traditional good in both countries

When trade costs are so high that wages are equal in the two countries, aggregate expenditure in a growth equilibrium is given by $\bar{E} = w(L_h + L_f) + \rho\left[v_h n_h + v_f n_f\right] = w(L_h + L_f) + \rho w\left[\kappa_h n_h + \kappa_f n_f\right]$, where the latter equality is due to the free entry condition (9). Letting $L \equiv L_h + L_f$ and inserting for R we find

$$w = \frac{\overline{E}}{L + \rho\bar{\kappa}\left[R(\tau)\right]^{-1}}. \tag{14}$$

Summing the labour market equations (10) for h and f, and substituting x_j and w from (12) and (14), the growth rate of new inventions can after some algebra be expressed as

$$g = \frac{R(\tau)\eta L}{\sigma\bar{\kappa}} - \frac{\sigma - \eta}{\sigma}\rho. \tag{15}$$

The growth rate is thus, as would be expected, increasing in η (the share of the modern good in consumption) and $R(\tau)$ (the research efficiency), while it is decreasing in ρ (the subjective discount rate) and σ (because a higher elasticity of substitution implies that the intermediates are more homogenous).[14] A more detailed and thorough interpretation is offered in Appendix A3.

Since $R \equiv 1$ for an autarky with no international connections (and which, in particular, does not receive any knowledge spillovers from abroad), equation (15) implies that the autarky growth rate equals

$$g_j^{aut} = \frac{\eta L_j}{\sigma\bar{\kappa}} - \frac{\sigma - \eta}{\sigma}\rho. \tag{16}$$

3.2.2 Production of the traditional good only in the small country

If trade costs are so low that the whole production of z takes place in f (which requires $L_f > (1-\eta)\bar{E}/p_z$), we must modify the equation for the wage level in each country to $w_j = \frac{E_j}{L_j + \rho\kappa_j n_j}$. Using this in the labour market equations (10), it can be shown that

$$\tilde{g} = \frac{R(\tau)}{\sigma\bar{\kappa}}\left[L - \frac{(1-\eta)\overline{E}}{w_f}\right] - \frac{\sigma - 1}{\sigma}\rho. \tag{17}$$

The term in the square bracket is nothing but aggregate employment in the modern sector $(L - L_{zf})$. We thus see from equation (17) that trade liberalization may affect the growth rate in two ways: by changing research efficiency R and through changing the allocation of labour between the modern and the traditional sector.

[14] To make things interesting, it is always assumed in this paper that the countries are large enough to generate growth. Otherwise the growth rates would be the maximum of zero and those given by the g-equations.

3.3 Some special cases of knowledge spillovers

In order to give some numerical illustrations of the relationship between trade liberalization, knowledge spillovers, and growth, we shall assume that

$$S(\tau) = a + (b - a)\tau^{-q}, \tag{18}$$

where the constants obey $0 < a \leq b \leq 1$ and $q \geq 0$. It seems reasonable to assume $a > 0$ and thus $\min_\tau S(\tau) = a > 0$. This would reflect that we have some knowledge spillovers, through research journals and other channels, even between countries that do not trade with each other. If $q > 0$ and $a < b$, the S-formulation implies (for reasons discussed earlier) that trade liberalization increases the knowledge spillovers and with limit $S(1) = b \leq 1$. To highlight the forces that might influence the growth rate in the economy described above, we shall look at some special cases of equation (18).

3.3.1 Perfect international knowledge spillovers

We have $R = S \equiv 1$ when the international spillovers are perfect and independent of trade costs. If both countries produce the traditional good, it follows from (15) that the growth rate of new innovations equals

$$g = \frac{\eta L}{\sigma \bar{\kappa}} - \frac{\sigma - \eta}{\sigma}\rho$$

From this equation it is clear that the growth rate is independent of the level of trade costs, and equal to the one that would apply for an autarky with a labour force $(L_h + L_f)$. This is not the case, however, when only f produces the z-good. We then see from (17) that

$$\tilde{g} = \frac{1}{\sigma \bar{\kappa}}\left\{L - \frac{(1-\eta)\bar{E}}{w_f}\right\} - \frac{\sigma - 1}{\sigma}\rho.$$

Though numerical simulations are necessary in order to find quantitative values on $\tilde{g}$, we are immediately able to see the qualitative relationship between $\tilde{g}$ and τ: it must be U-shaped. This is because $\text{sign}(d\tilde{g}/d\tau) = \text{sign}(dw_f/d\tau)$ - and we already know that w_f is a U-shaped function of τ when f produces world-wide demand for the traditional goods. We therefore have a situation as illustrated in Figure 2.

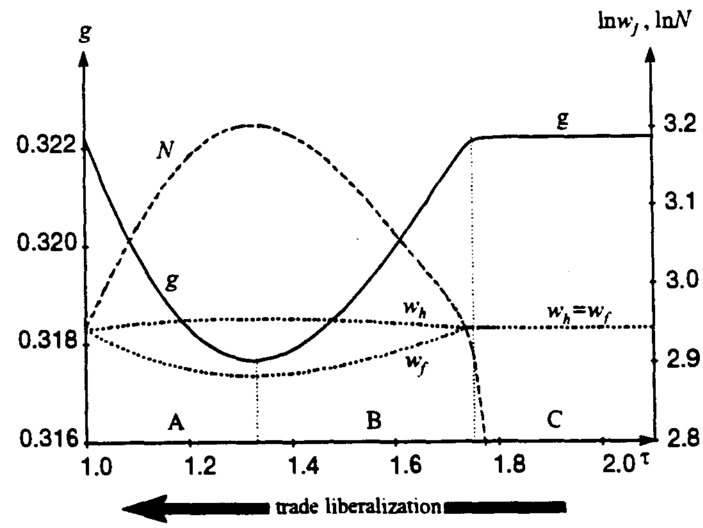

Figure 2: *Effects of trade liberalization when $S\equiv 1$.*

The intuition for the shape of the growth curve in Figure 2 is to be found in the home market effect. As shown by the N-curve trade liberalization increases the strength of the home market effect in regions C and B, and country f reallocates labour from the growth generating to the traditional sector. However, in region C the growth rate is nonetheless unaffected because the reduced R&D incentives in f are exactly matched by the higher incentives in country h. This is no longer the case in region B, since the labour force in h already is fully employed in the modern sector. Therefore the growth rate decreases. Finally, in region A trade liberalization has a beneficial growth effect because trade costs are so low that liberalization increases the R&D incentives in f.[15]

[15]Some of the effects become quite exaggerated in this model due to the simple model structure. For instance, country h does not produce the traditional good even if we have only infinitesimal trade costs. Therefore n_h will be much larger than n_f also in the neighbourhood of τ=1.0. When τ is exactly equal to 1.0, however, any production allocation of intermediates and z between the countries is an equilibrium. An interesting extension of the model would be to assume that R&D requires skilled labour, while both skilled and unskilled labour may be used in the traditional sector. In that case there will be *de facto* decreasing returns to scale in the traditional sector, and both countries will always produce some z-goods.

3.3.2 Imperfect international knowledge spillovers

From (15) and (17) we have seen that g is an increasing function of the research efficiency R. The behaviour of $R(\tau)$ therefore plays a key role for the effect of a trade liberalization in this model. The total derivative of $R(\tau)$ equals

$$R'(\tau) = \frac{\partial R}{\partial N} N_1 + \left[\frac{\partial R}{\partial N} N_2 + \frac{\partial R}{\partial S}\right] S'(\tau), \tag{19}$$

where N_i is the partial derivative of $N = N(\tau, S(\tau))$ with respect to argument i.

With imperfect international knowledge spillovers the research efficiency is higher the more concentrated the R&D sector. Since h is a larger country than f we therefore have $\partial R/\partial N > 0$, from which it follows that sign $[\partial R/\partial N]\, N_1$ = sign N_1 (see Appendix A4 for a proof). Trade liberalization thus tends to decrease the growth rate if it leads to a fall in the ratio $n_h/n_f = N$. Baldwin and Forslid (1996b) formulate a growth model that has certain similarities with the one in this paper, but where the countries are symmetric and S is a fixed parameter. In their case both $N'(\tau)$ and $S'(\tau)$ thus equal zero, so Baldwin and Forslid conclude that mutual trade liberalization in this respect only has level, and not growth, effects. But this obviously is a result that hinges crucially on an assumption of symmetric countries.

The total effect of the second term in equation (19) is always negative (see Appendix A4) if $S'(\tau) < 0$, and shows the positive growth effects through knowledge spillovers of trade liberalization.

Case (i), imperfect and constant (but positive) knowledge spillovers, $S'(\tau) = 0$

In Figure 3 we have assumed that we have imperfect and constant knowledge spillovers, with $S(\tau) = 0.8$ (then the second term of equation (19) is zero, and $R'(\tau) = (\partial R/\partial N)N_1$). International wages are equalized when $\tau > 1.9$, and the home market effect implies that trade liberalization increases N. This is, as just discussed, positive for the growth rate when we have imperfect knowledge spillovers.

Only country f produces the traditional good when $\tau<1.9$, and wages are no longer equalized ($w_f<w_h$). There are now two opposing effects of trade liberalization, and to see what is going on we shall distinguish between the cases $\tau>1.35$ and

τ<1.35. As long as $\tau \in (1.35, 1.9)$ trade liberalization still increases N, but this positive growth effect is dominated by a growth reducing effect: Figure 3 shows that liberalization reduces w_f, and from equation (17) we know that we then have a reallocation of labour from the R&D sector to the traditional sector. For $\tau \in (1.0, 1.3)$ the situation is the opposite; even though trade liberalization reduces N, the growth rate increases because more labour becomes employed in the R&D sector. Note, however, that country f employs more labour in the traditional sector when $\tau = 1.0$ than when $\tau = 1.9$ (this is reflected in Figure 3 by the fact that w_f is highest at the latter point). We consequently have the interesting result that the growth rate is maximized at the interior point $\tau = 1.9$.[16] (The reason why the wage level in f is lower than in h even when there is completely free trade ($\tau = 1.0$) is that the countries *de facto* have different research technologies when we have imperfect knowledge spillovers.)

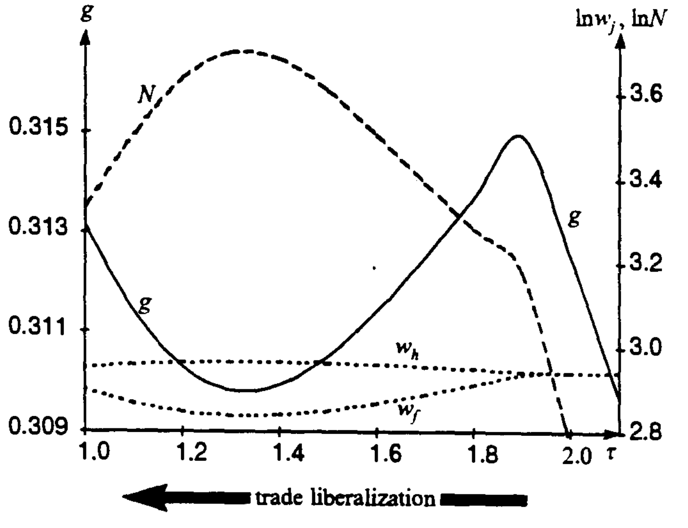

Figure 3: *Effects of trade liberalization when S=0.8.*

Case (ii), Inverse relationship between trade costs and knowledge spillovers

It could be argued that it is reasonable to assume both $S'(\tau) < 0$ and $S(1) = 1$. After all, if there are no trade costs (inclusive of differences in technical standards, culture, and language barriers), then knowledge should flow equally well between as

[16]The research efficiency (as measured by R) is nonetheless higher at $\tau = 1.0$ than at $\tau = 1.9$ since $N(1.0) > N(1.9)$.

within countries. Figure 4 therefore illustrates the case with $S(\tau) = 0.8 + 0.2\tau^{-0.1}$. Now it is no longer true that we have a global maximum when $\tau > 1.0$; the integrated world with perfect knowledge spillovers is growing fastest. This latter case confers well with the results of Rivera-Batiz and Romer (1991a), namely the potential beneficial effect of knowledge spillovers (named the 'integration effect' in their 1991b-paper).

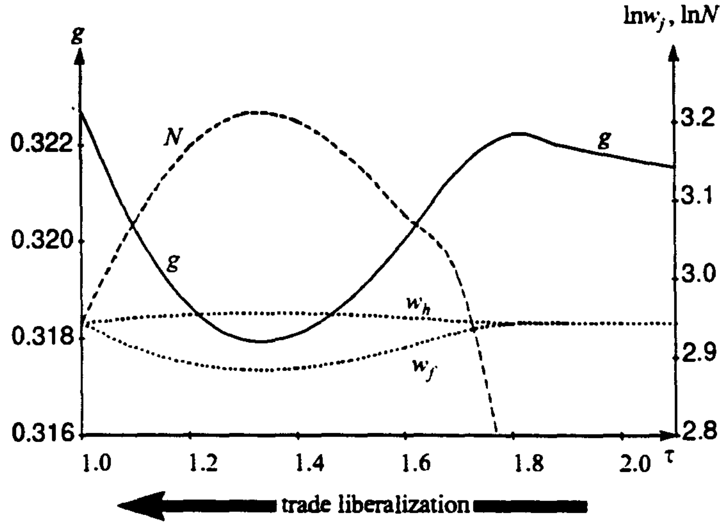

Figure 4: *Effects of trade liberalization when* $S=0.8+0.2\tau^{-0.1}$.

4 Discussion and conclusion

While a lot of research has been done to study growth implications of a change from autarky to completely free trade - in particular by Grossman and Helpman - the efforts to study consequences of partial trade liberalization are much smaller. Notable exceptions are Baldwin and Forslid (1996a,b) and Rivera-Batiz and Romer (1991b) who concentrate on liberalization between intrinsically symmetric countries. In this paper we have instead considered trade liberalization between a small and a large country, and opened up for trade in two sectors. It is shown that market size and factor cost effects may imply a non-monotonous relationship between trade costs and growth, and that liberalization measures that have only level effects between symmetric countries may have growth effects if the countries differ in size.

The ambiguous growth effects of trade liberalization that appear in this paper are to a large extent a logical consequence when we combine the endogenous growth approach first advocated by Grossman and Helpman (1990) and Romer (1990b) with Krugman's (1980) home market effect. It may therefore be worthwhile to take a closer look at some of the assumptions behind these models, and how they have been criticized in the literature.

In most R&D based endogenous growth models we have a so-called scale effect: other things being equal, the growth rate is predicted to be permanently higher if there is a permanent increase in the level of (effective) resources devoted to R&D.[17] Jones (1995a,b) claims that this scale effect obviously is rejected by empirical evidence, and he has instead proposed a semi-endogenous growth model where it becomes more difficult over time to make innovations because the most obvious ideas are discovered first. His formulation implies that the long-run growth rate is independent of the size of the R&D sector. In the context of the present paper this means that the steady state growth rate does not decline even if labour is reallocated from the R&D sector to the traditional sector, or if we have imperfect knowledge spillovers and a larger share of the research is conducted in the small country. Whether we really have a scale effect or not, and how the possible scale effect should be measured, is difficult to settle empirically in an open world economy. Careful discussions of some of the empirical problems are offered in Dinopoulos and Thompson (1998a,b) and in Aghion and Howitt (1998); see also Baldwin, Braconnier, and Forslid (1998) for a sharp criticism of the methodology and model interpretations that have been used by those who claim to have rejected endogenous growth theory.

It is beyond the scope of this paper to go into a discussion of whether the Romer-Grossman-Helpman framework is 'correct'. We find it more interesting to note that the scale effect is present also in Jones' model along the transitional path to the steady state, and the analysis in Jones (1995a) indicates that the transitional period may indeed be very long. The qualitative relationship between trade liberalization and growth that we have demonstrated in the present paper may therefore

[17] We must use the qualification 'effective' because, as we have seen, the research efficiency depends on the ratio n_h/n_f when there are imperfect knowledge spillovers.

still survive in the short and medium run. Whether this is the case would be an interesting topic for future research.

Finally, even though the home market effect, and the non-monotonic relationship between this effect and trade costs, may sound intuitively appealing, it has been questioned in the literature. In an empirical study of trade between OECD countries Davis and Weinstein (1996) were not able to find any strong indication of home market effects, and in a theoretical paper Davis (1997) showed that the effect may actually disappear if we introduce trade costs on the traditional good. However, a counterfactual predication of Davis' model is that there will be no inter-industry trade. In Krugman and Venables (1998) it is shown that the home market effect as well as inter-industry trade reappear if the countries produce imperfect substitutes in the traditional sector. This result holds even if the traditional goods are only slightly differentiated and the trade costs fairly high. At last, it should also be noted that in a re-examination of their earlier paper, Davis and Weinstein (1998) do indeed find evidence of market size effects also across OECD countries when they use a framework with a richer geographical structure.

To sum up, the home market effect - which is one of the driving forces in our paper - seems to be quite robust, theoretically as well as empirically. The recent research in growth theory that has been initiated by Jones and others is very interesting, and we may expect significant advances in endogenous growth theory in the future. Of course no one model is completely true, and our conjecture is that for many practical purposes the Romer-Grossman-Helpman framework may still be preferable, not at least due to the tractability of steady state analysis.

Appendix

A1 *Parameter values*

The following parameter values are used: $L_h = 4$, $L_f = 1$, $\bar{E} = 100$. $\sigma = 4$, $\rho = 0.1$, $\eta = 0.85$ and $\bar{\kappa} = 2.65$.

A2 *Proof that trade liberalization may reduce R&D incentives in f*

The instantaneous profit flow from an innovation is equal to $\pi_j = \frac{p_j x_{jj}}{\sigma} + \frac{(p_j\tau)/(x_{ji}/\tau)}{\sigma}$. Define $\mu_j \equiv \frac{p_j x_{jj}}{p_j x_{jj} + p_j x_{ji}}$ as the share of the profit flow that is earned on the home market, and let $\varepsilon(y, x)$ denote the partial elasticity of y with respect to x. We then have

$$\varepsilon(\pi_j, -\tau) = \mu_j \varepsilon(x_{jj}, -\tau) + \left(1 - \mu_j\right)\varepsilon(x_{ji}, -\tau). \tag{A1}$$

Using equation (6) and the expressions for the CES market shares we find $\varepsilon(x_{jj}, -\tau) = -(\sigma - 1)\varepsilon(p_{mj}, -\tau) = -(\sigma - 1)s_{ij}$ and $\varepsilon(x_{ji}, -\tau) = (\sigma - 1)(1 - s_{ji}) = (\sigma - 1)s_{ii}$.

