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SCALE ECONOMIES, WAGE DIFFERENTIALS

AND

NORTH-SOUTH TRADE

by

M. BENARROCH

A thesis submitted to
the Faculty of Graduate Studies and Research
in partial fulfilment of
the requirements for the degree of

Doctor of Philosophy
Department of Economics
Carleton University

Ottawa, Ontario

August 21, 1992

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The undersigned hereby recommend to
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submitted by

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in partial fulfilment of the requirements for the
degree of Doctor of Philosophy.

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Abstract

This dissertation develops a model that determines the allocation of production, the pattern of trade and the wage differential between developed countries (the North) and less-developed countries (the South). By incorporating external economies of scale in production, the model extends recent efforts to formalize the Vernon (QJE,1966) product-cycle theory.

The basic framework is an infinite-good Ricardian model (Dornbusch, Fischer and Samuelson (AER,1977) in which technology differences arise as a result of differences in external economies of scale; commodities are ranked on the degree to which they are subject to external economies in production. These industry-specific external economies of scale in production are assumed to arise from the existence of industry specific inputs. Given its comparative advantage in the development of new products, the North is assumed to export new goods, high technology goods, which are subject to greater external economies of scale while the South produces and exports the remaining set of good with the opposite characteristics.

In general, the division of production and the pattern of trade between the North and the South will be determined by differences in costs arising from the extent of economies of scale in each region and wage differentials. In particular, it is assumed that firms in each industry are competitive and the extent of economies of scale are directly related to industry output (modeled as in Markusen and Melvin (CJE,1981)). As a result, a firm in the North will shift production to the South only when the wage gap is large enough to compensate it for the fact that it is the only firm producing in the South and the extent of economies of scale are low. Therefore, in equilibrium there will be a positive North-South wage gap which is endogenously determined.

The impact of labor force growth, a change in the pattern of demand, and a technological improvement are also considered in this dissertation. Furthermore, the results indicate that innovation on the part of the North initiates the product cycle by raising the wage differential, whereas production transfers lower the wage gap. The South can however, reduce the wage differential and obtain an improvement in welfare by offering temporary production subsidies to Southern producers of the marginal goods.

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Dedication

I would like to dedicate this thesis to my partner Kim Bailey and our son Aden Joseph Bailey Benarroch. Without Kim's love, encouragement and strength I could not have completed this thesis.

Table of Contents

	Page
Abstract	ii
Acknowledgements	iii
Dedication	iv
Table of Contents	v & vi
List of Tables	vii
List of Figures	viii
 CHAPTER 1: Introduction	 1
CHAPTER 2: The Theory of the Product Cycle	9
2.1 The Product Life Cycle Theory	12
2.2 Modeling the Product Cycle	15
2.3 Testing the Product Cycle	30
2.4 Case Studies	42
2.5 Conclusion	51
CHAPTER 3: External Economies of Scale	60
3.1 Sources of External Economies of Scale	62
3.2 External Economies of Scale and International Trade: Static Models	69
3.3 Dynamic External Economies of Scale	78
3.4 Summary and Conclusions	87
CHAPTER 4: The Static Model	93
4.1 The Model	95
4.2 Demand	96
4.3 Production	100
4.4 The Allocation of Production and Production Transfers	107
4.5 Equilibrium	115
4.6 Conclusion	120
Appendix 1	128
Appendix 2	129
Appendix 3	131
Appendix 4	133
 CHAPTER 5: Comparative Statics	 140
5.1 Increase in Southern Labor Supply	142
5.2 Fall in Demand for Southern Goods	147
5.3 Technical Change in the South	152
5.4 Conclusion and Summary	156
CHAPTER 6: Innovation	166
6.1 Once-and-for-all Innovation	168
6.2 Continuous Innovation	178
6.3 Shocks to the Equilibrium	183
6.4 Conclusion	188

CHAPTER 7: Trade Policy	199
7.1 Production Subsidies in the Static Model	202
7.2 Production Subsidies and Continuous Innovation	217
7.3 Conclusion and Summary	226
Appendix 5	231
Appendix 6	233
CHAPTER 8: Summary and Conclusions	242

