Trade and Growth with Static and Dynamic Economies of Scale

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WP 1996: 12

ISSN 0804-3639

Working Paper
Chr. Michelsen Institute
Development Studies and Human Rights
Bergen Norway

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Bergen, November 1996

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Bergen, November 1996. 36 pp.

Summary:

This paper develops a dynamic two-country, two-sector model of international trade with asymmetric technological spillovers, static increasing returns to scale in one sector and dynamic increasing returns to scale in the other sector. It is found that the country with comparative advantage in the static sector is subject to slow structural changes, but the gains from exploiting economies of scale may outweigh the disadvantage of being locked into a static industrial structure.

Indexing terms:

Trade
Structural changes
Economic growth
JEL F 12, F43, O13, Q32

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1. Introduction

Most countries of the world industrialized by establishing "light," labor-intensive manufacturing industries in which latecomers benefited from the availability of mature and non-proprietary technology. Furthermore, a relatively large part of the labor force was exposed to industrial practices during industrialization. Over time industrial competence developed and laid the foundation for efficient production of more technology-intensive industries and introduction of more sophisticated production processes.[1]

A somewhat different industrialization pattern has been observed in a host of natural resource rich countries. Their development path has largely been determined by comparative advantage for natural resource-intensive industries, which in turn happen to be subject to substantial economies of scale.[2] An early case is Norway whose first significant industries produced fertilizers, carbide and aluminum. These industries entered the Norwegian economy during the period 1899-1911, and they were all based on abundant energy resources while raw materials were largely imported. Almost a hundred years later Norway's industrial structure is still heavily dominated by large-scale natural resource-intensive industries in spite of several efforts to diversify the economy. Similar industrialization patterns have been initiated in Latin America, the Middle East and South Africa. The discovery of natural resource deposits has been seen as a curse rather than a blessing to the extent that it has been set beside

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1 See Westphal et. al. (1981) for an instructive description of the South Korean industrialization process.

2 The mature (low technology) industries whose most critical factor for competitiveness is scale are also resource-intensive, and most mature industries whose most critical factor for competitiveness is access to natural resources are also subject to significant economies of scale, and dominated by large multinationals (OECD 1993).

contracting a disease (the Dutch disease). Sachs and Warner (1995) provide empirical evidence of a negative correlation between natural resource abundance and growth.

This paper focuses on the role of the market structure and technological features of resource-intensive industries in determining the development path of resource rich countries, an aspect which hitherto has been largely overlooked in the literature. Let us start with a brief outline of what the special features of natural resource-intensive industries are: First, they tend to be capital-intensive and subject to substantial economies of scale.[3] Second, and similar to labor-intensive industries, the technology applied is mature, largely non-proprietary and readily available. Third, the technology seems to be less generic than that of "light," labor-intensive industries. To illustrate the point, just imagine the shop-floor of a garment factory. From a birds-eye view it looks quite similar to, say, a consumer electronics plant. In contrast, aluminum smelter plants or oil refineries look a world apart from the electronics plant. Because of sector-specific technology, resource-intensive industries are not likely to generate the dynamic process described in Rosenberg (1976), where existing industries initiate the establishment of new industries based on the same or similar technologies. Fourth, the technology is to a large extent embodied in capital equipment which depreciates slowly, leading to relatively slow diffusion of technology.

This paper develops a dynamic model that captures the features described above. It is shown that under specified conditions the gains from exploiting economies of scale through trade outweigh the disadvantage of being locked into a static industrial

[3] An analysis of the South African manufacturing sector finds that natural resource intensive industries are by far the most capital-intensive industries in the economy (Nordås 1996).

structure. When these conditions hold, small resource-rich countries are not likely to gain from infant industry protection. The rest of the paper is organized as follows: Section two provides some empirical evidence and briefly review related research. The model is presented in section 3 where the static part is solved and analyzed under alternative assumptions of the market structure. In section 4 the dynamic part of the model is solved while section 5 concludes and suggests some areas for further research.

2. Relations to previous research and empirical evidence

The paper relates to four strands of previous research: natural resource economics, the Dutch disease, trade under imperfect competition and models of uneven development. Resource economics are simply ignored, since my concern is *industrialization* through the establishment of mature industries subject to economies of scale. Such industries happen to be largely, but not exclusively resource-intensive. I abstract from dynamic efficiency issues in the extraction or harvesting of natural resources also on the basis of the observation that resource intensive industries tend to import raw materials rather than relocate if and when local resources get scarce. Finally, it is simply assumed that the global stocks of natural resources are sufficient to sustain resource-intensive industries.