With equal wages the price of an imported good is τ times higher than that of an imported variant. Since the elasticity of substitution is equal to σ we therefore have $y_{ji} = x_{ji}/\tau = x_{ii}\tau^{-\sigma}$ and $y_{ij} = x_{ij}/\tau = x_{jj}\tau^{-\sigma}$. Moreover, equation (12) implies $x_{jj} + x_{ji} = \sigma(\rho + g)\kappa_j$ and $x_{ii} + x_{ij} = \sigma(\rho + g)\kappa_i$. With perfect international knowledge spillovers $\kappa_j = \kappa_i$, and we thus find $x_{ji} = \tau^{1-\sigma}x_{jj}$. Inserting this in the expression for μ_j it follows that $\mu_h = \mu_f \equiv \mu = \frac{1}{1+\tau^{1-\sigma}} > 0.5$, and we can rewrite equation (A1) as

$$\varepsilon(\pi_j, -\tau) = -(\sigma - 1)\mu s_{ij} + (\sigma - 1)(1 - \mu)s_{ii}. \tag{A2}$$

Trade liberalization thus has two direct and opposing effects; the first term on the r.h.s. of (A2) shows that the domestic profit flow decreases because the competitive pressure increases, while the second term shows the positive effect of improved market access to the foreign country.

Since $n_h > n_f$ it is easy to show that $s_{hh} > s_{ff}$, and after some manipulations we find

$$\varepsilon(\pi_h, -\tau) - \varepsilon(\pi_f, -\tau) = (\sigma - 1)(2\mu - 1)(s_{hh} - s_{ff}) > 0. \tag{A3}$$

Equation (A3) thus shows that it becomes relatively more profitable to make new innovations in the large country than in the small country when trade is liberalized (and wages are equalized). Therefore the equilibrium ratio $N = n_h/n_f$ must increase when τ is reduced. The intuition for the sign of (A3) was given in the main text: trade liberalization implies that firms in the large (small) country face increased competition from a relatively small (large) number of foreign competitors and vice versa.[18]

It will in general not be true that $\mu_h = \mu_f$ when we allow wages to differ. On the contrary, the market in h becomes the most important one for R&D firms in both countries when trade costs are sufficiently low (indeed, we must have $\lim_{\tau\to 1}(1 - \mu_f) = \lim_{\tau\to 1}\mu_h = L_h/(L_h + L_f)$). For low τ-values trade liberalization is consequently beneficial for the research incentives in f because the improved market access to the large market in country h is more important than the increased competitive pressure domestically.

A3 *An intuitive explanation of equation* (15)

Section (3.2.1) treated the case when both countries produce the traditional good, whereby $w = w_h = w_f$ and $p = p_h = p_f$. Labour is used to perform research (L_{nj}), and to manufacture intermediate goods (L_{xj}) and z-goods (L_{zj}); $L_{nj} = L_j - L_{xj} - L_{zj}$. From the main text we know that $L_{xh} + L_{xf} = \beta\eta\bar{E}/p$, and $L_{zh} + L_{zf} = (1 - \eta)\bar{E}/w$. Since the markup for intermediates equals $MU(\sigma) \equiv \sigma/(\sigma - 1)$ and $p = w\beta\sigma/(\sigma - 1)$ we can rewrite labour requirement for production of intermediates as $L_{xh} + L_{xf} = \eta\bar{E}/[w(\sigma - 1)]$.

[18] The negative effect of trade liberalization tends to be higher the greater the share of the profit flow that is earned on the home market. It can be shown that $\varepsilon(\mu_f, \kappa_f/\kappa_h) = \frac{\tau^{1-\sigma}}{(\kappa_f/\kappa_h) - \tau^{1-\sigma}} > 0$, and therefore the home market becomes relatively more important for researchers in f if there is imperfect international knowledge spillover.

Let $Q \equiv \frac{\eta}{wMU(\sigma)} + \frac{1-\eta}{w}$ be the quantity of labour which implicitly is required per unit of consumer expenditure, so that we can write $L_{nh} + L_{nf} = L - Q\overline{E}$ (where $L = L_h + L_f$). A total of $Q\overline{E}$ workers are therefore needed to satisfy consumer demand each period. This demand is financed partly from current wage income (wL) and partly from financial wealth ($\Omega = \Omega_h + \Omega_f$), and we thus have

$$L_{nh} + L_{nf} = L - QwL - Q\rho\Omega, \tag{A4}$$

where ρ is the propensity to consume out of financial wealth. But $\Omega = v_h n_h + v_f n_f = w\kappa_h(s)n_h + w\kappa_f(s)n_f = w\overline{\kappa}/R(\cdot)$ from equation (13). Inserting in (A4) we have

$$L_{nh} + L_{nf} = L - QwL - Q\rho\frac{w\overline{\kappa}}{R(\cdot)}. \tag{A5}$$

Q times wL workers are thus required to satisfy consumer demand from wage income, and Q times $\rho\left(\frac{w\overline{\kappa}}{R(\cdot)}\right)$ workers to satisfy demand from financial wealth.

The more differentiated the individual goods from the modern sector, the higher the markup in equilibrium. A lower σ thus permits a higher MU and therefore tends to reduce manufacturing employment ($\partial Q/(-\partial\sigma) < 0$) and allow higher employment in research.

A higher R means that researchers are more efficient, and tends to reduce current financial wealth because future research becomes more inexpensive. This means lower demand resulting from financial wealth, and thus more labour is released for research.

Simplifying (A5) we arrive at the reduced form equation (15). The other growth equations can be given similar interpretations.

A4 *Derivation of the sign on* $R'(\tau)$

Differentiation of $R(\tau) = R\left[N(\tau, S(\tau)), S(\tau)\right]$ yields

$$R'(\tau) = R_1 N_1 + \left[R_1 N_2 + R_2\right] S'(\tau) \tag{A6}$$

For the first term we find $R_1 = -SR^2\left[\frac{1}{(N+S)^2} - \frac{1}{(1+SN)^2}\right]$. Since $N = n_h/n_f > 1$ and $S \leq 1$, it follows that $(N+S)^2 > (1+SN)^2$, which implies $R_1 > 0$. Consequently sign$[R_1 N_1]$ =signN_1.[19] When trade costs are high, the market size effect implies that $\dot{N}$ increases, while factor cost differences have the opposite effect when τ is small. We therefore have

$$\begin{aligned} R_1 N_1 &> 0 \text{ when } w_h > w_f \text{ and } dw_f/d\tau < 0 \qquad \text{(A7)} \\ R_1 N_1 &< 0 \text{ otherwise} \end{aligned}$$

For the second and third terms in (A6) we find $R_1 N_2 + R_2 = -R^2 \left[\frac{SN_2 - N}{(N+S)^2} - \frac{SN_2 + N}{(1+SN)^2}\right]$, so

$$[R_1 N_2 + K_2]\, S'(\tau) = -R^2 \left[\frac{SN_2 - N}{(N+S)^2} - \frac{SN_2 + N}{(1+SN)^2}\right] S'(\tau) < 0 \qquad \text{(A8)}$$

Equation (A8) is always negative, since $S'(\tau) < 0$ and $(N+S)^2 > (1+SN)^2$.

A5 *Other possible steady state equilibria than those discussed in the main text*

As mentioned in footnote 9, there exist steady state equilibria where the small country does not employ any researchers. This may happen either if demand for the traditional good is 'high' or if there are no international knowledge spillovers. For the sake of completeness we shall here give a short and informal description of these two cases.

Researchers in the large country become increasingly more productive than those in the small country if $S(\tau)$=0 (pure national knowledge spillovers), with $\lim_{t\to\infty} [\kappa_f(t)/\kappa_h(t)] = \infty$. We then have $g_h = \lim_{t\to\infty}(\dot{n}_h/n_h) > 0$ and $\lim_{t\to\infty} \dot{n}_f = 0$. Labour market equilibrium in f thus implies $L_f = \frac{(1-\eta)\bar{E}}{w_f}$. Moreover, since $\lim_{t\to\infty} E_f = \lim_{t\to\infty} [w_f L_f + n_f x_f w_f/\sigma] = w_f L_f$, it follows that the expenditure levels asymptotically are given by $E_h = \eta \bar{E}$ and $E_f = (1-\eta)\bar{E}$. Using this it is easy to show

$$g_h = \frac{L_h}{\sigma \bar{\kappa}} - \frac{\sigma - 1}{\sigma}\rho. \qquad \text{(A9)}$$

Long term growth rates are consequently independent of trade costs in this case.

[19] Note, however, that $R_1 \equiv 0$ if $S \equiv 1$, c.f. the case when knowledge spillover is complete and irrespective of the level of trade costs.

Now suppose $S(\tau) > 0$, and let us look at the case when f is too small to satisfy aggregate demand for traditional goods. We already know from equation (15) that $g = \frac{R(\tau)}{\sigma \bar{\kappa}}\eta L - \frac{\sigma-\eta}{\sigma}$ as long as both countries are diversified, and thus that trade liberalization may improve research efficiency and speed up the growth rates. When trade costs are sufficiently low, however, market size effects imply that all research is gathered in h. It is then straightforward to show that

$$g = \frac{\eta L}{\sigma \bar{\kappa}} - \frac{\sigma - \eta}{\sigma}\rho. \tag{A10}$$

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Chapter 4*

Agglomeration and Growth Effects of Trade Liberalization

Abstract

This paper develops a growth model with two countries, where researchers use formerly developed intermediate goods as inputs. It is found that trade liberalization in these goods speeds up the growth rate if trade costs initially are small and we allow international wages to differ. On the other hand, there is possibly no relationship between growth and trade liberalization for higher levels of trade costs. The reason is that agglomeration forces then may have led the entire research sector to concentrate into one country.

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1 Introduction

The interest in endogenous growth theory has been revitalized after the path-breaking works of Romer (1986, 1990) and Lucas (1988). This has also led to intensified research about the relationship between growth and trade, and Grossman and Helpman (1991) as well as Barro and Sala-i-Martin (1995) offer comprehensive discussions about growth effects of complete trade integration between initial autarkies. The so-called 'new economic geography' literature does, however, indicate that it may be insufficient to look only at these extremes if there are significant non-convexities on the supply side. During the last two years we have consequently seen a number of papers which have integrated new economic geography and endogenous growth theory, one of the first contributions being Baldwin and Forslid (1996a).

The present paper is particularly relevant in a North-South perspective, and the point of departure for the formal discussion is Rivera-Batiz and Romer (1991) and Krugman and Venables (1995). The former is a dynamic model, and shows how free trade in intermediate goods to the research sector may increase long-term growth. The latter is static, and shows how vertical industry linkages and incomplete trade liberalization in intermediate goods may imply that industries with scale economies concentrate in one country. Combining the insight from these two papers, we find that the relationship between growth and trade liberalization may follow a quite complex pattern. In particular, it is found that trade liberalization is beneficial for the growth rate if trade costs initially are small and we allow international wages to differ. The reason is that both countries then produce intermediate goods, and research costs decrease as trade is liberalized. However, for some intermediate levels of trade costs (and possibly also for high levels, if there are strong economies of scale) there is no connection between trade liberalization and growth because trade has led the entire research sector to agglomerate into one country. Thus, according to this paper, we may expect positive growth effects of trade liberalization between North and South if it goes far enough - even if the effects of earlier liberalizations may have been uncertain.

There are two initially identical countries in the model, and a representative household consume two kinds of goods. One of these is traded costlessly and manufactured under constant returns to scale in a so-called traditional sector, with labour as the only input. The other is produced in a "modern" industrial sector, and consists of a composite of differentiated intermediate goods which are costlessly assembled. The modern sector in turn has two subsectors, one performing research and the other using labour to produce already invented goods.[1] Growth occurs if entrepreneurs find it profitable to develop new kinds of intermediate goods.

New intermediate goods are invented by using formerly developed goods as inputs, in the spirit of Rivera-Batiz and Romer's (1991) lab-equipment specification. It is further assumed that innovation costs are decreasing in the number of varieties available. This formulation implies that we have vertical industry linkages that may lead to a break-down of the symmetric equilibrium if there are trade costs on intermediate goods, and the forces have certain similarities to the ones we know from economic geography (e.g., Krugman and Venables 1995): suppose that for some reason one country produces a larger set of intermediate goods than does the other. This implies, other things being equal, that research costs are relatively low in this country which therefore may be expected to have the majority of research firms in the future (cost linkage). But if one country ends up with a higher number of research firms than the other, then also future demand for innovated goods is highest in this country (demand linkage). These self-reinforcing centripetal forces may lead to an international concentration of the modern sector. On the other hand,

[1]It is assumed that product innovation and subsequent manufacturing must take place in the same country, and the financial markets are supposed to be purely national. These assumptions seem natural as a first approximation in a North-South perspective, but clearly leave open possibilities for outsourcing and foreign direct investment. Martin and Ottaviano (1997) study regional consequences of reduced transaction costs, and have consequently assumed completely integrated financial markets and (possible) geographical separation of research and production. Their framework implies that the research sector always agglomerates in one region, independent of the level of trade costs and the degree of scale economies. Something in-between our approach and the one taken by Martin and Ottaviano would presumably be preferable, but very little work has been done so far to study consequences of imperfect capital mobility and effects of costly outsourcing/foreign direct investments.

concentration may generate too high competitive pressure and lead to an excessive demand for labour which presses up the wage level. These are centrifugal forces which tend produce international decentralization if, as we assume, the labour force is immobile between the countries.

Both countries produce modern goods and perform research if trade costs are high and scale economies at most are moderate. A small trade liberalization is then likely to lead to a somewhat higher growth rate because it reduces the costs of imported intermediate goods to the research sectors. It may also happen, however, that all research and production of modern goods agglomerate into one country (due to centripetal forces). In that case there will be a sudden positive jump in the long-term growth rate because the research sector is no longer subject to trade costs, but wages may fall in the 'unfortunate' country which now produces only the traditional good.[2] Further trade liberalization will have no growth implications as long as this specialization pattern remains. But will it remain? Not if trade costs are sufficiently reduced, because then innovators will find it profitable to take advantage of the low wage level and produce modern goods also in the unfortunate country.[3] There will consequently be a positive relationship between growth and trade liberalization both when trade costs are high or low as long as scale economies are not too substantial. If they are substantial, the centripetal forces are so strong that we shall see a positive relationship only for low levels of trade costs, because

[2] The long-term growth rates in real wages are the same in the two countries in this kind of model. (This is consistent with the observation that there does not seem to be any systematic relationship between relative income levels and growth rates, see, e.g., Lucas (1988).) Therefore it is not obvious that consumers in the country which ends up without any modern industry are worse off than they would have been without trade liberalization - in the short run they probably are, but the higher growth rate works the other way.

[3] Note, however, that with our technology specification international wages will always be the same if demand for the traditional good is so large that it must be produced in both countries. This would not have been the case if we had assumed that the traditional sector uses a technology with decreasing returns to scale (due to some fixed factor). It may be argued that the case where we always have wage equalization is only a consequence of our simplified technology specification, and as such not too interesting. The case with 'high' demand for the traditional good is therefore relegated to the appendix.

the research sector otherwise is concentrated in one country.

The rest of this paper is organized as follows. The formal model is presented in section 2, where also the stability of different international specialization patterns is examined. The growth consequences of trade liberalization are studied in section 3, and section 4 concludes. The appendix offers a discussion of the case where we always have wage equalization.

2 The model

There are two countries, h (home) and f (foreign), with population sizes equal to L_j ($j = h, f$). In general we shall assume that $L_h = L_f$, although we allow $L_h \neq L_f$ when we derive the growth equations. Each inhabitant supplies one unit of labour, and is internationally immobile. We abstract from population growth. The consumers have identical preferences, and demand goods from a modern (m) and a traditional (z) sector. We do not consider differences in relative factor endowments, and (skilled) labour is the only primary input.

Demand side:

A representative consumer in country j has preferences of the form

$$U_j = \int_0^\infty \ln \left[m_j(s)^\eta z_j(s)^{1-\eta} \right] e^{-\rho s} ds. \tag{1}$$

The sub-utility of the m-good is in turn given by the CES specification $m_j = \left[\sum_{k=1}^{n} x_k^{\frac{\sigma-1}{\sigma}} \right]^{\frac{\sigma}{\sigma-1}}$ ($\sigma > 1$) where $n = n_h + n_f$ is the available number of variants at time s. Let $q_k(s)$ be the consumer price of good k. All producers have access to the same technology, so prices from firms in a given country will not differ. The price index for the m-good can accordingly be written as

$$p_{mj} = \left[n_i q_i(s)^{1-\sigma} + n_j q_j(s)^{1-\sigma} \right]^{\frac{1}{1-\sigma}} \tag{2}$$

by taking the dual of m_j.

Each consumer inelastically supplies one unit of labour, and the intertemporal budget constraint may consequently be written as

$$\int_0^\infty [p_{mj}(s)m_j(s) + p_{z,j}(s)z_j(s)]\, e^{-\int_0^s r_j(v)dv} ds = \int_0^\infty w_j(s) e^{-\int_0^s r_j(v)dv} ds + \Omega_j(0)/L_j. \quad (3)$$

The symbol $\Omega_j(0)$ denotes the present value of aggregate financial wealth in country j, w_j the wage level, $p_{z,j}$ the price of the traditional good, and r_j the interest rate.

Let E_j be consumer expenditure in country j. Utility maximization then implies

$$\frac{\dot{E}_j}{E_j} = r_j(s) - \rho. \quad (4)$$

The z-good is chosen as numeraire, and there is no technological progress in the traditional sector. Since consumers spend a fixed share of their income on the traditional good with the Cobb-Douglas specification, we have $\frac{\dot{E}_j}{E_j} = 0$ and $r_j \equiv \rho$ in steady state.

Supply side:

Production of one unit of the z-good requires one unit of labour, and the good is traded costlessly. This implies $p_z = p_{zh} = p_{zf}$. We choose $p_z = 1$, and consequently $\min\{w_h, w_f\} = 1$.

It is the modern sector that potentially gives rise to growth. The most common way to model linkages between trade and growth is to assume that there exist international knowledge externalities (e.g., Baldwin & Forslid 1996a, 1996b, and chapter 3 of this thesis). Here we shall rather use a variant of what Rivera-Batiz and Romer (1991) call a lab-equipment model, where the underlying idea is that development of new kinds of goods uses formerly developed goods as inputs.