List of Table

Table	Description	Page
2.1	Decline in U.S. Exports as a Percentage of U.S. Production, Seven Petrochemical, 1914 to 1969.	55
2.2	Imitation Lag and U.S. Exports Peak for Seven Petrochemicals, 1914 to 1969.	56

List of Figures

Figure	Description	Page
2.1	U.S. Trade Balance for all Manufactures	54
2.2	Japanese Exports of Electronics Equipment by Product	54
4.1	Trade Balance Schedule	135
4.2	Index of Comparative Advantage	135
4.3	Complete specialization in each region	136
4.4	Market equilibrium; $\omega < 1$.	136
5.1	Increase in L_s no production transfers	160
5.2	Increase in L_s with production transfers	160
5.3	Uniform Density Function	161
5.4	Density Function After Change in Demand	161
5.5	Decrease in $B_s(r)$	162
5.6	Increase in α_s	162
6.1	Uniform Density Function at End of Period One	193
6.2	Innovation, ω Constant	193
6.3	Innovation, $d\omega < 0$	194
6.4	Innovation, $d\omega > 0$	194
6.5	Continuous Innovation	195
6.6	Innovation and a Continuous Increase in L_s	195
6.7	Innovation and a Technological Improvement in the North	196
7.1	Initial Equilibrium	237
7.2	Subsidy Level	237
7.3	Ad Valorem Subsidy in the Static Model	238
7.4	Case (i): Ad Valorem Subsidy with Innovation, Period One.	238
7.5	Case (ii): Ad Valorem Subsidy with Innovation and production transfers period one.	239

Chapter 1.0

Introduction

Understanding the forces that determine the allocation of production and the pattern of trade between the developed (DC) and less developed (LDC) countries, i.e. between the North and the South, has become increasingly important. Policy makers have become extremely concerned with the expanding gap in the standard of living between the North and the South. In particular, the related issues of technology transfer and the migration of production of manufactured goods between the North and South are widely seen as being of great significance because of the high level of value added associated with manufactured goods.

This dissertation examines the effect of external economies of scale in production on the pattern of trade and the wage gap between DCs and LDCs. Both Linder (1961) and Vernon (1966) assert that technological transfers are part of a normal product life cycle. Vernon (1966) and (1979) suggests that innovation, the development of new products, occurs primarily in the North (in particular the United States) and that the variety of products developed reflect the specific characteristics and needs of the country. Initially, the innovating country completely specializes in the production of the new good but as external markets and sales expand it becomes economically efficient to produce the

good in foreign countries. The length of the initial stage of the product cycle, the stage in which the innovating country produces the commodity, depends on the extent of the economies of scale in production and the wage gap. Goods with the lowest economies of scale and most standardized production processes are transferred to the South. Vernon sites several examples such as textiles, men's shirts, electronics, and light furniture.

Interest in Linder (1961) and Vernon (1966) has been revived in a number of recent papers. Krugman (1979) for example, constructs a simple Ricardian model of trade, innovation and technology transfers with one factor of production, many goods and exogenous rates of both innovation and technology transfer. He concludes that the North will specialize in the production of newly developed goods and that the North-South wage gap is related to the ratio of goods produced in each country. Likewise, Dollar (1987) derives similar results within a slightly different framework in which the rate of production transfer is determined endogenously as a positive function of production cost differences between the two regions.

Jensen and Thursby (1987) and Grossman and Helpman (1990) on the other hand, extend the initial work of Krugman (1979) and Dollar (1987) to construct models of the product cycle with both endogenous innovation and technology

transfer. The findings in these two studies suggest that there exists an optimal rate of innovation in the North which is directly related to the rate of imitation in the South and vice versa.

Finally, Flam and Helpman (1987) develop a model of North-South trade that generates a quality-based product cycle. In their model, the North produces higher quality products than the South. Faster technological progress by the South leads to the introduction of new high quality products in the North and the transfer of lower quality products to the South.

These initial attempts to formalize the product cycle have the common feature that international production cost differences are due solely to the wage gap between the North and the South. However, Vernon (1966) and (1979) suggests that production cost differences are not only a result of the North-South wage gap but also due to economies of scale in production.