The Dutch disease literature deals with macro-economic, demand-driven repercussions of a windfall income (Corden and Neary 1982, Van Wijnbergen 1984, Krugman 1987). The discovery of a natural resource deposit or a windfall gain from price hikes in commodity markets are treated as exogenous shocks that may drive more dynamic traded sectors out of business, while redundant factors of production are absorbed by an expanding non-traded sector.[4] I claim that this is only part of the story. As table 1 suggests, extraction/harvesting and processing of primary commodities occupy a significant amount of scarce factors of production at the expense of both traded and non-traded sectors. In addition, natural resource abundance appears to have bearings on the structure of the manufacturing sector which, as expected, tend to be biased towards mature (low-technology) resource-intensive industries.[5]

Table 1 **Correlation coefficients, primary commodities/ industrial structure**

	Exports of primary commodities
Manufacturing share of GDP	-0,71
Service share of GDP	-0,18
Share of total manufacturing value added:	
Resource intensive	0,64
Labor-intensive	-0,21
High-technology	-0,58
Medium-technology	-0,22
Low-technology	0,45

Source: Calculated from World Bank (1995) and United Nations (1993)

On this background it is assumed that resource-rich countries have comparative advantage for resource-intensive industries, meaning that at any given output level, the opportunity cost of producing one additional unit is smaller in the resource-rich country. Resource-rich countries in Latin America, the Middle East, Australia, South

[4] Corden and Neary (1982) developed a three-sector model in which "energy" is a capital-intensive industry.

[5] The correlation analysis encompasses all the middle-income countries included in the World Bank's World Development Report, except the former Soviet Union. Middle-income countries are chosen because they are in the process of industrialization, while low-income countries have not started the process yet, and high-income countries are in the transition to post-industrialized economies. The classification is taken from the OECD (1993).

Africa and Norway seem to be relevant cases. This leads us to the third strand of related research, which is trade theory. Krugman (1990) summarizes the history of trade theory as a "long dominance of Ricardo over Smith - of comparative advantage over increasing returns" (p. 4). "New" trade theory on the other hand is almost exclusively preoccupied with increasing returns and imperfect competition. In this paper the two approaches are combined by raising the question: What determines the development of a country which has comparative advantage in an industry subject to economies of scale? Let the sector be denoted the Y- sector and let the other sector in a two-sector, two-country model be subject to constant returns to scale and denoted the X-sector. Ricardo predicts that our country will export the Y-good, while Smith predicts that the largest country will export the Y-good (Markusen and Melvin 1981). If our country is large, then the two approaches give the same result - it will export the Y-good. If our country is small, on the other hand, the two approaches offer conflicting results and there is a need to establish under which conditions Ricardo dominates Smith.

Finally, the paper is related to the uneven development problem which arises from the assumption that the X-sector is subject to dynamic increasing returns, while increasing returns are of a static nature in the Y-sector. The possible disadvantage of being locked into a static industrial structure is addressed by Krugman (1987), Lucas (1988), and Brezis et. al. (1993). In their models the disadvantage does not amount to much unless the two goods are good substitutes (i.e. elasticity of substitution above 1). Otherwise the growing productivity gap is compensated by an improvement in the laggard's terms of trade. I extend these models to allow for technological spillovers to the static sector while the dynamic sector is subject to learning by doing, and show that the lock-in effect still prevails, but not the terms of trade effect. Furthermore, increasing returns in the static sector prevent the dynamic sector from expanding once it is established in the economy. Table 2 below provides some evidence that the lock-in effect is stronger for relatively resource-abundant than relatively labor-abundant developing countries. It shows the correlation between the structure of the manufacturing sector in 1960 and 1990 in countries classified as middle-income countries in 1990.[6]

Table 2 **Correlation industrial structure 1960-1990**

	Share resource-intensive 1960	Share labor-intensive 1960
Share resource-intensive 1990	0.74	-0.42
Share labor-intensive 1990	-0.33	0.67
Share high-technology 1990	-0.48	0.05
Share medium-technology 1990	-0.70	0.28
Share low-technology 1990	0.69	-0.19

Source: Calculated from UN various issues

The results should be interpreted with caution, but the table does suggest that developing countries which embarked on a labor-intensive industrialization process in the 1960s underwent more significant structural changes towards more technologically advanced sectors during the subsequent three decades than did developing countries which embarked on a resource-intensive industrialization process.

[6] The sample includes only 14 countries because data on industrial structure in 1960 were not available for the others.

3. The static model

The model is a two-sector, two country, one-factor Ricardian model of international trade. Resource-intensive industries produce mainly homogenous products, so the appropriate market structure when increasing returns are internal to firms is oligopolistic competition. The strategic variable is assumed to be quantity, and hence Cournot competition applies. However, I will first consider the case of contestable markets as described by Baumol et. al. (1982) and Helpman and Krugman (1985 ch. 4) as a benchmark. Contestable markets yield the highest attainable total world output and have the property that whether economies of scale are internal to the firm or to the industry is immaterial for our results. The basic contestable market model is extended to incorporate the Ricardian approach.