As in Evans, Hokapohja, and Romer (1998) we shall assume that the cost of a new innovation equals

$$P_j = \frac{1}{n_i + n_j}\left[\frac{n_i q_i^{1-\sigma} + n_j q_j^{1-\sigma}}{n_i + n_j}\right]^{\frac{1}{1-\sigma}}. \quad (5)$$

Innovation costs thus decrease by one per cent if the number of varieties in each country increases by one percent, and this specification secures a constant steady state growth.[4]

The labour requirement to manufacture an x-good is equal to one. Producers in the modern sector must incur some fixed costs, implying that there is a finite number of competitors. In line with Dixit and Stiglitz (1977) we assume monopolistic competition in order to abstract from strategic interactions. Thereby firms use the constant markup $\frac{\sigma}{(\sigma-1)}$ over marginal costs, so the f.o.b. price from country j is

$$p_j = \frac{\sigma}{\sigma - 1} w_j. \tag{6}$$

Trade costs on x-goods are modelled in a manner which is well known from economic geography literature; of each unit shipped, only $\frac{1}{\tau}$ reaches its destination ($\tau \geq 1$). This means that the c.i.f. price is τ times higher than the f.o.b. price for an imported good. The price indexes (2) and (5) can accordingly be written as

$$\begin{aligned} p_{mj} &= \left[n_j p_j^{1-\sigma} + n_i (p_i \tau)^{1-\sigma}\right]^{\frac{1}{1-\sigma}}, \text{ and} \\ P_j &= \frac{1}{n_i + n_j}\left[\frac{n_j p_j^{1-\sigma} + n_i (p_i \tau)^{1-\sigma}}{n_i + n_j}\right]^{\frac{1}{1-\sigma}}. \end{aligned} \tag{7}$$

General equilibrium

It is easy to verify that the aggregate market share for domestic intermediate good producers in country j is $s_{jj} = n_j (\frac{p_j}{p_{mj}})^{1-\sigma}$ while that of foreign firms is $s_{ij} = n_i (\frac{\tau p_i}{p_{mj}})^{1-\sigma}$. The cost of $\dot{n}_j$ new innovations is $\dot{n}_j P_j$, and expenditure on respectively local and imported variants are thus $n_j p_j x_{jj}^{inn} = s_{jj} \dot{n}_j P_j$ and $n_i (p_i \tau)(\frac{x_{ij}^{inn}}{\tau}) = s_{ij} \dot{n}_j P_j$. Let $g_j \equiv \frac{\dot{n}_j}{n_j}$ be the growth rate of new innovations. Gross demand from innovators for each variety is thus (for $k = i, j$)

$$x_{kj}^{inn} = \frac{s_{kj} P_j}{p_k} \frac{n_j}{n_k} g_j. \tag{8}$$

[4]Several interpretations are consistent with equation (5), see Baldwin and Forslid (1996b), Martin and Ottaviano (1997), Evans, Hokapohja, and Romer (1998), and chapter 5 of this thesis. The point is, as stressed by Lucas (1988), that all endogenous growth models necessarily hinge on knife-edge assumptions.

Gross consumer demand is, by the same kind of reasoning, given by

$$x_{kj}^{cons} = \eta \frac{s_{kj} E_j}{p_k n_k}. \tag{9}$$

Equilibrium in the labour market requires

$$L_j = n_j x_j + L_{zj}, \tag{10}$$

where L_{zj} is employment in the traditional sector, and $x_j = \sum_{k=h}^{f} (x_{jk}^{cons} + x_{jk}^{inn})$.

We will confine ourselves to analysis of steady state (balanced growth), where by definition the sector division of labour is constant. It can be shown that we then have $g_h = g_f$ if both countries innovate (see, e.g., Grossman and Helpman 1991). We may therefore simplify and use the common notation g. From the shape of the utility function we know that $L_{zh} + L_{zf} = \frac{(1-\eta)(E_h+E_f)}{p_z}$, and using equations (7), (8), and (9) we can find that $\frac{d}{dt} n_j x_{jk}^{cons} = \frac{d}{dt} n_j x_{jk}^{inn} = 0$.

The value v_j of a firm that manufactures intermediate goods must at least equal P_j if an entrepreneur shall be willing to invest in development of a new variant. With positive growth and free entry into the innovative sector, it must therefore always be true that

$$P_j = v_j. \tag{11}$$

From equation (7) it follows that $\frac{\dot{P}_j}{P_j} = -g$ in steady state, and thus equation (11) implies that $\frac{\dot{v}_j}{v_j} = -g$. The aggregate firm value - which equals the consumers' financial wealth - is consequently constant in steady state and given by

$$\Omega_j = n_j v_j = n_j P_j. \tag{12}$$

The instantaneous profit flow received by a representative firm equals $\pi_j = (p_j - w_j)x_j = \frac{p_j x_j}{\sigma}$. The present value of this flow is $\frac{\pi_j}{(\rho+g)}$ since the value of each intermediate producing firm decreases by the rate g and the interest rate equals ρ. We may therefore interpret $(\rho + g)$ as the required rate of return (or the effective discount rate) and rewrite the free entry condition (11) as

$$\frac{p_j x_j}{(\rho + g)\sigma} = P_j. \tag{13}$$

2.1 Autarky equilibrium

The growth equation can easily be derived by using equations (8), (9), (10), and (12), but in order to show the economic logic we shall do it in a somewhat more circumstantial manner: labour requirement to satisfy consumer demand for modern and traditional goods in an autarky is, respectively, $\frac{\eta E_j}{p_j}$ and $\frac{(1-\eta)E_j}{w_j}$, while $\frac{\dot{n}_j P_j}{p_j}$ units of labour are used in the innovation sector. The latter term can be simplified to g^{aut} since from equation (7) we have $(n_j P_j)^{aut} = p_j$ (superscript *aut* for autarky). With a labour supply equal to L_j we must then have that the quantity of labour used to make new innovations equals $g^{aut} = L_j - \frac{\eta E_j}{p_j} - \frac{(1-\eta)E_j}{w_j}$. Since consumers receive wage income ($w_j L_j$) and dividends from their financial wealth ($\rho\Omega_j = \rho n_j P_j$), it follows that $E_j = w_j L_j + \rho n_j P_j$ in steady state. Using this we can write

$$g_j^{aut} = L_j - \left[\frac{\eta}{p_j} + \frac{(1-\eta)}{w_j}\right] w_j L_j - \left[\frac{\eta}{p_j} + \frac{(1-\eta)}{w_j}\right] \rho n_j P_j. \tag{14}$$

The first term on the r.h.s. is labour supply. The second and third terms show how much labour is needed to satisfy the part of consumer demand which is financed from current wage- and interest income, respectively. Therefore the third term, which can be written as $\frac{(\sigma-\eta)}{(\sigma-1)}\rho$, shows labour requirement to satisfy consumer demand financed from dividend income. We thus have $g^{aut} = \eta \frac{w_j L_j}{(\sigma-1)n_j P_j} - \frac{\sigma-\eta}{\sigma-1}\rho$, or

$$g_j^{aut} = \eta \frac{L_j}{\sigma} - \frac{\sigma-\eta}{\sigma-1}\rho. \tag{15}$$

The growth rate is consequently increasing in η (since modern goods then are more important in consumption) and decreasing in ρ (because a higher subjective discount rate implies that the willingness to invest is lower). The relationship between growth and σ is more uncertain: the positive effect of a lower σ (more specialized inputs, higher markup) is to release labour for innovative purposes by reducing the amount of labour needed to cover demand from current wage income. This 'efficiency effect' is shown by the first bracket in equation (14); $\frac{\eta}{p_j} = \frac{\eta}{w_j}\left(\frac{\sigma-1}{\sigma}\right)$ is smaller the lower the σ. But a lower σ also increases the share value $\left(\Omega_j^{aut} = n_j P_j = \frac{\sigma}{(\sigma-1)} w_j\right)$ because firms are allowed to use a higher mark-up. This wealth effect in turn tends to increase current consumption and thereby reduce the growth rate, as shown by the last term in (14). Therefore the growth rate is increasing or decreasing in σ, depending on whether the efficiency or the wealth effect is strongest. In the appendix it is shown that the latter effect possibly dominates if $\eta < \sigma(\sigma - 2)$.

2.2 Trade equilibria

With our technology specification international wages are always equalized if demand for the traditional good is so large (η small) that it must be produced in both countries. This may seem to be an unrealistic implication unless the countries are identical in every respect (or trade is completely liberalized), and the result would disappear if we had allowed decreasing returns to scale in the z-sector. Since a model modification along those lines would make the algebra considerably more complicated, we shall instead in the main text assume that η is so large that we possibly have $w_h \neq w_f$. The case where η is small is treated in the appendix. Without loss of generality we shall throughout this paper assume that $w_h > w_f$ if international wages differ.

2.2.1 Asymmetric equilibria

It is in principle possible for f to satisfy world-wide demand for the traditional good if $(1 - \eta)(E_h + E_f) \leq w_f L_f$. Suppose that, for some reason, both countries are specialized, h in production of modern goods and f in production of the traditional good. In that case $E_h = w_h L_h + \rho n_h P_h$, $E_f = w_f L_f$, and $\frac{E_h}{E_h+E_f} = \eta$. The wage level in f thus equals

$$w_f = \frac{1-\eta}{\eta}\left[\frac{w_h L_h + \rho\Omega_h}{L_f}\right]. \tag{16}$$

Given this specialization pattern, a higher demand for the traditional good (lower η) increases wages in f. We also have $\frac{dw_f}{d\sigma} < 0$, and the reason for this is the fact that financial wealth - and thus steady state consumer demand - in h is decreasing in the homogeneity of the intermediate goods.

With complete international specialization the growth rate is given by

$$g = \frac{L_h}{\sigma} - \rho. \tag{17}$$

Is this an equilibrium, or does it seem profitable for a single entrepreneur in f to defect and invest in an innovation? To answer that question, we can calculate the profitability of making an innovation in country f if nothing else in the world economy changes (i.e., each entrepreneur believes that his influence is infinitesimal).

Net demand in f for a representative imported intermediate good is $\frac{x_{hf}^{cons}}{\tau}$, and since the elasticity of substitution between any pair of intermediate goods equals σ, an entrepreneur in f would face a domestic demand which is $\left(\frac{p_f}{\tau p_h}\right)^{-\sigma}$ times higher. Net demand equals gross demand for domestic sales, and we thus have ${}^d x_{ff}^{cons} = \left(\frac{p_f}{\tau p_h}\right)^{-\sigma} \frac{x_{hf}^{cons}}{\tau}$ (superscript d for defection). Gross export sales are similarly given by ${}^d x_{fh}^{cons} = \tau \left(\frac{\tau p_f}{p_h}\right)^{-\sigma} x_{hh}^{cons}$ and ${}^d x_{fh}^{inn} = \tau \left(\frac{\tau p_f}{p_h}\right)^{-\sigma} x_{hh}^{inn}$. The profitability of these sales is $\left(\frac{p_f}{\sigma}\right)\left({}^d x_{fh}^{cons} +{}^d x_{fh}^{inn} +{}^d x_{ff}^{cons}\right)$ in each period. Since $P_f = \tau P_h$ an entrepreneur in f finds innovation profitable if

$$\frac{p_f\left({}^d x_{fh}^{cons} +{}^d x_{fh}^{inn} +{}^d x_{ff}^{cons}\right)}{\sigma(\rho+g)} \geq \tau P_h. \tag{18}$$

Using equations (8) and (9) we find after some manipulations that inequality (18) can be written as

$$\left(\frac{1}{\rho+g}\right)\left(\frac{1}{\sigma}\right)\frac{\left\{\left(\frac{\tau p_f}{p_h}\right)^{1-\sigma}\left[p_h L_h-(1-\eta)E_h\right]+\left(\frac{p_f}{\tau p_h}\right)^{1-\sigma}\eta E_f\right\}}{n_h} \geq \tau P_h. \tag{19}$$

Equation (19) can be interpreted as follows. There are L_h workers in h, and each produces one unit of intermediate goods. Consequently $p_h L_h$ is the value of production in h, so the domestic demand facing a representative firm in the rich country is $\frac{[p_h L_h-(1-\eta)E_h]}{n_h}$ (i.e., the sum of demand from consumers and innovators). Due to markup pricing this gives an operating profit equal to $\left(\frac{1}{\sigma}\right)$ times $\frac{[p_h L_h-(1-\eta)E_h]}{n_h}$ each period. The *c.i.f.* price of an imported good is $\left(\frac{\tau p_f}{p_h}\right)$ times higher than a domestic good, and a defector would thus sell only $\left(\frac{\tau p_f}{p_h}\right)^{-\sigma}$ as much as a domestic entrepreneur in h - but the *value* would only be $\left(\frac{\tau p_f}{p_h}\right)^{1-\sigma}$ smaller. The interpretation of the term $\left(\frac{p_f}{\tau p_h}\right)^{1-\sigma}\eta E_f$ is analogous, but here trade costs give entrepreneurs in f a cost advantage. Finally we must divide by $(\rho+g)$ to find the present value of the demand. Consequently, unless the l.h.s. of (19) equals τP_h or more, a single entrepreneur in f will not find innovation to be profitable.

It is convenient to measure the profitability of innovation in f in terms of innovation costs (τP_h). Using (17) inequality (19) can then be written as

$$\frac{1}{\sigma}\left(\frac{p_f}{p_h}\right)^{1-\sigma}\frac{\{\tau^{-\sigma}\left[p_h L_h-(1-\eta)E_h\right]+\tau^{\sigma-2}\eta E_f\}}{n_h P_h}\geq \rho+g=\frac{L_h}{\sigma}. \qquad (20)$$

This expression clearly shows the significance of whether σ is smaller or greater than 2. Suppose (20) initially holds with equality, but that there is a small increase in trade costs. Then the domestic market in f becomes more protected, and this increases the incentives to defect, but simultaneously imported inputs become more expensive. The term $\tau^{\sigma-2}\eta E_f$, which applies for the defector's home market, shows that these two effects cancel each other if $\sigma=2$, while the positive (negative) effect dominates if $\sigma > 2\,(\sigma < 2)$. With respect to the market in h both effects work negatively for a potential entrepreneur in f; inputs become more expensive and export possibilities worsened when trade costs increase.

Defection must be profitable if $w_f < w_h$ and trade costs are sufficiently low. The reason is that inequality (20) must be strict when τ=1 (if $g_h > 0$), otherwise innovation cannot be profitable in h either. But then we also know that the inequality holds in the neighborhood of $\tau = 1$, since demand is a continuous function of τ. Defection must also be profitable for high levels of trade costs if $\sigma > 2$ even though the term $\tau^{-\sigma}\left[p_h L_h-(1-\eta)E_h\right]$ approaches zero as τ increases. The reason is that $\tau^{\sigma-2}\eta E_f$ goes towards infinity as τ increases, and increases faster the higher the σ. This reflects the fact that a high σ means that the goods from the modern sector are closer substitutes, so that the home market *de-facto* is more protected. Defection is consequently unprofitable only for some medium level of trade costs if $\sigma > 2$.[5]

Figure 1 (where $\tau = 1.5$, see Appendix A1 for other parameter values) summarizes some of the discussion above. Below the solid line, which is defined by $w_f = w_h$ from equation (16), demand for the traditional good is so large that it must be produced in h as well as in f.[6] Between the two lines (and for lower values

[5]Intuitively one might think that deviation is always profitable if σ is sufficiently high (independent of the level of trade costs). Simulations indicate that this is not the case if we require g from equation (17) to be positive.

[6]We would then expect to observe production of modern goods in both countries only if trade costs are high, see Appendix A2.

of η than those in the figure) there is complete international specialization, given that one country (f) initially was specialized in z-production. Above the broken line it is profitable for entrepreneurs in f to innovate, so both countries will then produce modern goods. Using equations (8), (9), (10), and (12) - or the same kind of reasoning as led us to the autarky growth rate, equation (15) - we find that the growth rate in this latter case is given by

$$g = \eta \frac{w_h L_h + w_f L_f}{(\sigma - 1)(n_h P_h + n_f P_f)} - \frac{\sigma - \eta}{\sigma - 1}\rho. \tag{21}$$

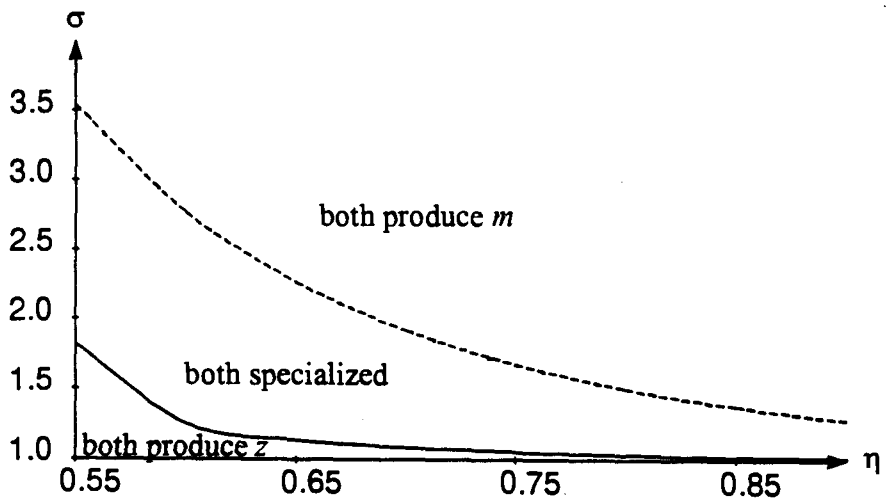

Figure 1: *Some possible production patterns.*

2.2.2 Symmetric equilibrium

Suppose $L_h = L_f = L$, and that the countries trade and are identical ($n_h = n_f = n$). Let $w \equiv w_j = p_z$, $p \equiv p_j$, $E = E_j$ and $P = P_j$. Equations (8), (9), (10), (12) give

$$g^{sym} = \eta \frac{wL}{(\sigma - 1)nP} - \frac{\sigma - \eta}{\sigma - 1}\rho \tag{22}$$

where $nP = \frac{p}{2}\left[\frac{1+\tau^{1-\sigma}}{2}\right]^{\frac{1}{1-\sigma}}$. It is obvious that trade liberalization speeds up the growth rate (since nP is strictly increasing in τ). However, comparing with equation (15), we also find that $g^{sym} > g^{aut}$ if and only if $\frac{1}{2}\left[\frac{1+\tau^{1-\sigma}}{2}\right]^{\frac{1}{1-\sigma}} < 1$, or

$$\tau < \hat{\tau} = \left(2^{2-\sigma} - 1\right)^{\frac{1}{1-\sigma}}. \tag{23}$$

Note that (23) always holds if $\sigma > 2$. The inequality will be further commented on in section 3, and shown to have limited economic relevance.

2.2.2.1 Stability of the symmetric equilibrium

We are now ready to examine the stability of the symmetric equilibrium. To this end, assume that there is a small exogenous shock which increases h's share of the world-wide number of firms, $dN_h = -dN_f > 0$, where $N_j = \frac{n_j}{(n_h+n_f)}$. Does this lead to a further concentration in h, or are we brought back to the symmetric equilibrium?

The question of stability may be answered by examining whether $g_h > g_f$ or $g_h < g_f$ after the shock. In the former case research has become more profitable in h than in f, and there will be a further concentration in h. In the latter case we are brought back to the initial equilibrium. If $g_h = g_f$ then also the new (relative) allocation of firms is an equilibrium. The problem of using this method is that when the growth rate changes in a possibly complex manner, so does the required rate of return (c.f. equation 13). This makes the analysis rather hard. A simpler and equally good approach is to assume that $g_h = g_f$ also after the shock (but possibly different from the initial growth rate) and thus allow disequilibrium in the market for innovations; $P_j \neq v_j$. Let $V_j \equiv \frac{v_j}{P_j} = \frac{\pi_j}{(\rho+g)}\frac{1}{P_j}$ and $V \equiv \frac{V_h}{V_f}$. With symmetry we have $V^* = 1$, $(nP)^* = \frac{p}{2}\left[\frac{1+\tau^{1-\sigma}}{2}\right]^{\frac{1}{1-\sigma}}$, and $E^* = L + \rho\,(nP)^*$. The symmetric equilibrium is stable (unstable) if $dN_h = -dN_f > 0$ implies dV<0 ($dV > 0$).