In this dissertation, a model of North-South trade incorporating external economies of scale in production is constructed to determine the allocation of production, the pattern of trade and the wage gap between the North and South. The analysis builds upon recent efforts to formalize the Vernon (1966) product cycle theory of trade. The model attempts to explain why industries such as steel,

automobiles, and electronics are moving to the Third World.

The basic framework is an infinite-good Ricardian model (Dornbusch, Fischer and Samuelson (1977) (DFS)) in which technology differences arise as a result of differences in external economies of scale; goods are ranked on the degree to which they are subject to external economies of scale in production. As in Markusen and Melvin (1981) it is assumed the extent of economies of scale is positively related to industry output.

In general, the division of goods production and the pattern of trade between the North and South is determined by cost differences arising from both the extent of economies of scale in each region and wage differentials, and not merely the wage gap as in the rest of the product cycle literature. These results may, in part, explain why Transnational Corporations do not transfer their entire production lines to lower wage LDCs. A firm in the North will shift its production to the South only when the wage differential is large enough to compensate it for the fact that the extent of economies of scale in the South are low. In equilibrium there will be a positive North-South wage gap which is endogenously determined within the model. As the North introduces new products which are subject to a higher degree of economies of scale in production, the equilibrium wage gap will grow in its favor. Furthermore, the South will produce

the commodities with the lowest degree of economies of scale and the North the remaining set of goods with the opposite characteristics.

Essentially, it is assumed that the economies of scale are external to the firm, but internal to the industry, and country specific because these external economies capture fundamental differences between the North and South. For example, in New York's historic garment industry and California's Silicon Valley semiconductor and computer industries, firms gained from being located in close proximity to one another. In contrast, LDCs often lack economies of agglomeration, a network of suppliers of intermediate goods, an extensive infrastructure of transportation, communication and electrical power, and a well-trained and highly-skilled labor force. Meade (1954) points out that these are the factors which are external to the firm but influence the atmosphere for production. Hence, as the output of new industries expands in these countries their average costs should fall.

Therefore, unlike previous attempts to model the product life cycle, the current approach allows for an examination of the factors that determine the long-run rate of production transfer. The model indicates that growth in the Southern labor force, a rise in the demand for Northern products, or a technological improvement in the South will

lead to an increase in the rate of production transfer. However, unlike other efforts to formalize the product cycle in which the production technology exhibits constant returns to scale, production transfers will alter the extent of economies of scale and the productivity of labor in the current model. Essentially, as industries migrate to the South, the Northern labor supply is spread across fewer industries raising output and the productivity of labor in the North. Consequently, some industries that would be transferred to the South in models with constant returns to scale remain in the North in the present analysis.

When innovation is introduced into the model, the results suggest that the development of new products in the North induces a transfer of production to the South. As in other attempts to formalize the product cycle the equilibrium is characterized by both a constant relative wage and a constant proportion of goods produced in each country. The unique feature of the current model is that it identifies the conditions necessary to maintain this equilibrium. In particular, it is required that the economies of scale in the borderline industry in the North remain constant.

Furthermore, as in Itoh and Kiyono (1987) the effects of production subsidies offered by the government of the South are examined in the dissertation. The current analysis extends that of Itoh and Kiyono by incorporating economies of

scale and innovation into the model. The recent success of Japan, South Korea, Taiwan, Singapore and Hong Kong implies that industrial targeting strategies can play an important role in economic development. The results of the current model suggest that an industrial targeting strategy can be welfare improving when production exhibits increasing returns to scale because the subsidies are only required on a temporary basis. As in Krugman (1987) the South gains a comparative advantage in the subsidized industries and the subsidies can be removed. The subsidies in turn, cause Southern income and the relative Southern wage to rise. Southern welfare will improve when the present discounted value of the permanent benefits of the subsidies outweigh the temporary expense needed to finance the subsidy.

However, when innovation is introduced into the model the results show that the subsidies do not alter the the rate of transfer or North-South wage gap. As the North innovates the proportion of goods it produces rises generating an increase in the Northern relative wage. Consequently, the initial benefits to the South are eroded and the South must subsidize a new set of goods to maintain a higher relative wage.