Throughout the paper capital letters represent the home country while lower case letters represent the foreign country. Both countries have a fixed labor force that is the only factor of production.[7] A Ricardian model does not determine the trade pattern unanimously, so I start with examining the possible static trade equilibria. The basic structure of the model is as follows: Consumers spend their entire income in each period, and have homothetic preferences according to the utility function:

$$U = X^{\mu} Y^{1-\mu} \tag{1}$$

[7] Bearing in mind the resource-and capital intensity of the static sector, this is a brave simplification, but labor input can be interpreted as comprising both direct and indirect labor, since all other inputs are ultimately produced/extracted by labor. The simplification does not alter the main results of the model, and allow us to abstract from capital accumulation in the dynamic part of the model.

Further, it is assumed that domestic and foreign goods of the same category are perfect substitutes in consumption, and consumers have the same preferences in both countries. Hence, world demand derived from equation (1) presupposes that a fixed share of world income is spent on each good. The production functions for the two sectors of the home country are given by:

$$Y = A_Y L_Y^{\alpha} \quad (2)$$

$$X = A_X L_X \quad (3)$$

$$L_X + L_Y = L \quad (4)$$

where L_i , $i = X,Y$ is labor employed in the two sectors, adding up to the fixed total labor force, and A_i is a productivity parameter. It is assumed that $A_Y / A_X > a_y / a_x$, while $\alpha > 1$ reflects increasing returns to scale.

3.1 Contestable markets

When markets are contestable, we know that prices equal average costs: $P_Y = W / A_Y L_Y^{\alpha-1}$, where W is the wage rate. Further, if both countries produce the X good, $P_X = W / A_X = w / a_x$, such that relative wages equal relative productivity in the X sector. From this it is clear that whenever $A_X / a_x \neq 1$ a diversified trading equilibrium with factor price equalization is ruled out. Let us start by finding the autarky equilibria and from there derive the direction of trade and gains from trade.

The production possibility frontiers are drawn for both countries in figure 1.[8] Both are slightly convex, and their slopes are derived from maximizing the output of Y for a given level of X, i.e. max $A_Y L_Y^\alpha$ s.t. $X-(L-L_Y)A_X$, which yields the marginal rate of transformation. In autarky relative prices are given by relative average costs, hence we get the familiar equilibrium condition:

$$MRT = \frac{A_X}{\alpha A_Y L_Y^{\alpha-1}} \Rightarrow \alpha MRT = \frac{P_Y}{P_X} \equiv P \tag{5}$$

From (1) we know that relative prices are determined by preferences and technology, and their interrelationship is given by $\mu/(1-\mu) = P_X X / P_Y Y$. Using (2), (3) and the condition that prices equal average cost, we find resource allocation to be $\mu/(1-\mu) = L_X / L_Y$. The autarky equilibria are represented by points C and c in figure 1 for the home and foreign country respectively, and the composition of output and consumption is given by:

$$\frac{X}{Y} = \frac{A_X \mu L}{A_Y\left((1-\mu)L\right)^\alpha} \tag{6}$$

When the ratios P and X/Y are lower in the home country compared to the foreign country in autarky, as shown in figure 1, then there exists a trading equilibrium where the home country exports the Y-good. This condition is fulfilled when:

[8] The figure is drawn for $\alpha = 1.2$ and $\lambda = 2$.

$$\frac{l}{L} \equiv \lambda < \left(\frac{A_Y}{a_y} \frac{a_x}{A_x} \right)^{1/(\alpha-1)} \quad \text{or equivalently:} \quad \frac{A_X}{a_x} < \frac{A_Y}{a_y \lambda^{\alpha-1}} \qquad (7)$$

In other words Ricardo dominates Smith when the relative size of the labor force is smaller than the product of the two countries' relative productivity advantage in each sector raised to a factor that declines with the degree of scale economies. Note that the condition depends only on relative productivity and the relative factor endowment, and is independent of demand conditions.

In our context of a resource-rich home country this can be interpreted as follows: If the home country is very small, resource-intensive industries will not be established there in a trading equilibrium. It can, however, be argued that even in this case the upstream activity is large-scale and capital intensive, particularly if we are concerned with mining or off-shore oil extraction. Therefore, if we are looking at a period in time during which natural resources are abundant, the model may be applied to a Y-sector defined as large-scale upstream activity. Otherwise, the case when (7) is not fulfilled is adequately analyzed by the Dutch disease literature, and is not further discussed here.