Using equations (8) and (9) together with $\pi_j = \frac{p_j x_j}{\sigma}$, we find

$$V = \frac{\left[\frac{s_{hh}(\eta E_h + g n_h P_h) + s_{hf}(\eta E_f + g n_f P_f)}{n_h}\right]\frac{1}{P_h}}{\left[\frac{s_{ff}(\eta E_f + g n_f P_f) + s_{fh}(\eta E_h + g n_h P_h)}{n_f}\right]\frac{1}{P_f}}. \tag{24}$$

Since we cannot be certain that $\frac{\dot{v}_j}{v_j} = -\frac{\dot{n}_j}{n_j}$ after the shock, the equation for the expenditure level in each country must be changed to $E_j = w_j L_j + n_j \pi_j - \dot{n}_j P_j$, or

$$E_j = w_j L_j + n_j \pi_j - g n_j P_j. \tag{25}$$

Defining $dN \equiv dN_h - dN_f$, $dnP \equiv d(n_h P_h) - d(n_f P_f)$, $dE \equiv dE_h - dE_f$, and differentiating equation (24) around the point of symmetry, we find after a while that

$$\frac{dV}{dN} = \left(-\frac{dP_h}{P_h} + \frac{dP_f}{P_f}\right) + \frac{2(ds_{hh} + ds_{hf})}{s_{hh}^* + s_{hf}^*} + \frac{s_{hh}^* - s_{fh}^*}{s_{hh}^* + s_{hf}^*}\left[\frac{\eta dE + g dnP}{\eta E^* + g^*\,(nP)^*}\right] - \frac{1}{N_j}. \tag{26}$$

Innovation costs in h relative to in f decrease after the relocation as long as $\tau > 1$. This effects, which is reflected by the first term on the r.h.s. of (26), tend to increase V. The second term shows that V also tends to increase because research firms in h expand their aggregate market shares, domestically and abroad. Moreover, the relocation may also lead to increased demand from consumers and innovators in h relative to in f, and this is captured by the third term.[7] Since all these positive sales effects must be shared by a relatively larger number of firms in h, we must subtract the fourth term.

Inserting for P_j, dP_j, s_{jk}, and ds_{jk}, $(k = i, j)$, equation (26) can be written as

$$\frac{dV}{dN} = \frac{2}{\sigma - 1}T + \frac{8\tau^{1-\sigma}}{(1+\tau^{1-\sigma})^2} + \frac{\eta dE + gdnP}{\eta E_j + g(nP)^*}T - 2, \tag{27}$$

where $T = \left(\frac{1-\tau^{1-\sigma}}{1+\tau^{1-\sigma}}\right)$, and $dnP = (nP)^*\left[2 - \frac{2T}{(\sigma-1)}\right]$. Both dnP and the first terms in (27) are positive, since $0 \leq T \leq 1$. An explicit expression for the third term can be found by differentiating nP and equation (25), from which we after a significant amount of algebra find

$$dE = \frac{8\tau^{1-\sigma}(\eta E^* + g^*(nP)^*)}{(\sigma - \eta T)(1+\tau^{1-\sigma})^2} + \frac{2g^* T\left[1 - \frac{T}{(\sigma-1)}\right](nP)^*}{\sigma - \eta T} - \frac{2\sigma g^*\left[1 - \frac{T}{(\sigma-1)}\right](nP)^*}{\sigma - \eta T}. \tag{28}$$

The sum of the two first terms in (28) is equal to $d(n_h\pi_h) - d(n_f\pi_f)$, and is positive. This shows that aggregate operative profits in h relative to those in f increase after the relocation. The third term, which equals the difference $d(\dot{n}_h P_h) - d(\dot{n}_f P_f)$, is negative and shows the consequence on the consumer demand of the relative increased investment requirement in h. The difference dE is consequently negative if and only if the increased investment requirement is larger than the profit gain, a result which is intuitively reasonable.

Though we have an explicit analytical solution for $\frac{dV}{dN}$ if we combine (26) and (28), the solution is too complex to be very informative. Simulations show that

[7] Consumer demand increases in country h relative to in country f if the financial wealth becomes higher in h than in f after the shock. The reason why there may be a relatively higher demand from innovators in h than in f is that the relocation of firms ($dN_h = -dN_f > 0 \Rightarrow n_h > n_f$) implies that $\dot{n}_h > \dot{n}_f$ when $dg_h = dg_f$.

the qualitative behaviour depends on whether $\sigma \leq 2$ or $\sigma > 2$: The symmetric equilibrium is always unstable for $\sigma \leq 2$, while it is stable for high levels of trade costs if $\sigma > 2$. The critical σ where the symmetry breaks down goes toward 2 (from above) when $\tau \to \infty$. These results are not surprising, given what we found in section 2.2.1.

The parameter σ may be interpreted as an inverse index of the economies of scale, and stronger scale economies make it more important to be close to a large market.[8] In the asymmetric equilibrium the local market in f is smaller than in h. Therefore defection may be unprofitable even for relatively 'high' values of σ, making both countries completely specialized. However, other things being equal, a possible symmetric equilibrium may still be stable since in that case both countries have a 'large' local market.

3 Growth effects of trade liberalization

Figure 2 shows the effects of trade liberalization, and compares growth rates in asymmetric and symmetric equilibria. The former gives a higher growth rate, because concentration of research implies that fewer resources are wasted in trade. We have here chosen $\sigma > 2$, and thus the symmetric equilibrium is stable for high levels of trade costs (the broken line shows where it is unstable). The asymmetric equilibrium exists for $\tau < \tau_3$, with f producing only the traditional good for $\tau \in (\tau_1, \tau_3)$, while we must have $\tau < \tau_2$ before the symmetric equilibrium becomes unstable. This shows the importance of the initial situation: if the countries were equally well developed when they started to trade, then they are most likely to remain identical all the way down to $\tau = \tau_2$. In that case trade liberalization has positive growth effects as long as $\tau > \tau_2$ because it gives innovators in both countries access to more

[8] The degree of scale economies may be defined as the ratio of average costs (AC) to marginal costs (MC) (see, e.g., Varian 1992). We know that the annuity of the innovation costs equals $(\rho + g)P_j$, so average costs per period are $\frac{[(\rho+g)P_j - w_j x_j]}{x_j}$. Marginal costs are equal to w_j. Substituting for x_j from equation (13) and using $p_j = \frac{\sigma}{\sigma-1} w_j$ we find $\frac{AC}{MC} = \frac{\sigma}{(\sigma-1)}$. This ratio is strictly decreasing in σ.

inexpensive intermediate goods. On the other hand, trade liberalization does not have any growth effects as long as $\tau \in (\tau_1, \tau_2)$ because all research and manufacturing of modern goods then are concentrated in h. Reductions in τ are then irrelevant for h, but have positive *level* effects in f (the consumer price $p_{m,f}$ is reduced).[9] Finally, when $\tau < \tau_1$, the countries are so closely integrated that it is profitable for entrepreneurs to take advantage of the low wage level in f (as shown by equation 20). Therefore trade liberalization again has positive growth effects because it reduces the costs of intermediate goods to the research sector.

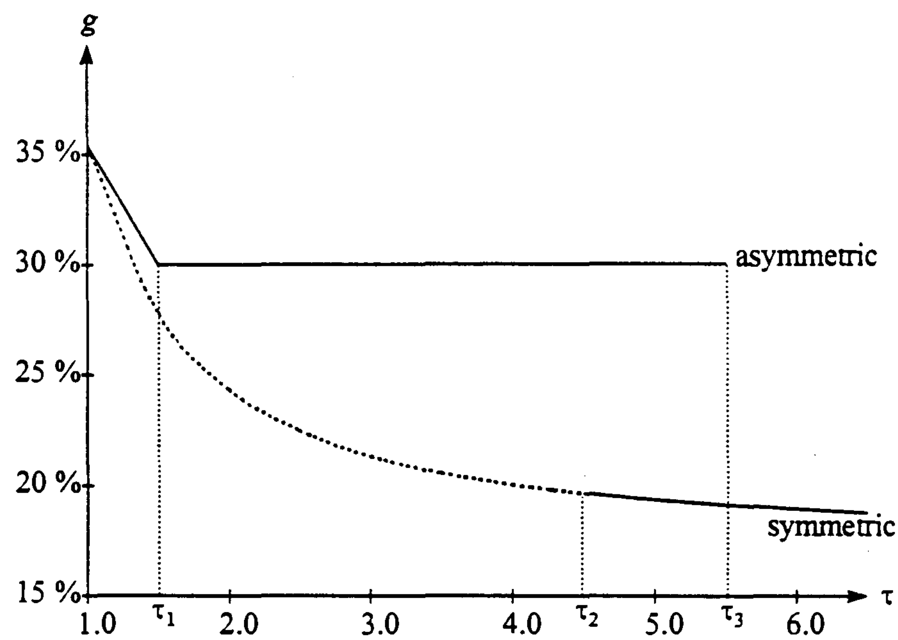

Figure 2: *Growth with symmetric and asymmetric equilibria ($\sigma > 2$).*

Do there exist other equilibria than those shown in Figure 2? This question may be answered by looking at how different international allocations of manufacturing firms affect the relative value of an innovation, a method quite similar to the one we used to determine the stability of the symmetric equilibrium: We choose an

[9] As mentioned in the introduction, the welfare level in f may be negatively affected by trade liberalization if it causes the symmetric equilibrium to break down (in the limit all goods must now be imported, and w_f and Ω_f decrease - the latter approaches zero over time). See Krugman and Venables (1995) for a discussion in a static framework. However, the higher growth rate in the asymmetric equilibrium has beneficial welfare effects.

arbitrary value N_h and let all markets be in equilibrium, except that the free entry condition in h may be violated (this means that consumer expenditure in h is given by equation 25). There will now be faster (slower) entry of new firms in h than in f if $V_h > 1$ ($V_h < 1$). The left panel of figure 3 shows the outcome for $\tau = 5.0$, and illustrates that we have five possible equilibria. To see this, we first note that the net present value of an innovation in h is negative ($V_h < 1$) if $N_h < 0.25$. Therefore N_h decreases, and the figure illustrates that $N_h = 0.00$ asymptotically. We also see that $V_h > 1$ if $0.25 < N_h < 0.50$, and consequently $N_h = 0.25$ is an unstable equilibrium (as shown by the arrows). Using this logic for all $N_h \in (0,1)$, we can conclude from the figure that there exist three stable equilibria ($N_h = 0.00, 0.50, 1.00$) and two unstable ($N_h = 0.25, 0.75$) for this level of trade costs. The result can also be illustrated in a (τ, N_h)-diagram. This is done in the right panel of figure 3, where solid (dotted) lines trace stable (unstable) equilibria.[10]

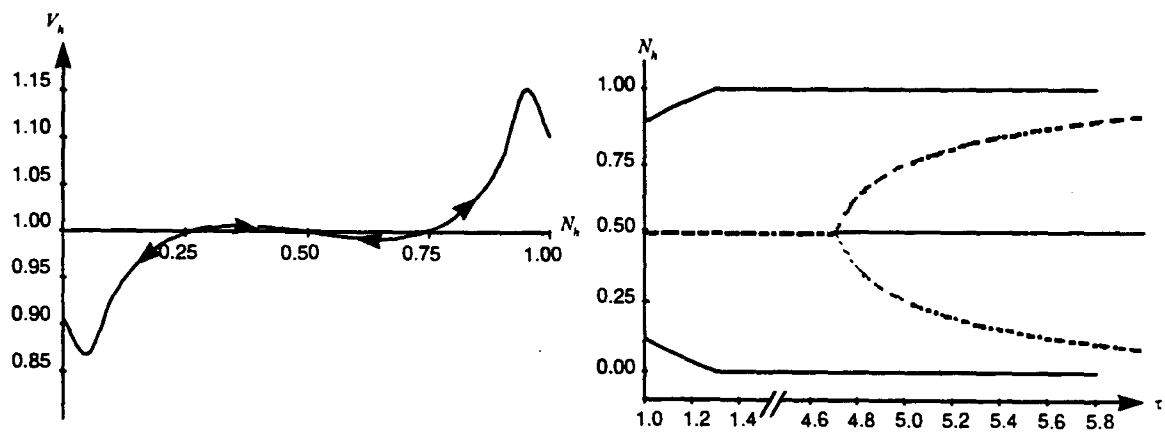

Figure 3: *Stable and unstable equilibrium allocations of research firms* ($\sigma > 2$).

Hitherto we have assumed that $\sigma > 2$, but what if this is not the case? Then we already know that the symmetric equilibrium is unstable for all levels of trade costs, and equation (20) told us that defection from a specialized equilibrium is no

[10]In order to simplify the picture, the growth patterns corresponding to the two unstable asymmetric equilibria are not drawn in figure 2. The relative concentration implies that the growth rate would have been somewhat larger than the one given by the symmetric equilibrium.

longer profitable for high levels of trade costs. This is illustrated in the left panel of figure 4. Moreover, the right panel of figure 4 shows that for "low" levels of trade costs the asymmetric equilibrium now gives a *lower* growth rate than does the symmetric one. Though it is certainly still true that concentration tends to reduce trade costs, too few resources are here allocated to the modern sector (compared to the symmetric case). The economic reason for this is that the lower the elasticity of substitution between the intermediate goods (or the higher the economies of scale), the less reason there is to locate at a distance from other producers - the competitive pressure is then low in any case, while it is important to be close to the large market. Indeed, no matter how large $\eta < 1$ is, the lower wage level in f cannot compensate for the smaller home market if σ is sufficiently low.[11] Thus, when τ is low, so that relatively few resources are "wasted" in trade independent of the international allocation of research firms, the incentive to invest in the small market is in a sense too small and this reduces the growth rate (compared to the unstable symmetric equilibrium). Note, however, that autarky growth is likely to be lower than growth in a trade equilibrium. This is easily seen by comparing g^{aut} from equation (15) with the growth rate which applies when both countries are specialized (equation 17). The latter is largest if $\frac{L_h}{\sigma} > \frac{-\rho}{(\sigma-1)}$, which is always the case. Since the growth rate in a stable trade equilibrium cannot be lower than the one given by (17), the possibility that $g^{aut} > g^{sym}$ (which holds if $\tau < (2^{2-\sigma} - 1)^{\frac{1}{1-\sigma}}$, c.f. equation 23) is rather uninteresting.

[11]Recall that as $\sigma \longrightarrow 1$ the economies of scale approach infinity.

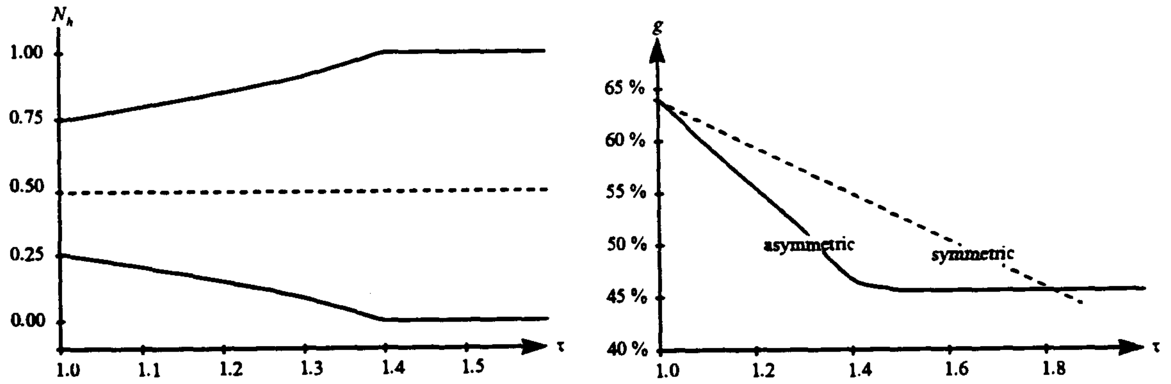

Figure 4: *Growth and equilibrium allocations of research firms* $(\sigma < 2)$.

4 Conclusion

This paper has shown how symmetry breaking in a world with non-convexities may give us a non-monotonous relationship between trade liberalization and growth. In the main text we have focused on a case where trade liberalization speeds up the growth rate when trade costs initially are high if the economies of scale are not too strong. This happens because innovators in the two countries gain better market access for inputs and outputs. If trade liberalization implies that the symmetric equilibrium becomes unstable and breaks down, we shall see a positive jump in the growth rate since the research sector then no longer is subject to trade costs. Further trade liberalization does not have any growth consequences as long as we have this international specialization pattern. If trade becomes sufficiently liberalized, and we have differences in international wages, factor cost differences again make it profitable to perform research in both countries. We may thus expect a positive relationship between growth and trade liberalization for low, and possibly for high, levels of trade costs.

Appendix

Parameter values

In all the simulations $L_h = L_f = 1$ and $\rho = 0.1$. Unless otherwise noted, we have further chosen $\tau = 1.5$, $\eta = 0.6$, $\sigma = 2.5$. In the left panel of figure 3 $\tau = 5.0$, and $\sigma = 1.8$ in figure 4.

A1 Sufficient conditions to ensure $\partial g/\partial\sigma < 0$.

Differentiating g_j^{aut} in equation (15) with respect to σ, we find

$$\frac{\partial g_j^{aut}}{\partial\sigma} = -\frac{\eta L_j}{\sigma^2} - \frac{\eta - 1}{(\sigma-1)^2}\rho. \tag{29}$$

We thus see that $\frac{\partial g_j^{aut}}{\partial\sigma} < 0$ if

$$L_j > \frac{\sigma^2(1-\eta)}{\eta(\sigma-1)^2}\rho. \tag{30}$$

In this paper we are looking only at situations where an autarky would have a positive growth rate, and we thus require that $L_j > \frac{\sigma(\sigma-\eta)}{\eta(\sigma-1)}\rho$ (c.f. equation 15). Inserting the minimum value of L_j into (30), we find that the wealth effect does not dominate if $\eta > \sigma(2-\sigma)$.