The remainder of this dissertation is organized as follows. Chapter 2 reviews the literature on the product cycle. In Chapter 3 the literature on external economies of

scale is surveyed. Chapter 4 develops the model and the equilibrium in the static framework - at one point in time. In Chapter 5, comparative static exercises are conducted using the model developed in the previous chapter. Chapter 6 builds upon the model by introducing innovation, the development of new products, into the analysis. The properties of the equilibrium are determined and both the effects of ongoing growth in the Southern labor force and a one-time technological improvement in the North are analyzed in Chapter 6. Chapter 7 examines the impact of production subsidies offered by the government of the South on a set of Northern goods within the context of both the static model introduced in Chapter 4 and the model presented in Chapter 6. Finally, Chapter 8 summarizes and concludes the dissertation.

Chapter 2

The Theory of the Product Life Cycle

The product life cycle theory of international trade proposes a theory of dynamic comparative advantage based on innovation and technology transfer rather than the primarily static comparative advantage doctrine generated by the Heckscher-Ohlin-Samuelson model. The introduction of new products by developed countries is often used to explain the changing pattern of world trade. Vernon's (1966, 1979) concept of the product life cycle stresses dynamic aspects of trade by examining the importance of economies of scale and the timing of innovation on the pattern of world trade.

The purpose of this chapter is to survey the development of the product life-cycle theory of trade. The model constructed in Chapters 4 to 7 builds upon earlier attempts to formalize the concept of the product life cycle and better explain the pattern of trade between developed and less-developed countries (DC and LDC).

The product life cycle theory of international trade, as outlined by Vernon (1966, 1979), suggests that the pattern of trade continuously changes as new products are developed and goods pass through different stages of their life cycle. According to Vernon products are initially developed and produced in DCs but over time production is transferred to lower wage countries as the production process becomes more

standardized, economies of scale are fully exploited and demand spreads to foreign markets.

Initially, the theory of the product cycle was used to interpret the pattern of U.S. trade with other advanced countries. However, Vernon (1979) indicates that the product cycle is now better suited to explain trade flows between DCs and LDCs. The reason for this is that the United States no longer has a comparative advantage in research and development (R&D) over other DCs, in particular Japan and West Germany, although it does have a comparative advantage in R&D over LDCs. As a result, the United States competes in the same markets as other DCs.

The empirical literature on the product cycle shows that there is a strong positive relationship between research effort and the export performance of U.S. industry. Specifically, there is a direct correlation between research effort by U.S. industries and trade with non-European countries. Moreover, the empirical studies indicate that economies of scale in production and a high per capita GNP are positively related to the development and production of new products, a result which is consistent with Vernon's concept of the product cycle.

The findings of the empirical literature on the product-life cycle have important implications for LDCs. The results indicate that labor skills, technical knowledge, and

human capital are comparatively more important in determining the pattern of international trade than physical capital. Therefore, as long as LDCs are deficient in human capital, they will continue to manufacture older highly standardized products originally introduced by DCs.

This chapter is divided into five parts. In Section 2.1 the product life-cycle hypothesis as outlined in Vernon (1966) and (1979) is reviewed. Section 2.2 surveys recent attempts to formalize Vernon's life cycle hypothesis and explain the pattern of North-South trade. The key papers in this group are by Krugman (1979), Dollar (1986), Jensen and Thursby (1986), Flam and Helpman (1987) and Grossman and Helpman (1989).

Section 2.3 examines a series of articles which test for the existence of a product cycle in international trade. The relevant papers in this part are by Gruber, Mehta and Vernon (1967), Keesing (1967), Hufbauer (1970), Hufbauer and Chilas (1974), Stern and Maskus (1981) and Bowen (1984).

Section 2.4 outlines a few case studies of the product cycle. In particular, the history of the color television receiver (CTV) industry, the textile and clothing industries as described in a publication of the Organization for Economic Co-Operation and Development (1985) and Walker (1979) and the history of the petrochemical industry analyzed by Stobaugh (1971). Finally, a brief summary of the chapter

is provided in section 2.5.

2.1 The Product Life Cycle Theory

In his 1966 paper, Vernon asserts that the pattern of trade is in a continuous state of flux as products pass through different stages of their life cycle. He hypothesizes that there are three stages to the product cycle, (i) new products, (ii) maturing products and (iii) standardized products.