It remains to determine under which conditions the home country produces both goods in a trading equilibrium. With partial specialization relative prices are given by: $\mu / (1-\mu) = P_x(x+X)/P_Y Y$. Applying this and the condition that prices equal average cost yields $P = A_X / A_Y L_Y^{\alpha-1}$ and:

$$\frac{L_Y}{L} = (1-\mu)(1+\frac{a_x}{A_X}\lambda) \text{ where } \frac{L_Y}{L} < 1 \Rightarrow \frac{A_X}{a_x} > \lambda\frac{(1-\mu)}{\mu} \tag{8}$$

$$P = A_X / A_Y\left[(1-\mu)(1+\lambda a_x / A_X\right]^{\alpha-1} \tag{9}$$

Conditions (7) and (8) determine the pattern of specialization and trade as a function of relative productivity, relative size of the labor force and degree of economies of scale: When the resource-rich country is very small, it will be fully specialized in the X-sector and susceptible to the Dutch disease. When it is small to medium-sized, it will be fully specialized in the Y-sector, while only when $\lambda < \mu / (1-\mu)$ will there be a trading equilibrium where the home country produces both goods when $A_X / a_x < 1$. In all cases a higher relative productivity level in the X-sector compensates for a smaller labor force. Sector allocation of labor as s function of A_X / a_x is shown in figure 2. Note that with full specialization relative wages are given by:

$$\frac{W}{w} = \lambda\frac{1-\mu}{\mu} \quad \text{where } \frac{W}{w} \geq 1 \text{ if } \lambda \geq \mu / (1-\mu) \tag{10}$$

The only possible Ricardian trading equilibrium with factor price equalization is therefore obtained when there is complete specialization and $\lambda = \mu / (1-\mu)$. This can only be attained through free international flow of labor or by sheer coincidence. When partial specialization is the trading equilibrium, relative wages equal relative productivity in the X-sector; $W / w = A_X / a_x < 1$ which implies that when (10) holds, the home country would not gain from introducing the X-sector through industrial policy measures in a static setting. These results are summarized in proposition 1:

Proposition 1

Given (1)-(4) and average cost pricing in both sectors:

i) Increasing returns dominate comparative advantage when $\lambda > \left(\frac{A_Y}{a_y}\frac{a_x}{A_X}\right)^{1/(\alpha-1)}$

ii) When $\lambda\frac{(1-\mu)}{\mu} < \frac{A_X}{a_x} < \frac{A_Y}{a_y\lambda^{\alpha-1}}$ *partial specialization is the trading equilibrium.*

iii) When $\frac{A_X}{a_x} < \lambda\frac{1-\mu}{\mu}$ *full specialization is the trading equilibrium.*

iv) Given $A_X / a_x < 1$*, the only possible trading equilibrium with factor price equalization occurs when* $\lambda = \mu / 1-\mu$*.*

We now turn to gains from trade by comparing real income in the various trading equilibria to autarky. The relevant deflator is $(P_Y / (1-\mu))^{1-\mu}(P_x / \mu)^{\mu}$. Deflating autarky income, expressed as the nominal value of output in the two countries, yields the following real income per capita:

$$\Omega_{au} = \gamma A_X^{\mu} A_Y^{1-\mu}((1-\mu)L)^{(\alpha-1)(1-\mu)} \tag{11}$$

where $\gamma \equiv \mu^{\mu}(1-\mu)^{1-\mu}$. Note that real income per capita is an increasing function of the labor force, such that the larger country has the highest income per capita in autarky, everything else equal. The trading equilibrium with full specialization yields the following real per capita income in the home and foreign country respectively:

$$\Omega_{fs} = \gamma a_x^{\mu} A_Y^{1-\mu}\left(\lambda\frac{1-\mu}{\mu}\right)^{\mu} L^{(\alpha-1)(1-\mu)} \tag{12a}$$

$$\omega_{fs} = \gamma a_x^{\mu} A_Y^{1-\mu}\left(\frac{\mu}{\lambda(1-\mu)}\right)^{1-\mu} L^{(\alpha-1)(1-\mu)} \tag{12b}$$

In a fully specialized trading equilibrium the home country has a higher income per capita the larger it is in absolute terms, but the smaller it is relative to the foreign trading partner. In contrast, the foreign country's real income per capita is not affected by its own absolute size, but is higher the smaller it is relative to the trading partner. To see why this result occurs, consider terms of trade in the case of full specialization:

$$P = \frac{(1-\mu)}{\mu}\frac{a_x\lambda}{A_Y L^{\alpha-1}}; \quad \frac{\delta P}{\delta L} < 0, \qquad \frac{\delta P}{\delta \lambda} > 0 \tag{13}$$

From (13) we see that the home country can exploit economies of scale with less adverse impact on its terms of trade the smaller it is in relative terms. Comparing (12a) to (11) it appears that real income per capita is higher in the full specialization trading equilibrium in the home country whenever $A_X / a_x < \lambda(1-\mu)/\mu\varphi$, where $\varphi \equiv (1-\mu)^{(\alpha-1)(1-\mu)/\mu} < 1$. Since this condition is less restrictive than proposition 1 point iii), the home country will always gain from free trade. In contrast there may exist trading equilibria where the foreign country lose compared to autarky. To see this, compare (12b) and (11) and observe that $\omega_{fs} > \omega_{au}$ when $A_Y / a_y > [\lambda(1-\mu)]^{\alpha} / \mu$. The foreign country loses the increasing returns sector and gains from trade only when its relative cost disadvantage in the Y-sector is sufficiently large.