A2 Trade liberalization and growth effects when wages cannot differ

There must always be wage equalization if demand for the traditional good is so large (η small) that it must be produced in both countries. Let $w \equiv w_h = w_f$. $p \equiv p_h = p_f$, $L \equiv L_h = L_f$ and assume that f is specialized in z-production while h produces both z and m. This must mean that $wL_f < (1-\eta)(E_h + E_f)$ where $E_h = wL_h + \rho\Omega_h$ and $E_f = wL_f$. Trade liberalization neither reduces innovation costs nor changes employment in the modern sector when f is specialized in z-production. The growth rate is thus independent of τ, and from equations (8), (9), and (10) we find that it is equal to

$$g = \eta\frac{2L}{\sigma} - \frac{\sigma-\eta}{\sigma-1}\rho. \tag{31}$$

Comparing equation (31) with equation (22), it can be shown that the growth rate is higher in the asymmetric than in the symmetric equilibrium (if $\tau >1$). The reason is, as explained earlier, that less resources are wasted in trade when innovation is completely concentrated in one location.

To find out whether defection is profitable if f is specialized in z-production we follow the same methodology as we used to derive (20) in the main text. Inserting equations (18) and (8) into (9) gives

$$\left(\frac{1}{\sigma}\right)\left[\frac{\tau^{-\sigma}(\eta E_h + n_h P_h g) + \tau^{\sigma-2}\eta E_f}{n_h P_h}\right] \geq \rho + g. \tag{32}$$

The intuition behind this inequality is simple: $\dot{n}_h(t)$ innovations are made in country h at time t, and each firm in h thus faces a demand equal to $\frac{\dot{n}_h P_h}{n_h} = P_h g$ from innovators. The profitability of this demand equals $\frac{1}{\sigma}P_h g$, while the profitability from domestic consumer demand similarly equals $\frac{1}{\sigma}\frac{\eta E_h}{n_h}$. The terms $\tau^{-\sigma}$ and $\tau^{\sigma-2}$ show the net effect of trade costs on the foreign and domestic market for a potential innovator in f. The interpretation of (32) is thus analogous to the one we gave for (18) and (20).

Inequality (32) shows that defection must be profitable if $\sigma >2$ and τ is high (because of the protection of the home market).[12] What if trade costs are low? Denoting the terms in the square bracket of (32) by A, and differentiating with respect to τ at $\tau = 1$, we find

$$\left.\frac{dA}{d\tau}\right|_{\tau=1} = \sigma\left[\eta E_f - (\eta E_h + n_h P_h g)\right] - 2\eta E_f < 0. \tag{33}$$

This tells us that defection is unprofitable for "low" levels of trade costs (so now defection is *never* profitable if the elasticity of substitution between the intermediate

[12] A bit surprisingly, perhaps, it is not obvious that a higher η makes defection more profitable if there already is 'high' demand for the traditional good. The direct effect of a higher η is to increase consumer and producer demand for modern goods, and this certainly is positive from a defector's point of view. But the indirect effect is negative: a higher η increases the innovation rate in h and thereby also the future competition facing a defector. Thus a higher effective rate of return $(\rho + g)$ is required. (The two opposing effects are easily seen by differentiating (32) with respect to η.)

goods is equal to or lower than 2). It can be argued that this result is an artefact of our technology specification (as discussed in the introduction), and that the case discussed in the main text therefore gives more insight.

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Chapter 5*

Trade Costs, Innovation, and Imitation

Abstract

This paper presents an endogenous growth model where it is endogenously determined whether entrepreneurs in the poor East choose to innovate or to imitate goods from the rich West. It is shown that we have a unique equilibrium with imitation when trade is relatively expensive, in which case the global growth rate is higher and the international wage gap smaller than if both regions innovate. This changes fundamentally for some intermediate levels of trade costs, where there exist multiple equilibria - one equilibrium where both regions innovate, and one where the East imitates. Economic growth is moreover lower and international wage differences larger in the equilibrium with imitation.

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1 Introduction

Trade liberalization and imitation seem to have been key words for countries like South Korea and Taiwan when they were transformed into modern industrial nations - or for the earlier industrialization processes of Germany and France, for that matter.[1] It is therefore important to understand both how imitation affects development in poor countries, and how it affects innovation incentives - and thereby growth - in the industrialized world. The present paper argues that the level of trade costs may be decisive in this respect. In particular, global economic growth may be higher and international wage gaps smaller if poor countries choose to imitate rather than to innovate when trade is costly, while the opposite may be true for some intermediate levels of trade costs. With extensive trade liberalization we may further expect international cost and income differences to be so small that all countries find imitation less profitable than innovation. To show these ambiguous effects of imitation we use a framework which departs from most of the existing literature in three important ways. First, we explicitly incorporate trade costs. Second, we assume that the countries are symmetric *ex ante*. Thereby we do not have to rely on any exogenous international differences. Third, the choice between innovation and imitation is endogenously determined.

In the formal model we consider a world consisting of two initially identical world regions with internationally immobile labour, in which a representative consumer has preferences for two kinds of goods. One of these is manufactured under constant returns to scale in a so-called traditional sector. The other is produced under increasing returns to scale and imperfect competition in a "modern" indus-

[1] The terms *trade liberalization* and *reduction of trade costs* will be used interchangeably. As in economic geography literature, trade costs are interpreted as everything that, other things being equal, makes it more expensive to buy foreign than domestic goods. This includes factors such as pure communication and transportation costs and handling of red tape. The *de facto* international trade costs for firms in East Asia, for instance, were presumably significantly reduced when circumstantial trade procedures and bureaucratic interference gradually were abolished from the late 1960's (see, e.g., Aoki, Kim, and Okuno-Fujiwara, 1997). We do not consider income-generating tariffs.

trial sector, and consists of a composite of intermediate goods which are imperfect substitutes. Both intermediate goods and the traditional good may be traded, but the former only at a cost.

It takes one unit of labour to produce one unit of an intermediate good, but in the spirit of the lab-equipment specification of Rivera-Batiz and Romer (1991) we assume that new varieties are developed by using already invented intermediates as inputs. The modern sector is thus both a major supplier and a major customer from itself. It is further assumed that innovation costs are decreasing in the number of available varieties. Our formulation implies that there are vertical industry linkages which may destabilize the symmetric equilibrium and generate geographical concentration of the modern sector. To see why the symmetric equilibrium is possibly unstable, suppose that the West for some reason has an infinitesimal larger share than the East of the intermediate goods producers. Other things being equal, the presence of trade costs implies that the incentives to found new research firms are then highest in the West (cost linkage). Simultaneously, the more research firms there are in a region, the higher the demand for intermediate goods in that region. This demand linkage in turn makes production of intermediate goods more profitable in the West than in the East. These self-reinforcing centripetal forces possibly imply that a larger number of new firms will be established in the West than in the East in the future, in which case the modern sector ends up being more or less concentrated internationally. Concentration may, however, generate excessive labour demand and too high competitive pressure in the West, and we therefore also have centrifugal forces which work against concentration.

Since there are no intrinsic differences between the regions, the symmetric equilibrium does always exist, but it will never be stable in the cases we consider. Instead, we shall see a stable asymmetric equilibrium where one region ends up having the majority of the firms in the modern sector; the industrialized West. Wages in the West will be relatively high because of the advantages created by the centripetal forces. The importance of the centripetal forces (and the corresponding disadvantage of a small home market for modern goods in the East) does, however, decrease if international trade becomes less costly. Consequently, both the size of the international wage gap and the degree of international concentration of the modern sector are reduced if trade is liberalized.

When we allow imitation to take place we follow Grossman and Helpman (1991. chapter 11) and assume Bertrand competition between two producers of the same good. However, contrary to Grossman and Helpman we do not presuppose that the poor region imitates. The choice between imitation and innovation is instead endogenously determined. As a simplification, the basic research technology for imitation is specified to be the same as for innovation, but with lower input requirement for the former. Imitators are not given any benefits when it comes to actual production of intermediate goods, so one unit of output requires one unit of labour both in the East and in the West. Imitation may still be profitable because entrepreneurs in the East can take advantage of their access to relatively inexpensive labour and undercut the prices of their foreign competitors.[2]

The only stable equilibrium that exists when trade is relatively expensive is one where entrepreneurs in the East copy goods from the West. Part of the reason is that the domestic market is relatively protected when trade is costly, and therefore the price war is moderate even with Bertrand competition. With expensive trade it is, moreover, particularly important that imitation requires less resources than does innovation (since the costs of imported inputs are strictly increasing in the level of trade costs). Thereby imitation tends to reduce the disadvantage of a small home market in the East and increase the regions's equilibrium wages. The subsequent higher demand for modern goods in turn lifts the value of making innovations in the West. We thus find that imitation reduces the international wage gap and increases the global growth rate compared to an outcome where both rich and poor regions innovate when trade is costly.[3]

There are also some negative effects of imitation that should be considered. In

[2]Since trade liberalization monotonically reduces international wage differences, we are immediately able to deduce that with Bertrand competition a profit maximizing entrepreneur will not imitate when trade costs are 'small' (wages are equalized in the absence of trade costs). We then have a unique equilibrium where both regions innovate.

[3]The model formulation implies that the two regions have the same steady state growth rate in Net National Product.

fact, at some intermediate levels of trade costs, these negative effects imply that we end up with a picture which is completely different from the one above. We then have multiple equilibria - one equilibrium where both regions innovate, and one equilibrium where entrepreneurs in the East imitate goods from the West. Moreover, the global growth rate is lower and the international wage gap wider in the latter equilibrium. There are two major reasons why growth is highest in the equilibrium where both regions innovate. First, imitation does by its very nature involve some duplication of research effort which tends to reduce the feasible growth rate. Second, the more imitators there are in the East the shorter the expected monopoly period for the original innovator in the West; an increase in the number of imitators therefore has a negative effect on innovation incentives. Because trade liberalization reduces the importance of the centripetal forces and thus increases the share of world-wide research that takes place in the East, these negative effects do not dominate before trade costs are reduced down to some intermediate levels. Trade liberalization likewise reduces the protection of the home market and exposes imitators to increasingly tougher price competition. This in turn reduces the sustainable equilibrium wages in the East compared to the equilibrium where both regions innovate.

The explanation of why we have multiple equilibria is the presence of pecuniary externalities. Consider first the equilibrium where the East imitates. Despite the low wage level in the region, it is not profitable for a single entrepreneur to deviate. Why? The reason is that imitations are sold at low prices, and a potential innovator would therefore face too high price competition from domestic producers of (imperfect) substitutes to be able to cover the relatively high innovation costs. However, by lowering the competitive pressure, innovation does become profitable if a sufficiently high number of entrepreneurs in the East choose to innovate rather than to imitate. This in turn allows higher equilibrium wages in the East. But then, because of this higher wage level, imitation is no longer profitable; due to the (latent) price competition from the original innovator in the West the profit margin will be too low to cover imitation costs.[4]

As far as we know, this is the first paper that studies how trade liberalization af-

[4]For a careful discussion of pecuniary externalities, see Matsuyama (1995).

fects imitation and innovation incentives in a model where the countries moreover are intrinsically identical. Grossman and Helpman (1991), on which the present paper builds, considers a completely integrated world in a knowledge-driven model. They presuppose that the poor region does not innovate, and have de-facto exogenous wages. Barro and Sala-i-Martin (1995, ch. 8) assume that intermediate goods are non-traded. They do not focus on how imitation affects the growth rate; their aim is rather to show convergence effects of imitation and knowledge spillovers. Currie et al (1996) use the same framework as Grossman and Helpman, but presuppose that one region - for some reason - has an advantage over the other in knowledge assimilation. This may lead the backward region to imitate goods from the more advanced one. In effect, Currie et al further assume increasing returns to knowledge accumulation in the copying sector and show how the backward region eventually finds it profitable to innovate. Their primary focus is policy implications in a North-South perspective. Segerstrom (1991) deviates from both the present article and those mentioned above by assuming that there is a tacit price collusion between the original innovator and the imitator (rather than Bertrand competition) in a 'Quality Ladder' model. What Segerstrom seeks to explain is why entrepreneurs in the rich industrialized world copy goods from other firms in the same region, and his framework is not suited for analysis of interactions between rich and poor countries.

The rest of this paper is organized as follows. The formal model is presented in section 2, while section 3 treats the case where both regions are completely specialized. Imitation and innovation incentives are discussed in section 4, which also compares growth rates with and without imitation. Section 5 concludes.

2 The model

There are two regions, W (West) and E (East), with population sizes equal to $L_j\,(j = W, E)$. In general we shall assume that $L_W = L_E$, although we allow $L_W \neq L_E$ when we derive the growth equations. Each inhabitant supplies one unit of labour, is internationally immobile, and there is no population growth. The consumers have identical preferences, and demand goods from a modern (m) and a traditional (z) sector. We abstract from traditional comparative advantages, and assume that (skilled) labour is the only primary input.

Demand side:

A representative consumer in region j has preferences of the form

$$U_j = \int_0^\infty \ln\left[m_j(s)^\eta z_j(s)^{1-\eta}\right] e^{-\rho s} ds. \tag{1}$$

The m-good consists of a number of differentiated intermediate goods which are costlessly assembled, and we assume the CES specification $m_j = \left[\sum_{k=1}^{n} x_k^{\frac{\sigma-1}{\sigma}}\right]^{\frac{\sigma}{\sigma-1}}$ ($\sigma > 1$) where $n = n_W + n_E$ is the available number of variants at time s. Let $q_k(s)$ be the consumer price of good k. All active producers of intermediate goods in a given region charge the same price in the cases we consider,[5] so the price index for the $m-$good can be written as (for $i, j = W, E$; $i \neq j$)

$$p_{mj} = \left[n_i q_i(s)^{1-\sigma} + n_j q_j(s)^{1-\sigma}\right]^{\frac{1}{1-\sigma}}. \tag{2}$$

Each consumer inelastically supplies one unit of labour, and the intertemporal budget constraint may consequently be written as

$$\int_0^\infty [p_{mj}(s)m_j(s) + p_{zj}(s)z_j(s)]\, e^{-\int_0^s r_j(v)dv} ds = \int_0^\infty w_j(s)e^{-\int_0^s r_j(v)dv} ds + \frac{\Omega_j(0)}{L_j}. \tag{3}$$

The symbol $\Omega_j(0)$ denotes the present value of aggregate financial wealth in region j, w_j the wage level, p_{zj} the price of the traditional good, and r_j the interest rate.

Let $\mathcal{E}_j$ be consumer expenditure in region j. Utility maximization then implies

$$\frac{d\mathcal{E}_j/dt}{\mathcal{E}_j} = r_j(s) - \rho. \tag{4}$$

Our focus will be on equilibria where one region - which, without loss of generality, is taken to be the East - produces world-wide demand for the traditional good, and in this stable asymmetric equilibrium $w_E < w_W$ whenever we have positive trade costs (see section 3). The choice of nominal values does not affect the real side of the economy, and it turns out to be convenient to choose $w_W \equiv 1$. With this choice

[5] This need not necessarily be the case if there is imitation, see Appendix A2.

of numeraire the expenditure level in each region is constant in steady state, so that in both regions we have $r(s) = \rho$ along the balanced growth path.

Supply side:

The z-good is produced with labour as the only input, and with a constant returns to scale technology. We normalize such that unit labour requirement is one, and assume that the good is traded costlessly. Consequently $p_z = p_{zj} = w_E$.

It is the modern sector that potentially gives rise to growth. The most common way to model linkages between trade and growth is to assume that there exist international knowledge externalities (e.g., Baldwin and Forslid 1996a, 1996b). Here we shall rather use a variant of what Rivera-Batiz and Romer (1991) call a lab-equipment model. The underlying idea is that the development of new kinds of goods uses formerly developed goods as inputs. In this formulation knowledge *per se* has no productive value since intermediate goods are the only inputs. We shall follow Ethier (1982) and Holtz-Eakin and Lovely (1996), and let the production function for new varieties of intermediate goods be of the form

$$h(x,n) = n^{\alpha}\left[\frac{1}{n}\left(\sum_{k=1}^{n} x_k^{\frac{\sigma-1}{\sigma}}\right)\right]^{\frac{\sigma}{\sigma-1}}, \tag{5}$$

where α is a positive constant. Note that we do not need to distinguish between the number of available varieties (n) and those that are actually used, since the specification implies that all invented goods will be used in a positive amount by a profit maximizing firm. Ethier developed (5) in order to capture Adam Smith's notion of division of labour, and the higher the α the higher the gains from increased specialization.[6] We shall use the same interpretation, but in order to obtain a constant steady state growth rate we must choose $\alpha = 2$. If we take the dual of (5), and let q_k denote the *c.i.f.* price (i.e., inclusive of possible trade costs) on good k, we then find that the cost of a new innovation equals

$$P_j = \frac{1}{n_i + n_j}\left[\frac{n_i q_i^{1-\sigma} + n_j q_j^{1-\sigma}}{n_i + n_j}\right]^{\frac{1}{1-\sigma}}. \tag{6}$$

[6]For other interpretations of (5), see Baldwin and Forslid (1996b), Martin and Ottaviano (1997), and Evans, Hokapohja, and Romer (1998).

Innovation costs thus decrease by one percent if the number of varieties increases by one percent in each region.[7]

Labour requirement to manufacture an x-good is, by choice of scale, set equal to one. The inverse elasticity rule consequently gives us that a monopolist charges the *f.o.b.* price

$$p_j = \frac{\sigma}{\sigma - 1} w_j. \tag{7}$$

Trade costs on x-goods are modelled in a manner which is well known from economic geography literature; of each unit shipped, only $\frac{1}{\tau}$ reaches its destination ($\tau \geq 1$). This means that the *c.i.f.* price is τ times higher than the *f.o.b.* price for an imported good.

3 Complete international specialization

Even though the West and the East are symmetric *ex ante*, the fact that the research sector is both a major supplier and a major customer of itself may imply that the modern sector ends up being more or less concentrated in one region. To see why, suppose that the West for some reason produces a larger set of intermediate goods than does the East. In that case the West may be expected to have the majority of research firms in the future because of the region's easier (less expensive) access to inputs (cost linkage). But if the West ends up with a higher number of research firms than the East, then also future demand for innovated goods is highest in the West (demand linkage). These self-reinforcing centripetal forces may lead to an international concentration of the modern sector. On the other hand, concentration may intensify product market competition and lead to excessive demand for labour.[8]

[7] The growth rate would approach zero if we had chosen $\alpha < 2$ and infinity if $\alpha > 2$. Thus, to quote Romer (1990, p. 84): "Linearity in $[n]$ is what makes unbounded growth possible, and in this sense, unbounded growth is more like an assumption than a result of the model." Lucas (1988) also makes similar linearity assumptions, and stresses that all endogenous growth models necessarily hinge on knife-edge assumptions.

[8] Careful discussions of centripetal and centrifugal forces in static economic geography models are offered by Krugman (1991), Krugman and Venables (1995), and Venables (1996). For extensions to dynamic frameworks, see Martin and Ottaviano (1997) and chapter 4 of this thesis.

These centrifugal forces tend to generate international decentralization, but the symmetric equilibrium is never stable in the cases we consider. The only stable equilibrium is instead one where the West ends up with the majority of the firms in the modern sector. Wages in this region will then be relatively high due to the advantages created by the centripetal forces.[9]

In the stable asymmetric equilibrium both regions are specialized when trade is 'expensive': the West in production of modern goods and the East in production of the traditional good. We will now characterize this equilibrium. To this end it is useful to define x_{jl}^{inn} and x_{jl}^{cons} as the gross demand that a representative producer in region j faces from innovators and consumers, respectively, in region l $(l = i, j)$.

The cost of making $\dot{n}_W$ new innovations in the West is $\dot{n}_W P_W$. There are n_W suppliers of intermediate goods (as long as only the West produces modern goods), and equality between aggregate supply and aggregate demand to the research sector therefore requires $n_W p_W x_{WW}^{inn} = \dot{n}_W P_W$. Producers of intermediates moreover sell goods to consumers in the two regions, and due to the shape of the utility function we know that consumers in region j use a share η of their income $\mathcal{E}_j$ on modern goods. In equilibrium we must therefore have $n_W p_W x_{WW}^{cons} = \eta \mathcal{E}_W$ and $n_W p_W x_{WE}^{cons} = \eta \mathcal{E}_E$.[10] Let $g = \frac{\dot{n}_W}{n_W}$ be the growth rate of new innovations in the West. Gross demand for goods produced in the modern sector can then be written as (for $j = W, E$)[11]

$$\begin{aligned} x_{WW}^{inn} &= \frac{P_W}{p_W} g, \text{ and} \\ x_{Wj}^{cons} &= \frac{\eta \mathcal{E}_j}{n_W p_W}. \end{aligned} \tag{8}$$

Let x_W be aggregate demand for goods produced by a representative firm in the

[9] See Appendix A1 for a discussion of parameter values and possible equilibria.

[10] Recall that of each unit shipped only $\frac{1}{\tau}$ actually reaches its destination. Consumption of modern goods in the East is therefore equal to $n_W \frac{x_{WE}^{cons}}{\tau}$. Since the *c.i.f.* price is $p_W \tau$ we thus have $n_W \left(\frac{x_{WE}^{cons}}{\tau}\right)(p_W \tau) = n_W x_{WE}^{cons} p_W$.

[11] The demand functions can also be deduced by using Shepard's lemma on equations (2) and (6).

West. Labour market equilibrium can then be expressed as

$$\begin{aligned} L_W &= n_W x_W, \text{ and} \\ L_E &= \frac{(1-\eta)\left(\mathcal{E}_W + \mathcal{E}_E\right)}{w_E}. \end{aligned} \tag{9}$$

From equations (6) and (8) we find that $\frac{d}{dt} n_W x^{inn}_{WW} = \frac{d}{dt} n_W x^{cons}_{Wj} = 0$ when $\frac{d\mathcal{E}_j/dt}{\mathcal{E}_j} = 0$ and $\frac{\dot{g}}{g} = 0$.[12] This gives a time invariant sector division of labour, and will be called a steady state equilibrium.

The value v_W of a firm that manufactures intermediate goods must at least equal innovation costs P_W if an entrepreneur shall be willing to invest in development of a new variant. With positive growth and free entry into the innovative sector, it must therefore always be true that

$$P_W = v_W. \tag{10}$$

The ownership of the firms is evenly spread among domestic consumers as share holders. From equations (6) and (10) we find $\frac{\dot{v}_W}{v_W} = -g$ in steady state, and that aggregate share value - which equals consumer wealth - is constant and given by

$$\Omega_W = n_W v_W = n_W P_W. \tag{11}$$

The instantaneous profit flow received by a representative firm equals $\pi_W = (p_W - w_W)x_W = \frac{p_W x_W}{\sigma}$, and the present value is $\frac{\pi_W}{(\rho+g)}$ since the share price decreases by the rate g and the interest rate equals ρ.[13] We may therefore interpret $(\rho + g)$ as the required rate of return, or the effective discount rate. The free entry condition (10) may consequently be reformulated as

$$\frac{p_W x_W}{(\rho+g)\,\sigma} = P_W. \tag{12}$$

Consumer expenditure equals wage income plus profit flows from existing firms minus new investments (savings);

$$\mathcal{E}_W = w_W L_W + n_W \pi_W - \dot{n}_W P_W \tag{13}$$

[12] Equilibrium prices on intermediates are constant since $w_W \equiv 1$. Therefore equation (6) now implies $\frac{\dot{P}_W}{P_W} = -\frac{\dot{n}_W}{n_W}$.

[13] See Appendix A2 for a formal proof.

This can be simplified to $\mathcal{E}_W = w_W L_W + \rho\Omega_W$ in steady state because financial wealth then is constant (c.f. equation (11)). Since we further have $\mathcal{E}_E = w_E L_E = (1-\eta)(\mathcal{E}_W + \mathcal{E}_E)$, it follows that

$$w_E = \frac{1-\eta}{\eta}\left[\frac{w_W L_W + \rho\Omega_W}{L_E}\right]. \tag{14}$$

Labour requirement to cover consumer demand for modern goods is $\frac{\eta\mathcal{E}_W + \eta\mathcal{E}_E}{p_W}$, which equals $\frac{\mathcal{E}_W}{p_W}$ since balanced trade requires $\eta\mathcal{E}_E = (1-\eta)\,\mathcal{E}_W$. Note also that it takes $n_{WW}^{inn} x_{WW} \frac{\dot{n}_W P_W}{p_W}$ workers to develop $\dot{n}_W$ new varieties (see also equation 8), so therefore $\frac{n_W P_W}{p_W}$ times $\left(\frac{\dot{n}_W}{n_W}\right)$ workers are needed to generate a constant growth rate g. A total of g workers are thus used in the innovative sector, since

$$\frac{n_W P_W}{p_W} = 1 \tag{15}$$

from equation (6). In this case the variable g thus measures both the growth rate and the number of workers which implictly is employed in the research sector. Using $\mathcal{E}_W = w_W L_W + \rho\Omega_W$ we thus have $g = L_W - \frac{\mathcal{E}_W}{p_W} = L_W - \frac{w_W L_W}{p_W} - \frac{\Omega_W}{p_W}\rho$. The first term on the far r.h.s. is labour supply to the modern sector (since the West is specialized). The second and third terms show how much labour is needed to satisfy the part of consumer demand which is financed by current wage and interest income, respectively. Inserting for Ω_W, the equation can be simplified to

$$g = \frac{L_W}{\sigma} - \rho. \tag{16}$$

The growth rate of new innovations is thus increasing in the labour force, which is a standard scale effect in endogenous growth models. Equation (16) moreover shows that g is decreasing in σ (because a high σ means that the goods are poor complements) as well as in ρ (reflecting consumer impatience).

The growth rate in real consumption in region j is equal to $\mu_j = \frac{p_{mj}\dot{m}_j + p_z\dot{z}_j}{E_j} = \eta\frac{\dot{m}_j}{m_j}$, where the last equality follows because there is no progress in the traditional sector ($\dot{z}_j = 0$) and because a share η of the income is spent on goods from the modern sector. It can further be shown that $\frac{\dot{m}_j}{m_j} = \frac{g}{\sigma-1}$, and consequently

$$\mu_E = \mu_W = \eta\frac{g}{\sigma-1} \tag{17}$$

Thus, even though the East is relatively poor and does not perform research, the steady state growth rate in real per capita consumption is the same in the two regions.[14] Note that this fits well with the observation that there does not seem to be any systematic relationship between long-term growth and per capita income (e.g. Lucas 1988). The result that $\mu_E = \mu_W$ is not surprising; it simply reflects that by participating in trade, countries gain access to technologies developed by their trading partners. See also Baldwin, Braconnier and Forslid (1998) for a discussion of this point.

4 Innovation and imitation incentives

We are now ready to look at growth consequences of product imitation and trade liberalization. It will be assumed that input requirement to actually *produce* intermediate goods is the same for an imitator and an innovator (with unit labour requirement as above),[15] but that imitation in itself calls for less resources than does innovation.[16] For analytical convenience the development costs for an imita-

[14] "Physical" output in the modern sector is equal to $Y_m = n_W x_W \Rightarrow \frac{\dot{Y}_m}{Y_m} = \frac{\dot{n}_W}{n_W} + \frac{\dot{x}_W}{x_W} = 0$. In this sense there is no output growth in the present model, and the same holds for the knowledge driven models developed by Grossman and Helpman (1991). Barro and Sala-i-Martin (1995, ch. 6.2) find this aspect unappealing, and typically prefer models with a single consumer good which is produced in ever increasing quantities. Matsuyama (1995, p. 702), on the other hand, claims that "..our standard of living rises not so much by producing more of the same products, but by adding new products to the list of those we already produce and consume.". But Barro and Sala-i-Martin (1995, p. 236) point out that "fundamentally the only final good is the flow of utility" and in both approaches it is the absence of diminishing returns that allows sustainable utility growth. The controversy should therefore not be exaggerated.

[15] There are of course many reasons why this assumption need not be true. Internal learning-by-doing, for instance, could give the initial innovator an advantage, while an imitator may have uncovered better production technologies after the product initially was developed. Such effects are discussed by, e.g., Barro and Sala-i-Martin (1995), Grossman and Helpman (1991), and Lucas (1993).

[16] In an empirical study for the USA Mansfield et al (1981) have identified several sectors where imitation requires less effort than innovation, and found that imitation costs, on average, equal 65% of the original innovation costs. It is worth noting that they also found that patents rarely

tion are specified as

$$Q_j = \kappa P_j \tag{18}$$

where $\kappa < 1$. The basic production technology for imitation is hence the same as for innovation, but with a higher input requirement for the latter.

We shall follow Grossman and Helpman (1991) and assume that there is Bertrand competition between two producers who manufacture the same product, and this amounts to limit pricing if the preferred monopoly price is higher than the rival's marginal cost. Therefore it is unprofitable to incur fixed costs in order to copy domestic products, which in particular precludes imitation to take place in the West. Moreover, it cannot be profitable for entrepreneurs in the East to imitate goods from the West when trade costs are "low' because the difference in marginal costs then is too small (at the extreme τ=1 it would be impossible to cover any fixed costs at all since we then have $w_E = w_W$).[17]

Before we extend the model to allow for imitation, it may be useful to look at the wage curves in Figure 1 (which holds in a pure innovation equilibrium). The lowest price at which it is possible for a producer in region j to sell for in region i is τw_j ($i \neq j$). The left panel of Figure 1 shows that $p_E < \tau w_W$ with our parameter values (see Appendix A1) when trade costs are above ca. 1.38. An imitator in the East would consequently charge its monopoly price domestically - and thus be unaffected by the original innovator in the West - as long as $\tau >1.38$.[18] Below this level of trade costs the optimal price would be (infinitesimally lower than) τw_W. The right panel of Figure 1 likewise illustrates the outcome in region West, but τp_E (not shown) is always higher than w_W for the chosen parameter values. Therefore an imitator is unable to charge the preferred monopoly price on the export market, but there is still room for a positive profit rate since $\tau w_E < w_W$ for $\tau <1.9$. Note that trade liberalization tends to reduce the profit margin for an imitator both domestically

hinder imitation, but typically make it more expensive.

[17]Grossman and Helpman assume exogenous international differences in productivity and wages (in a completely integrated world), so this point is not relevant for their case. Still, many of the techniques applied in this paper are inspired by Grossman and Helpman.

[18]This critical τ-value is higher if imitation actually takes place, because the increased labour demand in the East then presses up the wage level.

and abroad when τ is below approximately 1.4.

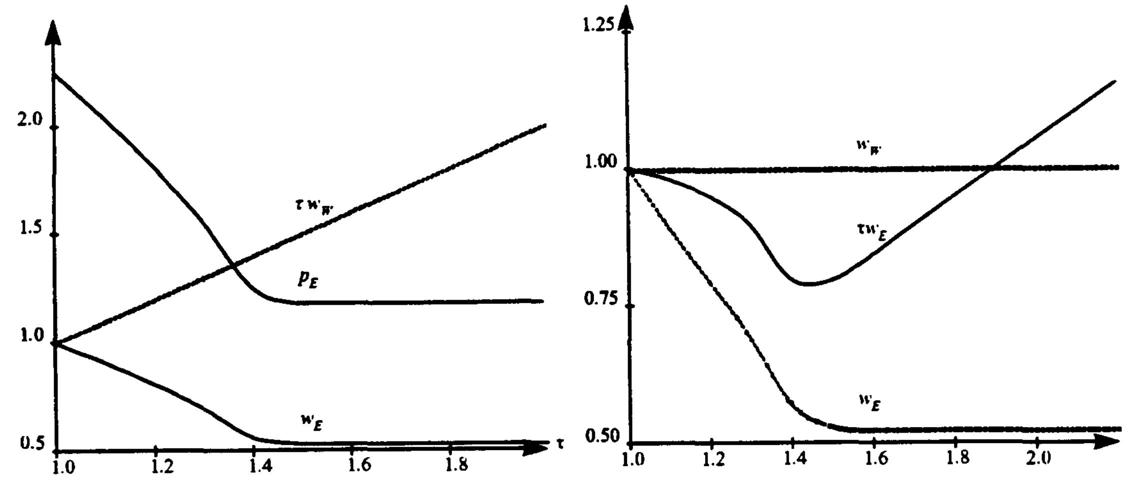

Figure 1: *Trade costs and possible price patterns.*

The growth equations when we allow imitation to take place are derived in section 4.1.1. Section 4.1.2 discusses innovation incentives when there is a positive rate of imitation, while growth rates with and without imitation are compared in 4.2. The system of equations which determines the general equilibrium is rather complex, and to a large degree we shall therefore rely on simulations and figure examinations. Some of the effects are illustrated mathematically in the appendix.

4.1 An equilibrium with imitation

The starting point of the analysis is a situation where trade costs initially are so high that the East is specialized in production of the traditional good. The wage level w_E is then given by equation (14).

We might imagine several changes in price outcomes both for innovators and imitators as trade costs are reduced (see Appendix A2). Here in the main text we shall look at a particularly simple case, namely one where the original innovator in the West is never able to earn a positive profit rate in any market on a product that has been copied. Though imitators are always bound by limit pricing on their export market, they are nonetheless able to charge monopoly prices domestically if trade costs are relatively high. Trade liberalization does, however, reduce the protection of the home market, and therefore imitators must use limit pricing both domestically and abroad for some lower levels of trade costs. Finally, it is more profitable to innovate than to imitate also in the East when trade is 'inexpensive'.

4.1.1 Growth equations in the presence of imitation

Suppose that the East is specialized in production of the traditional good, and that trade costs are too high to make innovation profitable for the region. How can we find out if it is profitable for a single entrepreneur to imitate a good from the West?

Assume that the level of trade costs is such that $p_E < \tau w_W$ and $\tau w_E < w_W < \tau p_E$ (c.f. Figure 1). In that case an imitator in the East would choose the price p_E domestically and the *c.i.f.* price w_W abroad (due to limit pricing). The corresponding profit margins are $(p_E - w_E) = \frac{p_E}{\sigma}$ and $(w_W - \tau w_E)$, respectively. *Net* demand for an imported good in the East is $\frac{x_{WE}^{cons}}{\tau}$. With an elasticity of demand equal to σ an imitator would therefore expect to sell $(\frac{p_E}{p_W \tau})^{-\sigma}\left(\frac{x_{WE}^{cons}}{\tau}\right)$ at home and, similarly, $(\frac{w_W}{p_W})^{-\sigma}(x_{WW}^{cons} + x_{WW}^{inn})$ abroad. We know that $x_{WE}^{cons} = \frac{\eta \mathcal{E}_E}{p_W n_W}$, and we also have $\left(x_{WW}^{cons} + x_{WW}^{inn}\right) = \frac{p_W L_W - (1-\eta)\mathcal{E}_W}{p_W n_W}$. The latter follows because there are L_W workers in the West who each produces one unit of intermediate good (so that the value of production in the West equals $p_W L_W$) and $(1-\eta)\,\mathcal{E}_W$ of the region's income is spent on the traditional good.

Since the cost of making an imitation is $Q_E = \kappa P_E = \kappa \tau P_W$, and the discount rate is $(\rho + g)$, it is thus profitable for a single entrepreneur in the East to imitate a good from the West if

$$\frac{\left(\frac{p_E}{\tau p_W}\right)^{1-\sigma} \frac{\eta \mathcal{E}_E}{n_W \sigma} + \left(\frac{w_W}{p_W}\right)^{-\sigma} \left(\frac{w_W - \tau w_E}{p_W}\right) \left[\frac{p_W L_W - (1-\eta)\mathcal{E}_W}{n_W}\right]}{\rho + g} \geq \kappa \tau P_W. \tag{19}$$

Note that there are three effects of reduced trade costs from a potential imitator's point of view. The negative effect, shown by the first term in the numerator of (19), is that the home market becomes less protected. The positive image of this, shown by the second term in (19), is that the access to the large export market improves. Finally, liberalization implies that imported inputs become less expensive, reducing the r.h.s. of (19).

Suppose imitation is profitable, and that n_E goods have been copied by entrepreneurs in the East. If n goods have been developed in the West so far, only $n_W = n - n_E$ are still produced in that region. The price indexes are consequently given by

$$\begin{aligned} P_W &= \frac{1}{n_W + n_E} \left[\frac{n_W p_W^{1-\sigma} + n_E w_W^{1-\sigma}}{n_W + n_E} \right]^{\frac{1}{1-\sigma}}, \text{ and} \\ Q_E &= \frac{\kappa}{n_W + n_E} \left[\frac{n_E p_E^{1-\sigma} + n_W (p_W \tau)^{1-\sigma}}{n_W + n_E} \right]^{\frac{1}{1-\sigma}}. \end{aligned} \tag{20}$$

The price P_W does not depend on the level of trade costs directly, but indirectly it is a function of τ through the split of n between n_W and n_E.