Finally, in the trading equilibrium with partial specialization where the home country produces both goods and the foreign country produces the X-good only, real income per capita in the two countries is given by:

$$\Omega_{ps} = \gamma A_X^{\mu} A_Y^{1-\mu}\left((1-\mu)\left(1+\lambda\frac{a_x}{A_X}\right)L\right)^{(\alpha-1)(1-\mu)} \tag{14a}$$

$$\omega_{ps} = \gamma a_x A_X^{-(1-\mu)} A_Y^{1-\mu}\left((1-\mu)\left(1+\lambda\frac{a_x}{A_X}\right)L\right)^{(\alpha-1)(1-\mu)} \tag{14b}$$

Comparing (14a) and (14b) to (11) reveals that both countries always gain from trade when partial specialization is the free trading equilibrium. Let us finally compare real income in the two relevant trade regimes. Comparing (14a) to (12a) it is clear that partial specialization yields higher real income than full specialization only when condition (8) holds. In contrast, comparing (14b) to (12b) reveals that the foreign country is better off with full specialization, since the introduction of the X-sector in the home country would imply a lower relative price of the X-good compared to the situation with full specialization. These findings are summarized in proposition 2:

Proposition 2

Given (1)-(4), and proposition 1,

i) Compared to autarky, both countries gain from free trade when $\frac{A_X}{a_x} > \lambda \frac{(1-\mu)}{\mu}$,

ii) The home country always gains from free trade.

iii) Compared to autarky the foreign country loses from trade when both $\frac{A_Y}{a_y} < \frac{[\lambda(1-\mu)]^{\alpha}}{\mu}$ *and* $\frac{A_X}{a_x} < \lambda \frac{(1-\mu)}{\mu}$ *hold.*

iv) The foreign country is better off with full specialization than partial specialization.

We have now seen that when Ricardo dominates Smith there exist possible trading equilibria where the larger country may lose from trade. This is a result in stark contrast to the familiar models focusing solely on increasing returns where the large country always gains from free trade, while the small country may lose.

Let us finally relate the results of this section to the uneven development literature. According to this literature, a developing country has to switch from a full specialization to a partial specialization trading regime in order to embark on a catch up growth trajectory. The relative productivity level given by condition (8) can be interpreted as this critical switch point of trade regime. When $\alpha = 1$, condition (8) corresponds to the standard case with a competitive, constant returns to scale static sector as explored for example by Brezis et. al. (1993). In their case the condition $A_X / a_x \geq (1-\mu)/\mu$ is necessary and sufficient for partial specialization to be an equilibrium. In the model developed here, there are two additional parameters, α and λ. Because $\alpha > 1$, λ matters and raises the threshold relative productivity necessary for the dynamic sector to enter the economy. Due to economies of scale, the average product of labor in the Y- sector declines when one unit of labor leaves for the X-sector, and more so the more scale intensive it is. This loss of income must be counterbalanced by the X- sector, which consequently has to be more productive to enter the economy the more scale intensive the Y-sector. Note that in the relatively small country case the X-sector will not be established unless its productivity level is almost on par with the technology-leading foreign country, as seen from figure 2 which is drawn for $\lambda = 2$. Industrialization based on scale-intensive, mature industries therefore tend to act as a barrier to entry for other sectors, particularly if the country is relatively small. On this account we arrive at a similar conclusion as the Dutch disease literature, but for a completely different reason. While a demand-driven cost increase crowds out tradable sectors in Dutch disease models, an expanding tradable scale-intensive industry prevents other sectors from entry in this model. The policy implications of the two approaches are therefore very different: Macro-economic demand management may cure the Dutch disease, but it will not stop scale-intensive industries from expanding at the expense of other sectors.

3.2 Cournot competition

Cournot competition represents the case when there are barriers to entry in the Y-sector. Usually entries into resource-intensive industries are regulated by government. In addition it can be argued that large upfront investment costs act as a barrier to entry in most scale-intensive industries and as such reduce the contestability of the market. In this section I explore how the results from section 3.1 are modified in the more realistic case of restricted entry into the Y-sector. Since my concern is structural features of countries who industrialize on the basis of scale-intensive industries, the analysis is confined to the case when the foreign country is fully specialized in the X-good.