At each moment of time $\dot{n}$ goods are developed in the West while $\dot{n}_E$ goods are copied in the East, and it is easy to verify that $\frac{\dot{n}}{n} = \frac{\dot{n}_E}{n_E} = \frac{\dot{n}_W}{n_W}$ in steady state. Due to the CES-formulation we know that firms in region j have an aggregate market share equal to $s_{jk} = \frac{n_k q_k^{1-\sigma}}{n_j q_j^{1-\sigma} + n_i q_i^{1-\sigma}}$ in market $k = i, j$ (where the q's are *c.i.f.* prices). By using the same kind of intuition as led us to equation (8) (which gave us demand for internediates when both countries were specialized), or by using Shepard's lemma equation (20), we find that

$$\begin{aligned} x_{WW}^{inn} &= \frac{s_{WW} P_W}{p_W} \frac{n}{n_W} g, \\ x_{WE}^{m} &= \frac{s_{WE} Q_E}{p_W} \frac{n_E}{n_W} g, \text{ and} \\ x_{EE}^{m} &= \frac{s_{EE} Q_E}{p_E} g, \end{aligned}$$

where superscript m denotes demand from imitators. The equations for x_{EE}^{cons} and x_{Wj}^{cons} ($j = W, E$) are similar to those given by (8), corrected for market shares, while gross demand for an imported imitated good is[19]

$$\begin{aligned} x_{EW}^{cons} &= \tau \frac{s_{EW} \eta \mathcal{E}_W}{w_W n_E}, \text{ and} \\ x_{EW}^{inn} &= \tau \frac{s_{EW} P_W}{w_W} \frac{n}{n_E} g. \end{aligned}$$

With a positive rate of imitation the corresponding free entry condition can thus

[19]An analytically convenient property of Samuelson iceberg trade costs and monopolistic competition is the fact that the export value $(p_j x_{ji})$ from country j of each particular variant equals the import value $(p_j \tau)(\frac{x_{ji}}{\tau})$ to country i. This is no longer true in the absence of mark-up pricing.

be written as

$$Q_E = \frac{p_E\left(x_{EE}^m + x_{EE}^{cons}\right)}{\sigma(\rho+g)} + \frac{\left(\frac{w_W}{\tau} - w_E\right)\left(x_{EW}^{inn} + x_{EW}^{cons}\right)}{\rho+g}. \tag{21}$$

During one period of time a share $m \equiv \frac{\dot{n}_E}{n_W}$ of the goods presently produced in the West is copied by entrepreneurs in the East. Since all non-imitated goods are considered identical by a potential imitator, they should also have the same probability of being copied. We can thus interpret m as the probability per unit of time that any given intermediate is imitated. The consumers will hold a well diversified portfolio of shares, and in steady state the expected value of an innovation will be equal to development costs:[20]

$$v_W = \frac{p_W x_W}{\sigma(\rho+g+m)} = P_W \tag{22}$$

It takes $\frac{s_{WW}\eta\mathcal{E}_W + s_{WE}\eta\mathcal{E}_E}{p_W}$ units of labour in the West to meet consumer demand for modern goods, while $\frac{s_{WE}\dot{n}_E Q_E}{p_W}$ workers are needed to satisfy demand from imitators in the East. This leaves

$$\frac{s_{WW}\dot{n}P_W}{p_W} = L_W - \frac{s_{WW}\eta\mathcal{E}_W + s_{WE}\eta\mathcal{E}_E}{p_W} - \frac{s_{WE}\dot{n}_E Q_E}{p_W} \tag{23}$$

workers to the research sector in the West. We shall find a growth equation which is very easy to read if we note that balanced trade requires

$$s_{WE}\eta\mathcal{E}_E + s_{WE}\dot{n}_E Q_E = (1-\eta)\mathcal{E}_W + s_{EW}\eta\mathcal{E}_W + s_{EW}\dot{n}P_W. \tag{24}$$

Using $\frac{\dot{n}}{n} = \frac{\dot{n}_E}{n_E} = g^m$ (superscript m for imitation) and $\mathcal{E}_j = w_j L_j + \rho\Omega_j$ together with equations (23) and (24) we have $\frac{nP_W}{p_W}g^m = L_W - \frac{w_W L_W}{p_W} - \frac{\Omega_W}{p_W}\rho$, or

$$g^m = \frac{p_W}{nP_W}\frac{L_W}{\sigma} - \frac{n_W}{n_W+n_E}\rho, \tag{25}$$

where

$$\frac{nP_W}{p_W} = \frac{\left[\frac{n_W p_W^{1-\sigma} + n_E w_W^{1-\sigma}}{n_W+n_E}\right]^{\frac{1}{1-\sigma}}}{p_W} < 1. \tag{26}$$

[20] A formal proof is given in Appendix A2.

Since $\frac{nP_W}{p_W} < 1$ comparison of (25) and (16) reveals that the growth rate is higher when the East imitates than when the region is specialized in the traditional sector. The intuition is simple: import of imitated goods means that a smaller number of workers in the West is needed for each percentage point of growth (c.f. equation (15) which showed that $\frac{n_W P_W}{p_W} = 1$ when both regions are specialized). Moreover, only a share $\frac{n_W}{n_W + n_E}$ of consumer demand financed from financial wealth is now covered by firms in the West.

Trade liberalization reduces the East's disadvantage with respect to market access. Therefore imitation becomes more profitable, and equations (25) and (26) thus make it clear that trade liberalization increases the growth rate g^m. But the higher imitation rate also increases labour demand, and therefore the wage level in the East is pushed up. Trade liberalization moreover makes the home market in the East less protected, and when trade is sufficiently liberalized we reach a critical level of trade costs where p_E exceeds τw_W. When this happens imitators must change to a limit-pricing strategy also domestically. Domestic demand for an imitation then equals

$$\begin{aligned} x_{EE}^{cons} &= \frac{s_{EE}\eta \mathcal{E}_E}{\tau w_W n_E}, \text{ and} \\ x_{EE}^{m} &= \frac{s_{EE} Q_E}{\tau w_W} g, \end{aligned} \tag{27}$$

while imitation costs Q_E and innovation costs P_W (indirectly) are given by

$$Q_E = \frac{\kappa}{n_W + n_E}\left[\frac{n_W(\tau p_W) + n_E(\tau w_W)^{1-\sigma}}{n_W + n_E}\right]^{\frac{1}{1-\sigma}} = \kappa \tau P_W. \tag{28}$$

The free entry condition for imitation is consequently

$$Q_E = \frac{(w_W \tau - w_E)\left(x_{EE}^{cons} + x_{EE}^{m}\right)}{\rho + g} + \frac{\left(\frac{w_W}{\tau} - w_E\right)\left(x_{EW}^{cons} + x_{EW}^{inn}\right)}{\rho + g}. \tag{29}$$

Because all variables are continuous in τ, the change in price strategy does not have any qualitative implications for the growth rate. This is also clear from the derivation of g^m from equation (25). Further trade liberalization does, however, still increase the wage level in the East, and when trade costs are sufficiently low, it becomes more profitable to innovate than to imitate also in this region. Using the same method as above, it is straightforward to show that this happens when

$$\frac{1}{\sigma}\left(\frac{p_E}{w_W}\right)^{1-\sigma}\frac{\tau^{1-\sigma}s_{EW}\left[\eta\mathcal{E}_W+nP_Wg\right]+\tau^{\sigma-1}s_{EE}\left[\eta\mathcal{E}_E+n_EQ_Eg\right]}{n_EQ_E}\geq\frac{1}{\kappa}\left(\rho+g\right). \quad (30)$$

Since $[\eta\mathcal{E}_W+nP_Wg]=[p_WL_W-(1-\eta)\mathcal{E}_W]$ the interpretation of (30) is analogue to the one we gave for equation (19).

We moreover find that the growth rate when both regions innovate is

$$g=\frac{p_W}{n_WP_W}\frac{L_W}{\sigma}-\rho, \quad (31)$$

where the labour requirement in the West per percentage point growth now is given by

$$\frac{n_WP_W}{p_W}=\frac{\frac{n_W}{n_W+n_E}\left[\frac{n_Wp_W^{1-\sigma}+n_E\left(p_E\tau\right)^{1-\sigma}}{n_W+n_E}\right]^{\frac{1}{1-\sigma}}}{p_W}. \quad (32)$$

4.1.2 Innovation incentives in the presence of imitation

This section takes a closer look at positive and negative effects of trade liberalization and the subsequent higher imitation rate from the point of view of innovators in the West. The analysis will be based on figure discussion, while Appendix A3 offers a mathematical treatment.

Figure 2 may be useful in order to understand the interaction between innovation and imitation. All markets in the East as well as in the West are in equilibrium along the curve $L_W^d=L_W^s$, except that v_W possibly differs from P_W.[21] Above this curve there is excess demand for labour in the West ($L_W^d>L_W^s$), and excess supply of labour below the curve. The curve is upward sloping because a higher rate of imitation releases labour in the West, and therefore allows a larger delivery of intermediate goods to the research sector (for any given consumer demand). This effect consequently gives us a positive relationship between m and g.[22] Along the

[21] To compute this curve we must use equation (13) since $\mathcal{E}_W\neq w_WL_W+n_WP_W$ in general.

[22] Analogue "labour saving" effects in the rich region are a major reason why imitation speeds up the global growth rate in Grossman and Helpman (1991).

curve $v_W = P_W$, where the labour market in the West is possibly in disequilibrium, innovations exactly break even, while the net present value of research is positive (negative) below (above) the curve. The curve is downward sloping because the expected net present value of making an innovation decreases when the imitation rate increases. This reflects both the fact that a higher m increases the probability of a given brand to be copied in the future - implying a higher effective discount rate $(\rho + g + m)$ - and that innovators loose market share to low price competitors. Note, however, that $v_W = P_W$ is relatively flat. The obvious reason for this is that imitation reduces innovation costs P_W. In addition, aggregate demand for intermediate goods may also increase; directly because imitators use intermediate goods as inputs, and indirectly because a higher m might increase wages and financial income in the East. These effects are discussed in detail in Appendix A3.

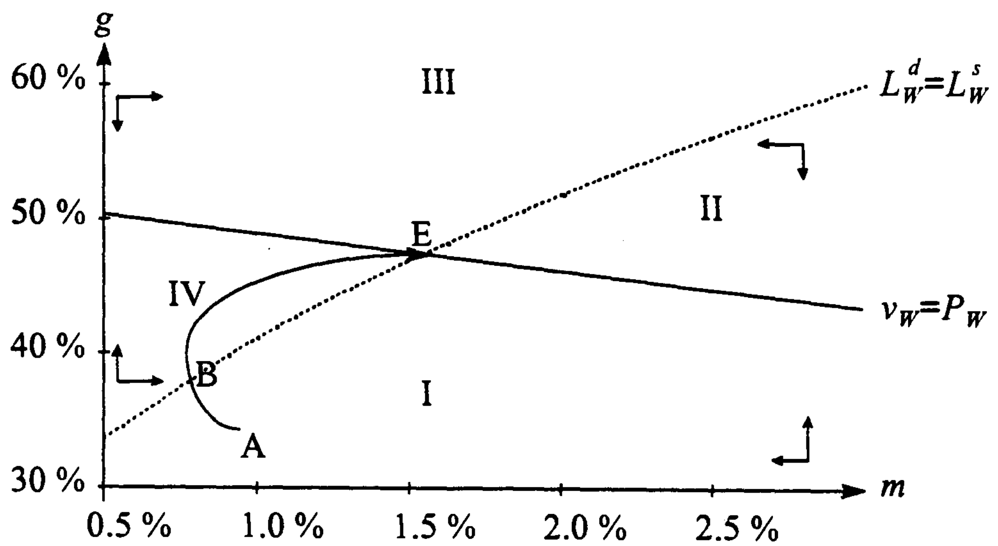

Figure 2: *Interaction between innovation and imitation.*

There is unemployment in quadrants I and II in Figure 2, and pure profits in quadrants I and IV.[23] Imagine that we have an exogenous shock which brings us from the initial equilibrium E to a point like A. Here excess supply of labour puts a downward pressure on relative wages in the West, and the region's competitiveness

[23]Note that Figure 2 is not really a phase diagram, and we have not given any story to tell why there should ever be disequilibrium in the labour market or the financial market. The discussion is only meant to highlight the forces at work.

improves (the East's cost advantage is reduced). Thereby it becomes less profitable for entrepreneurs in the East to produce intermediate goods, and m decreases. Simultaneously the growth rate in the West increases because innovators observe pure profits. At point B the labour market is in equilibrium, but the growth rate still increases because $v_W > P_W$. Consequently, demand for intermediate goods further increases. Other things being equal, this causes labour shortage in the West at the prevailing wages. Therefore the competitiveness in the East improves, and imitation becomes more profitable. This process continues until we are back at equilibrium point E.

Now let us look at consequences of trade liberalization. The *c.i.f.* price on imported goods relative to domestic goods is independent of the level of trade costs if an imitator uses limit pricing in both regions.[24] Trade liberalization gives the East better market access to the large West market, and increases the wage level w_E. For any given m this implies a higher demand for modern goods, and the firm value v_W increases. The curve $v_W = P_W$ is consequently shifted upwards, as shown in Figure 3. (Note that the shift would have been larger if there were limit pricing only in the West, since in that case the relative price of imported goods in the East would decrease.) But the higher consumer expenditure in the East also entails excess demand for labour in the West, so the $L_W^d = L_W^s$ curve is shifted downwards. Compared to the initial equilibrium, trade liberalization thus has led to pure profits for innovators and labour shortage in the West. Equilibrium is then restored by increasing both the imitation share m and the innovation rate g (similar to the process described for Figure 2, quadrant IV).[25]

[24]They are equal to $(\frac{p_W}{w_W})$ in East and $\left(\frac{w_W}{p_W}\right)$ in West, c.f. equation (28).

[25]In principle, these curve shifts could imply a higher m and a lower g in the new equilibrium, but we already now from equation (25) that trade liberalization has positive growth effects.

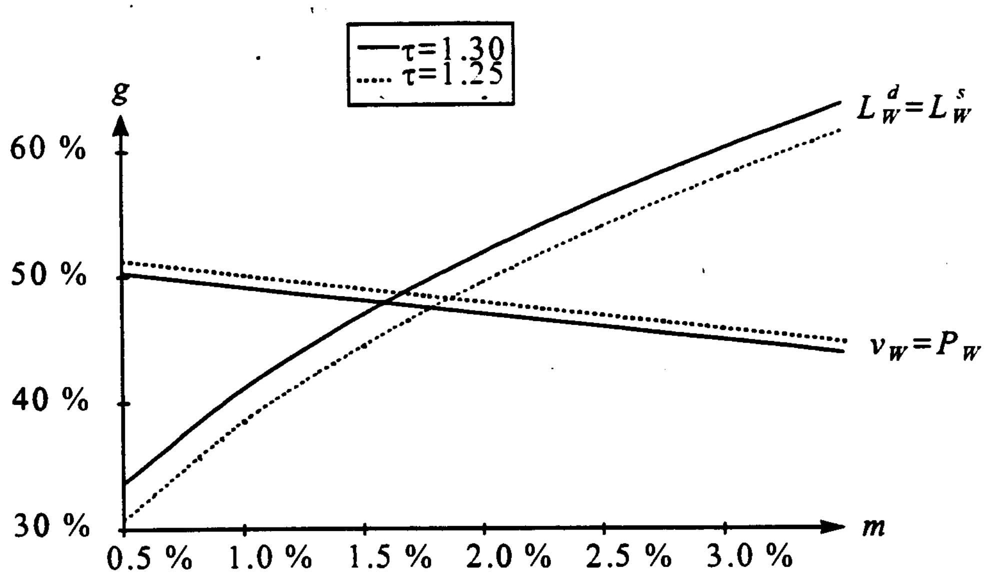

Figure 3: *Growth effects of trade liberalization.*

4.2 The possibility of an imitation trap

We have seen that imitation increases the global growth rate as well as the wage level in the East when we compare with an outcome where both regions are specialized. But what if we compare with a (possibly equilibrium) outcome where both regions innovate? Is imitation still preferable?

Part of the question is easy to answer; we have already seen that imitation cannot take place for low levels of trade costs, and from the discussion above we should moreover expect imitation in the East to be the more beneficial choice when trade costs are relatively high. Figure 4 illustrates, however, that the answer is more uncertain for some intermediate levels of trade costs. The curve $g - g$ shows the growth rate in absence of imitation - innovation equilibrium, for short - and the curve $g^m - g^m$ shows the growth rate in an imitation equilibrium.[26] Along the dotted part of $g - g$ innovation in the East is no longer an equilibrium outcome if we allow imitation to take place.

Figure 4 shows that the East does not innovate when $\tau \in (\tau_2, \tau_3)$. Since $g > g^m$

[26] An imitator must use limit pricing both abroad and domestically when $\tau \in (1.22, 1.41)$, but only abroad when $\tau \in (1.41, 1.60)$. The transition between these cases is, as would be expected from equation (25), smooth and does not lead to any qualitative changes in any of the variables.

for this range of trade costs, the possibility to imitate therefore unambiguously has negative growth effects. Also when $\tau \in (\tau_1, \tau_2)$, the growth rate is lower if imitation takes place, but now we have multiple equilibria: on the one hand, it is unprofitable to deviate from an innovation equilibrium when $\tau < \tau_2$. But if the East initially imitated goods from the West and trade is liberalized, then we may expect that the East continues to imitate unless trade costs are brought below τ_1.[27] This second path is in a sense the more likely one, because it exists continuously for all $\tau > \tau_1$. Some kind of shock would be necessary to bring the economy to the innovation equilibrium after a trade liberalization when $\tau \in (\tau_1, \tau_2)$.

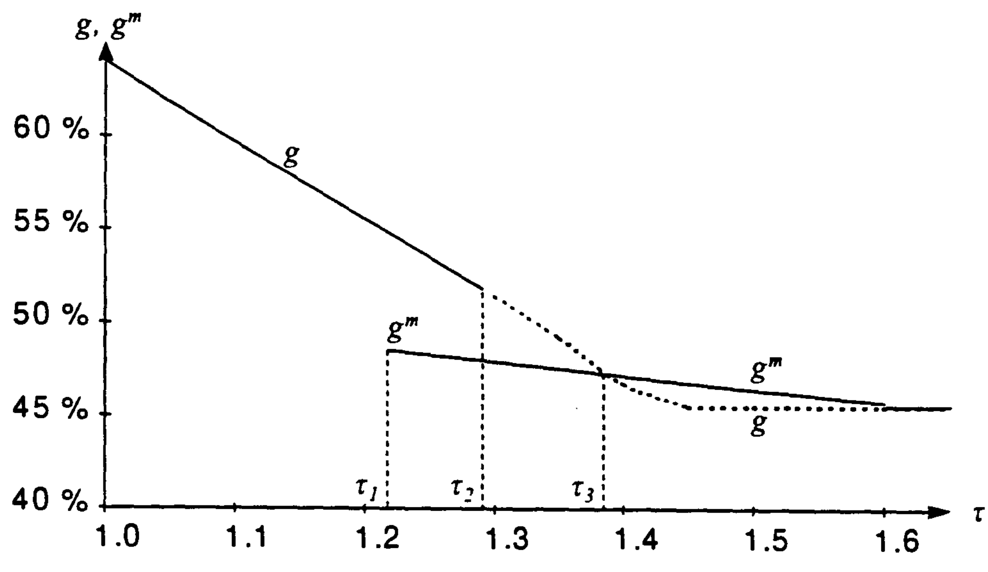

Figure 4: *Growth effects of trade liberalization.*

The existence of multiple equilibria is also illustrated in the left panel of Figure 5. The upward sloping solid line shows the ratio $\frac{v_E^m}{Q_E}$ in an outcome where all entrepreneurs in the East innovate and break even ($v_E = P_E$). However, this cannot be an equilibrium outcome if $\frac{v_E^m}{Q_E} > 1.0$: the present value of an imitation, v_E^m, is then greater than the imitation costs Q_E. Thus imitation offers pure profits, and deviation is profitable. The downward sloping dotted line likewise shows the ratio $\frac{v_E}{P_E}$ in

[27]The point $\tau = \tau_1$ is given by equation (30), while we find $\tau = \tau_2$ from $\left[\frac{1}{n_E Q_E}\right]\left[\left(\frac{w_W}{p_E \tau}\right)^{-\sigma}(w_W - \tau w_E)\frac{s_{EW}(\eta M_W + g n_W P_W)}{p_E \tau} + \left(\frac{w_W \tau}{p_E}\right)^{-\sigma}(w_W \tau - w_E)\frac{s_{EE}(\eta M_E + g n_E P_E)}{p_E}\right] \geq \kappa(\rho + g)$, which has a similar interpretation as (19) and (30).

an outcome where all entrepreneurs in the East imitate and break even $\left(v_E^m = Q_E\right)$: deviation from imitation to innovation is profitable whenever $\frac{v_E}{P_E} > 1.0$.