I start by finding the threshold relative productivity level for the X-sector corresponding to condition (8) above, when an exogenous number of companies, n, is established in the home country. Then the following conditions must prevail when partial specialization is an equilibrium: a) The wage rate is the same in both sectors of the home country and given by $W = P_X A_X$. b) The profit maximizing output in each firm in the Y-sector allows for non-negative profits. The i-th firm's profit maximization condition is given by $(1/\alpha)A_Y{}^{-1/\alpha} P_X A_X Y_i^{(1-\alpha)/\alpha} = P_Y(1-1/n)$. c) Trade between the two countries is balanced, which implies that $(1-\mu)P_x a_x \lambda L = \mu(P_X A_X(L-L_Y) + P_Y A_Y L_Y^{\alpha}) - P_X A_X(L-L_Y)$. Noting that $L_Y = nL_{Yi}$ and solving the profit maximizing condition b) and condition c) for relative prices and then for $L_Y = nL_{Yi}$ yields the sector allocation in the home country:

$$P = \frac{A_X}{\alpha(1-1/n)A_Y L_{Yi}^{\alpha-1}} = \frac{(1-\mu)(a_x \lambda L + A_X(L-nL_{Yi}))}{\mu n A_Y L_{Yi}^{\alpha}},$$

$$L_Y = \frac{\alpha(1-1/n)(1-\mu)(\lambda a_x / A_X + 1)}{\mu + \alpha(1-1/n)(1-\mu)} L \qquad (15)$$

Finally, when $L_Y < L$, partial specialization is an equilibrium, which implies that:

$$\frac{A_X}{a_x} \geq \alpha\lambda(1 - 1/n)\frac{1-\mu}{\mu} \qquad (16)$$

Proposition 3

The threshold relative productivity level given by (16) is always lower than the threshold level given by (8).

Proof: (16) is feasible only if condition b) above is fulfilled. Given this and the production function (2), $AC = \alpha MC \geq P_Y$, and consequently $\alpha(1 - 1/n) \leq 1$. *Q.E.D.*

Intuitively proposition 3 can be explained by the fact that each company exerts some degree of market power such that terms of trade are more favorable to the Y-sector in the Cournot setting than in the contestable market setting. In addition the same level of output is produced less efficiently by $n > 1$ companies than by one company, such that the X-sector can more easily match the productivity level in the Y-sector. This in turn implies that total world output is lower in the Cournot case. Real income per capita in the two countries in the Cournot case reads:

$$\Omega_C = \Omega n^{-(\alpha-1)(1-\mu)} \quad , \; \omega_C = \omega n^{-(\alpha-1)(1-\mu)} \qquad (17)$$

where subscript C represents the Cournot case and no subscript represents the contestable market case. Both countries have a lower real income per capita while their real relative income is unchanged compared to the contestable market case. We can therefore conclude that both countries are better off in a static setting when the Y-good is produced by one company which earns no net profits. When the Y-sector has market power, on the other hand, the trade regime switch point is more easily attainable, provided that the labor market is competitive, but less so the more companies are allowed to enter. Finally, since contestable markets combined with free trade yield the highest real income per capita attainable in the home country, industrial policy measures which restrict entry in the Y-sector or promote the X-sector whenever condition (16) does not hold, must induce dynamic gains which outweigh the initial losses if they are to raise welfare. Dynamics are analyzed in the next section.

4. Dynamics

The X-sector is competitive and subject to constant returns to scale at any point in time. Over time, however, the sector is subject to continuous productivity improvement through a learning-by-doing process which is internal to the sector but external to firms. In addition, there are one-way technological spillovers from the foreign to the domestic X-sector, assuming that the foreign country is technology-leading. The case with no technological progress in the Y-sector is previously analyzed by Lucas (1988) and Breezes et. al. (1993) whose models exhibit two effects which influence relative income in opposite directions. When preferences are homothetic, the two effects exactly offset each other: As the productivity gap in the X-sector widens over time, relative income remains constant due to an offsetting improvement in the Y-sector's terms of trade when the countries are fully specialized.

I show that this conclusion still holds when the Y-sector is subject to static increasing returns, and then extend the model to contemplate a more realistic case.