Suppose we are in an outcome where the entrepreneurs in the East innovate $(v_E = P_E)$, and consider a point like $\tau = 1.30$. The figure shows that for this level of trade costs we have $\frac{v_E^m}{Q_E} \approx 1.08 > 1.0$, so deviation from innovation would be profitable. Therefore the economy ends up in an equilibrium where all entrepreneurs in the East imitate, but then it is no longer possible to cover the region's relatively high innovation costs ($\frac{v_E}{P_E} \approx 0.96 < 1.0$ at the curve $v_E^m = Q_E$ when $\tau = 1.30$). The figure further shows that if the East is in an outcome with imitation, for example by historical reasons, it is not profitable to innovate unless the level of trade costs is lower than $\tau = \tau_1$. In the same way we find that deviation from an outcome with innovation is unprofitable if $\tau < \tau_2$. We thus have multiple equilibria for $\tau \in (\tau_1. \tau_2)$.

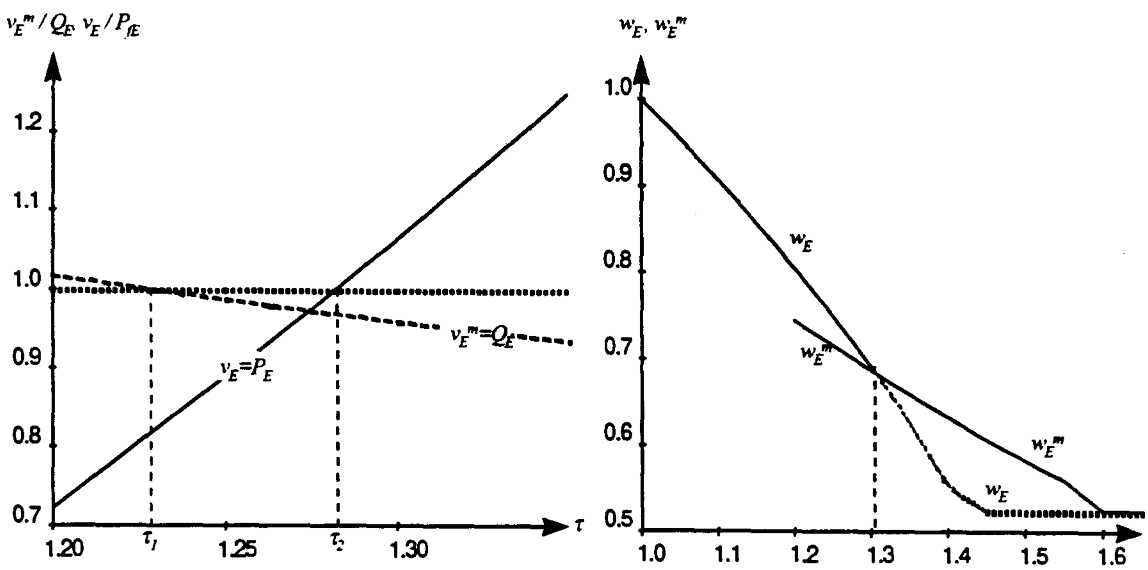

Figure 5: *Multiple equilibria, and international wage gaps.*

As discussed in section 4.1, the relatively low input requirement for imitations reduces the disadvantage of a small home market in the East. This cost saving is particularly important when trade is expensive because the price of imported inputs is strictly increasing in τ. Thereby the wage level in the East and the global growth rate are both highest in the outcome with imitation when trade is costly. One reason why this changes when τ is sufficiently reduced, is the fact hat trade liberalization reduces the significance of geographical location and therefore increases the size of the modern sector in the East. Consequently, the negative innovation incentives and the unavoidable duplication of research effort implied by imitation are more pronounced the lower the τ. Secondly, imitation restricts the sustainable equilibrium wages in the East because of the high degree of (latent) price competition from the original innovators - and also this effect is stronger the lower the level of trade costs.[28] The right panel of Figure 5 therefore shows that the wage level in the East under imitation $\left(w_E^m\right)$ is lower than under innovation (w_E) when τ is smaller than approximately 1.3.

The existence of multiple equilibria is caused by imperfect competition and pecuniary externalities. To understand what is going on, assume that $\tau \in (\tau_1, \tau_2)$ and that all entrepreneurs in the East imitate. It is individually unprofitable to deviate from this outcome because a potential innovator would face too strong price competition from domestic producers of (imperfect) substitutes to be able to cover the relatively high innovation costs. However, by reducing the competitive pressure, innovation does become profitable if a sufficiently large number of entrepreneurs in the East choose to innovate rather than to imitate. This in turn allows higher equilibrium wages in the region (as was shown in the right panel of Figure 5). But then, because of the higher wage level, imitation is no longer profitable because the latent price competition from the original innovator in the West implies that an imitator's profit margins - equal to $(\tau w_W - w_E)$ domestically and $\left(\frac{w_W}{\tau} - w_E\right)$ abroad - are too low to cover imitation costs.

Figure 6 sums up the discussion. Both regions are specialized when $\tau > 1.6$, the West in the modern sector and the East in the traditional sector. We have an equally clear result when $\tau \in (1.0, \tau_1)$; the regions are then so closely integrated that entrepreneurs in both regions unambiguously prefer to innovate. Between these extremes the picture is more complex, even though we have a unique equilibrium also when $\tau \in (\tau_2, 1.6)$ - the East imitates goods from the West, and $w_E^m > w_E$. However,

[28] Figure 1 indicated that trade liberalization reduces the profit margin both domestically and abroad when τ is lower than approximately 1.4.

the growth effects of imitation is not obvious, since $g^m > g$ when $\tau \in (\tau_3, 1.6)$ while $g^m < g$ when $\tau \in (\tau_2, \tau_3)$.

The most interesting region is perhaps for $\tau \in (\tau_1, \tau_2)$. Here we have multiple equilibria, and the international wage gap is largest and the global growth rate lowest in the equilibrium with imitation. Though we are not considering welfare effects and possible policy implications in this paper, it is worth stressing that the model clearly indicates the existence of an 'imitation trap'. In the long run, at least, it is obvious that consumers in both regions would be better off in the innovation equilibrium when $\tau \in (\tau_1, \tau_2)$, but coordination failures may prevent an escape from a possibly inferior equilibrium.

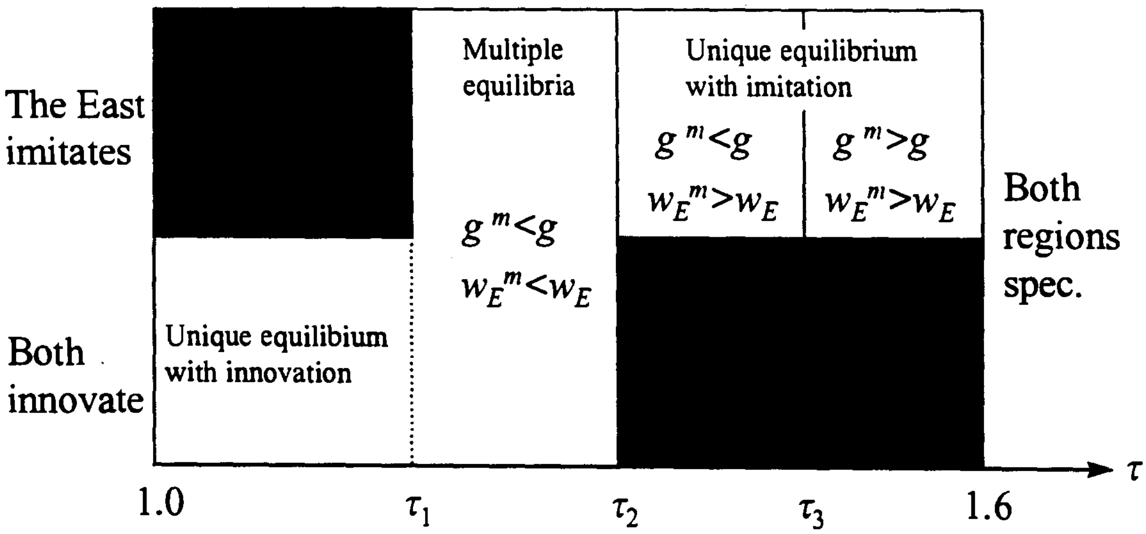

Figure 6: *Trade Costs and consequences of imitation.*

5 Conclusion

In the model presented in this paper the level of trade costs is decisive for whether imitation has beneficial effects on the global growth rate and the international wage gap. When trade is expensive, imitation reduces the disadvantage imposed on the poor region by a small home market, and therefore imitation speeds up the growth rate and reduces the international wage gap. For low levels of trade costs innovation is more profitable than imitation in both regions, so the opportunity to imitate is then irrelevant. However, for some intermediate levels of trade costs pecuniary externalities generate multiple equilibria. In that case the international wage gap is largest and the global growth rate lowest in the equilibrium with imitation. An interesting extension of the model would be to study the existence of multiple equilibria in greater detail, and in particular consider possible policy implications. A thorough welfare analysis does, however, require careful inquiry of transitional dynamics.

Appendix

A1 *Parameter values*

In all the simulations $L_W = L_E = 1$, $\kappa = 0.5$, $\eta = 0.7$, $\sigma = 1.8$, and $\rho = 0.1$.

There will always be international wage equalization if η is so small that the traditional good must be produced in both regions. The mere existence of an asymmetric equilibrium suggests that this outcome is somewhat artificial, and with diminishing returns to labour in the traditional sector we would in general have $w_E \neq w_W$. Since a model extension along those lines would make the algebra substantially more complex, we have instead assumed that η is so large that one region is able to produce world-wide demand for the $z-$good. In this way we allow international wages to differ in a simple model set-up.

The second essential parameter in this model is σ. It is easy to show that this is an inverse measure both of the heterogeneity of intermediate goods and of the degree of scale economies. In chapter 4 of this thesis it is shown that the symmetric equilibrium is always unstable if $\sigma < 2$. The pattern becomes somewhat more complex if $\sigma > 2$. We may still have the innovation and imitation stages mentioned above, but both regions would innovate also when trade costs are 'very high' (because the symmetric equilibrium is then stable). It is to avoid this stage, which is hardly particularly relevant empirically, that we have chosen $\sigma < 2$. Thereby the analysis is simplified, probably without losing any insight.

A2 *Derivation of the value of an innovation*

With other parameter values than those used in this paper we may find that it is unprofitable for an imitator to export because $\tau w_E^m > w_W$. What is the expected value v_W of making an innovation?

Let v_W^m denote the value of an innovation that has been imitated by a firm in the East. If $\tau w_E > w_W$ the optimal price strategy for the original innovator is to charge τw_E (given that $p_W > \tau w_E$) and continue to sell the good domestically. In that case $v_W^m > 0$. Otherwise, if $\tau w_E \leq w_W$, we have $v_W^m = 0$. The easiest way to find v_W in this more general case, is to extend the arbitrage arguments developed by

Grossman and Helpman. (1991): Consider a firm in the West that manufactures a product which has not yet been imitated: During a short time interval dt, this firm receives a profit flow $\pi_W dt$. During the same interval, $\dot{n}_E dt$ variants in the West are imitated, and the probability that any given brand is imitated equals $mdt = \frac{\dot{n}_E dt}{n_W}$. The share holders observe a capital loss equal to $\left[v_W - (v_W^m + \dot{v}_W^m dt)\right]$ if this occurs, otherwise the share value increases by $\dot{v}_W dt$ (with probability $(1 - mdt)$). Equating the return from holding a share in a firm whose product has not been copied, to the return on a bank deposit gives us

$$\pi_W dt - mdt\left[v_W - (v_W^m + \dot{v}_W^m dt)\right] + (1 - mdt)\,\dot{v}_W dt = \rho(v_W dt).$$

Dividing by dt and then taking the limit as dt goes towards zero, this can be written as

$$\frac{\pi_W}{v_W} - m\frac{(v_W - v_W^m)}{v_W} + \frac{\dot{v}_W}{v_W} = \rho. \tag{33}$$

The instantaneous profits for a monopolist equal $\pi_W = \frac{p_W(x_{WW} + x_{WE})}{\sigma}$, so equation (33) implies that

$$v_W = \frac{p_W(x_{WW} + x_{WE}) + \sigma m v_W^m}{\sigma(\rho + g + m)}, \tag{34}$$

where x_{WW} and x_{WE} denote aggregate sales domestically and abroad, respectively, for an innovating firm in the West. From this it is easy to verify that we have $v_W^m = \max\left\{0, \frac{(w_E\tau - w_W)x_{WW}}{\rho+g}\right\}$. Equation (12) is the special case of (34) where $\tau w_E \leq w_W$ so that $v_W^m = 0$.

A3 Innovation incentives and imitation

In order to illustrate how imitation affects the incentives to innovate, we shall look at the case where an imitator is obliged to use limit pricing both domestically and abroad. From equation (28) we know that the price indexes in both regions then are independent of the wage level in the East, and that $Q_E = \tau\kappa P_W$. Moreover, domestic and foreign market shares are equal, so we may define $s \equiv s_{WW} = s_{WE} = \frac{n_W p_W^{1-\sigma}}{n_W p_W^{1-\sigma} + n_E w_W^{1-\sigma}}$.

Instantaneous profit flow from an innovation is $\pi_W = \frac{s(\eta\mathcal{E}_W + \eta\mathcal{E}_E) + s(\dot{n}P_W + \dot{n}_E Q_E)}{n_W \sigma}$, while development costs are P_W, and the required rate of return equals $(\rho + g + m)$.

Let $q(m) \equiv \frac{\pi_W(m)}{P_W(\rho+g+m)}$. Imitation now tends to increase (decrease) the growth rate if $q'(m) > 0$ ($q'(m) < 0$).[29] Steady state consumer expenditure equals $\mathcal{E}_j = w_j L_j + \rho\Omega_j$. Since $Q_E = \tau\kappa P_W$ we have $\Omega_E = \frac{n_E}{n_W}\tau\kappa\Omega_W$ and $(\dot{n}P_W + \dot{n}_E Q_E) = g\left(\frac{n}{n_W} + \frac{n_E}{n_W}\tau\kappa\right) n_W P_W$. Using this in the expression for π_W, we can write

$$q(m) = \frac{S\eta\left(w_W L_W + w_E L_E\right) + s\eta\rho\left(1 + \frac{n_E}{n_W}\tau\kappa\right) + sg\left(\frac{n}{n_W} + \frac{n_E}{n_W}\tau\kappa\right)}{\sigma\left(\rho + g + m\right)}, \tag{35}$$

where $S \equiv \frac{s}{n_W P_W}$; the lower the S, the higher the innovation costs behind each unit market share per firm. Note that the numerator of (35) can be interpreted as the value of demand measured in units of innovation costs P_W; the first and second terms show revenue from consumer demand (financed from wage and interest income, respectively), and the third term shows revenue from sales to innovators and imitators.

The aggregate market share for innovators is decreasing in m, and from the expression for s we find

$$\frac{ds}{s}\frac{m}{dm} = -(1 - s). \tag{36}$$

Though innovators as a group lose market share when m increases, the same need not be true for each individual surviving firm. The low price on imitated goods moreover implies that there is an inverse relationship between m and P_W (for any given n), and differentiation shows that

$$\frac{d\left(n_W P_W\right)}{\left(n_W P_W\right)}\frac{m}{dm} = -\frac{n_E}{n_W + n_E}\left\{1 + \frac{1}{\sigma - 1}\left[\left(\frac{w_W}{p_W}\right)^{1-\sigma} - 1\right] s\right\}. \tag{37}$$

Equation (37) is always negative, and tends to increase the incentives to innovate. A low σ means that innovators use a high markup, and the cost reducing effect of imitation is therefore higher the lower the σ. It can be shown that $s\left(\frac{w_W}{p_W}\right)^{1-\sigma} = \frac{g}{m}(1-s)$, and using this together with equations (36), (37) we find

[29] This may be regarded as a Tobin's-q approach, where $q = 1$ along a balanced growth path. The methodology was introduced in endogenous growth models by Baldwin and Forslid (1996a), who note that while q determines the steady state capital-labour ratio in exogenous growth models, it determines the level of real investments in endogenous growth models.

$\frac{dS}{S}\frac{m}{dm} = \left(\frac{1}{g+m}\right)\left(\frac{\sigma-2}{1-\sigma}\right)[g(1-s) - ms]$, or

$$\frac{dS}{S}\frac{m}{dm} = \frac{n_E}{n_W + n_E}\left(\frac{\sigma - 2}{1-\sigma}\right)\left[\left(\frac{w_W}{p_W}\right)^{1-\sigma} - 1\right] s. \tag{38}$$

Equation (38) shows that the effect of smaller market shares and reduced innovation costs cancel each other exactly if $\sigma = 2$. Other things being equal, imitation therefore does not affect the profitability of innovation if $\sigma = 2$. But other things are, of course, not equal; a higher imitation share m may in fact increase the first term in the numerator of (35) even if $\sigma > 2$, if it leads to a higher wage level in the East. Similarly, a higher m tends to increase financial wealth in the East, and the positive effect of this is reflected by the expression $\frac{n_E}{n_W}\tau\kappa = \frac{m}{g}\tau\kappa$ in the second term of the numerator of (35). The resulting higher demand for modern goods has a positive incentive effect on innovators in the West.[30] The third term in the numerator, where $\left(\frac{n}{n_W} + \frac{n_E}{n_W}\tau\kappa\right) = \left(\frac{m+g}{g} + \frac{m}{g}\tau\kappa\right)$, reflects the positive demand effect, domestically and abroad, of a higher imitation rate. This positive effect must, however, also be weighted against the loss of market share s, so it is ambiguous whether the total effect is positive or negative.

The last effect, which is unambiguously negative, is that higher imitation increases the probability that a given brand in the West will be copied. Therefore the required rate of return increases: $\frac{d(\rho+g+m)}{(\rho+g+m)}\frac{m}{dm} = \frac{m}{(\rho+g+m)}$.

[30]Recall that the numerator in (35) measures revenue in terms of innovation costs, therefore terms with $n_W P_W$ in both the numerator and denumerator do not show up.

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