Although it is generally true that the relative price of new goods tends to decline as their market widens and technology becomes standardized, there is not much empirical support for the result that terms of trade in primary and mature industries improve to offset the widening technology gap towards the more dynamic industries. Besides, no sector is completely static. I therefore extend the standard model of uneven development to allow the Y-sector to benefit from the general technological development in the economy. Technical improvements in the Y-sector materialize through technology embodied in machinery and equipment and customers' product specification and are modeled as technological spillovers from the X-sector, foreign as well as local.[9] It turns out that this extension of previous models produces new insights as will be shown below. Following Krugman (1987) technological progress is given by:

$$A_{it} = K_i(t)^{\varepsilon}, \qquad i = \text{Y,X}, \qquad 0 < \varepsilon < 1. \tag{18}$$

$$K_Y(t) = \int_{-\infty}^{t} [\delta X(z) + \sigma x(z)]dz \qquad 0 < \sigma < \delta < 1, \tag{19}$$

$$K_X(t) = \int_{-\infty}^{t} [X(z) + \delta x(z)]dz \tag{20}$$

$$k_x(t) = \int_{-\infty}^{t} x(z)dz \tag{21}$$

[9] Westphal et. al. (1981) emphasize the importance of customers' specifications as a source of technological progress in Korea.

Equations (19) and (20) suggest that technological spillovers within an industry are stronger than across industries and that spillovers within a country are stronger than across national boundaries. For convenience, spillovers across countries within an industry are set equal to spillovers across sectors within a country. I start by examining the case of full specialization.

4.1 Full specialization

With full specialization the first term under the integral of equation (19) is zero, and relative productivity at any point in time is given by: [10]

$$\frac{A_Y(t)}{a_x(t)} = \left[\frac{\int_{-\infty}^{t} \sigma x(z)dz}{\int_{-\infty}^{t} x(z)dz} \right]^{\varepsilon} = \sigma^{\varepsilon} \qquad (22)$$

Relative prices are determined by (13) in the case of contestable markets and by $P = \frac{(1-\mu)}{\mu} \frac{a_x \lambda n^{\alpha-1}}{A_Y L^{\alpha-1}}$ in the Cournot case. Inserting (22) in these expressions yields the following interesting result:

[10] Strictly speaking, A_Y is rather a technology parameter than a productivity parameter, since productivity is also affected by scale.

Proposition 4

With full specialization and technological spillovers, terms of trade remain constant over time: $P = \frac{1-\mu}{\mu}\frac{\lambda}{\sigma^{\varepsilon}L^{\alpha-1}}$ *with contestable markets,* $P = \frac{(1-\mu)}{\mu}\frac{\lambda n^{\alpha-1}}{\sigma^{\varepsilon}L^{\alpha-1}}$ *with Cournot competition.*

Equation (22) together with proposition 4 imply that there are no catching up or falling further behind, but in absolute terms, the home country is left further and further behind. Moreover, (8), (18), (20) and (21) imply that full specialization remains an equilibrium forever in the absence of technology shocks or changes in relative demand. This result strengthens the lock-in effect demonstrated by Lucas (1988) and Brezis et. al. (1993). In their models real output grows faster in the country specialized in the dynamic sector, while in the extended model developed here real output grows at the same rate in both countries, but the lock-in effect still prevails.

4.2 Partial specialization

This section addresses the infant industry argument in the dynamic setting represented by equations (18) - (21). The less dynamic Y-sector passively absorbs a fraction of the general technological development taking place in the economy, assumed to emanate in the X-sector. Dynamics in the X-sector are independent of development in the Y-sector. Therefore, I follow Krugman (1987), and analyze the dynamics in two steps. First, relative productivity in the X-sector, taking resource allocation as given is determined. Next, resource allocation as expressed by equation (8) in the contestable market case and (15) in the Cournot case is taken into account. The dynamics of the two sectors are thus given by:

$$\frac{A_X(t)}{a_x(t)} = \left(\frac{K_X(t)}{k_x(t)}\right)^{\varepsilon} \tag{23}$$

$$\frac{dK_X(t)}{dt} = X(t) + \delta x(t) \tag{24a}$$

$$\frac{dk_x(t)}{dt} = x(t) \tag{24b}$$

$$\frac{dK_X(t)/dt}{K_X(t)} - \frac{dk_x(t)/dt}{k_x(t)} = \frac{X(t)+\delta x(t)}{K_X(t)} - \frac{x(t)}{k_x(t)} \tag{25}$$

$$\frac{dK_Y(t)}{dt} = \delta X(t) + \sigma x(t) \tag{26}$$

Given (18), (20) and (21) relative productivity in manufacturing will converge on a steady state, which implies that expression (25) approaches zero. This is a steady state in the sense that A_X/a_x is constant and by (8) and (15) allocation of resources between the two sectors in the home country is constant as well. However, relative productivity between the X and Y sectors in the home country diverges since, according to (18), (24a) and (26), A_X grows faster than A_Y and $A_X / A_Y > 1$. Therefore, long-run equilibrium with partial specialization is characterized by constant relative productivity in the X-sector and constant resource allocation while the divergence in relative technology level between the two sectors in the home country is counterbalanced by a continuous improvement of the home country's terms of trade as can be seen from equation (9). Interestingly, we get the offsetting terms of trade effect with partial specialization, but not with full specialization, since world real output grows at the same rate in the two sectors in the latter case while world real output grows faster in the X-sector in the former case.

I now proceed to derive steady state relative productivity in the X-sector in the home country. The first step is to substitute (3) in equation (25) and set relative change in experience indices to zero, which yield:

$$\left(\frac{K_X}{k_x}\right)^{\varepsilon-1} = \frac{\lambda}{1-L_Y/L}(1-\delta k_x/K_X) \tag{27}$$

The next step is to insert equation (8) and (15) with the restriction that (16) holds into equation (27) for the contestable market and the Cournot case respectively:

$$\left(\frac{K_X}{k_x}\right)^{\varepsilon-1} = \frac{\lambda}{\mu}\left(1-\left(\delta-(1-\mu)\right)\frac{k_x}{K_X}\right) \tag{28a}$$

$$\left(\frac{K_X}{k_x}\right)^{\varepsilon-1} = \lambda\left\{1+\alpha(1-1/n)\frac{1-\mu}{\mu}-\left[\delta-(1-\delta)\alpha(1-1/n)\frac{1-\mu}{\mu}\right]\frac{k_x}{K_X}\right\} \tag{28b}$$

A necessary and sufficient condition for a steady state to exist is that (8) and (16) hold and that the graphs of the left-hand side (LHS) and the graphs of the right-hand side (RHS) of equations (28) intersect. Since $L_Y / L > 1$ is not technically ruled out by (15), the former condition is more restrictive than the latter. LHS is a downward sloping function of K_X/k_x, provided that $0 < \varepsilon < 1$, while RHS is an upward sloping function of K_X/k_x whenever the coefficient in front of the relative experience indices is larger than zero. The latter condition yields the interesting result that the critical rate of technology spillovers, δ, for RHS to be upward sloping corresponds to the share of the labor force employed in the Y-sector in autarky:

In the contestable market case: $\delta \geq (1-\mu)$ (29a)

In the Cournot case: $\delta \geq \dfrac{\varphi(1-1/n)(1-\mu)/\mu}{1+\varphi(1-1/n)(1-\mu)/\mu}$ (29b)

Since it is not possible to solve equations (28) for the steady-state relative productivity level analytically, I proceed by analyzing the steady state by means of figures 4 and 5 which depict the LHS and RHS of equations (28a) and (28b) respectively. Recall from (18), (20) and (21) that steady-state relative productivity, $A_X / a_x = (K_X / k_x)^{\varepsilon} = \delta^{\varepsilon}$ with full specialization. Hence the minimum value δ^{ε} must take for the X-sector to enter the home country in the first place is the one given by the right hand side of (8) and (16). These levels, which may be interpreted as relative experience indices at the point of entry are shown as reference points in figures 4 and 5, marked with an arrow. By inspection of equations (28) we see that RHS is steeper and lies further to the north the larger is α, the larger is n, the larger is λ and the smaller is μ. An increase in δ does not affect the intersection, but makes the RHS curve flatter. In other words, provided that a steady state exists, the steady state technology gap is smaller the larger the home country, the smaller the number of firms established in the Y-sector, the smaller the share of total consumption spent on the Y-good, the smaller the extent of scale economies in the Y-sector and the higher the technology spillover rate.

Let us now turn to policy implications of these findings. First, the number of firms in the Y-sector is usually controlled by government through licensing. Limiting the number of companies will raise steady state relative productivity and thus relative income which is given by $\Omega_{ps}/\omega_{ps} = A_X/a_x$. Second, the government probably has policy measures available that affect the capacity to adopt new technology, and thereby influence the rate of technology spillovers, δ. The most common policy measure to promote dynamic sectors in developing countries is however to subsidize or protect them. Assume that an import tax is levied on the X-sector and the proceeds distributed as a lump sum transfer to consumers, and assume that the tariff rate is set to allow a target share of the labor force to be employed in the X-sector. In figures 4 and 5 this policy measure is illustrated by the graph of the right-hand side of equation (27) where the rate of technology spillovers is set below the level necessary for (16) to hold, and above the level given by conditions (29). The target share of the labor force employed in the X-sector is simply entered into the equation. It turns out that if δ is below conditions (29), no equilibrium exists where steady state relative productivity exceeds that given by (8) and (16). Consequently, the X-sector would have to be protected forever and real income per capita would have been lower than in the case with full specialization. If δ lies between (8) or (16) and (29), a steady state where partial specialization is a trading equilibrium in the absence of further protection exist if the targeted share of the labor force in the X-sector is high enough. In figures 4 and 5 the share is set to 25 percent which is not enough to generate a sustainable shift in trade regime since the intersection with the LHS curve lies to the left of the arrow.[11]

[11] The figures are drawn for α=1.2, $\mu = 0.7$, $\lambda = 2$