Vernon finds the variety of products developed in an innovating country and the technology used to manufacture these commodities reflect the specific characteristics and needs of the country. For example, labor costs are relatively high in the United States. Thus, the United States makes use of labor saving technologies in manufacturing and tends to develop products manufactured with large economies of scale. Also, innovation and production are closely linked to the pattern of demand in a country. In the case of the United States, it has the highest per capita income in the world and so products aimed at consumers with high income levels are developed and marketed in America.

According to Vernon (1966), commodities that are being marketed for the first time, new products, are sold primarily in the home market. The reason for this is that the specifications for new products and their production technology are initially not standardized. The innovating

firm markets the product at home in order to reduce any unnecessary costs in the early stages of production, i.e. transport costs, and to insure close contact with its buyers. Any information transmitted back to the firm is then used to improve the product.

Over time, the specifications for the commodity become standardized and technical possibilities for economies of scale arise through mass production so that production costs and prices begin to fall. Moreover, as demand spreads to foreign markets the innovating country begins to export the good. When economies of scale are fully exploited in the innovating country, lower foreign labor costs induce producers to transfer their production abroad. The length of the first phase of the product cycle in which the innovating country produces the new commodity therefore, depends on the extent of economies of scale and the wage gap between the two regions.

In his 1979 paper, Vernon updates his original theory of the product life cycle to conform with changes in the structure of world trade. Specifically, he cites two major events in the world environment that have influenced the product cycle. First, the growth of enterprises with highly developed multinational networks has lead to a significant increase in both the quantity and quality of information available to the innovating enterprise in DCs. Multinational

companies (MNCs) now have subsidiaries across the world and can gather their own information concerning foreign markets. As a result, new products are more likely to meet the needs of a homogeneous world demand, rather than just satisfying domestic demand. For example, innovations in chemicals, aircrafts, computers, automobiles and pharmaceuticals are now geared towards the global market. Consequently, the innovating firm can take advantage of global economies of scale in production and marketing.

Second, per-capita income levels in the United States no longer significantly exceed those of Canada, Western Europe, and Japan. In the 1940s and 1950s, lower relative labor costs in Canada and the United Kingdom made these countries the preferred location for new investments by U.S. MNCs. As labor costs in DCs rose and MNCs gained information about foreign markets, the preferred location for the establishment of U.S. subsidiaries in comparatively labor-intensive industries, shifted to Asia, Africa, and Latin America.

The product cycle is thus, less important in explaining U.S. trade with other DCs than trade between DCs and LDCs. In fact, many DCs have now become innovators exporting their own technologies to foreign countries. For example, Stobaugh (1971) finds that many petrochemicals were introduced commercially by Germany and various important plastics and

man-made fibers were developed by Germany, the United Kingdom and Italy. In addition, Walker (1979) shows that the Japanese are now a leading innovator in electronics. Nevertheless, the product cycle remains an important component of U.S. trade with LDC and it is lower labor costs in LDCs that triggers the product cycle.

Vernon cites several examples of commodities which have been transferred from the United States to LDCs. In the textile industry, production of cotton sheeting and men's shirts have been transferred to LDCs, while production of women's clothing, which is less standardized, remains in the United States. In electronics, the mass production of transistors has been transferred to LDCs, whereas research oriented production remains in the United States.

2.2 Modeling the Product Cycle

Interest in Vernon's theory of the product cycle has recently been revived in the trade literature. Krugman (1979), Dollar (1987), Jensen and Thursby (1986) and Grossman and Helpman (1989) construct formal models to explain the product cycle, whereas Flam and Helpman (1989) develop a model of the product cycle with vertical product differentiation. Each of these papers uses the product cycle to justify the pattern of North-South trade and the wage gap between these two regions.

Krugman (1979) constructs a simple model of trade,

innovation, and technology transfers with one input, labor, two countries, North and South, and many goods to explain the product cycle. He assumes that wages are always higher in the North and justifies the wage gap on the grounds that "the advantage of the DC does not lie in its greater endowment of nonhuman inputs per worker as much as in a superior ability to exploit new technologies" (p. 255). Furthermore, he assumes that there are only two types of goods, old goods and new goods. Each old good is produced with a production technology that is available to both countries. In contrast, new goods have been recently developed and can only be produced in the North. Since all goods are produced with the same cost function - that is, both goods require one unit of labor - Krugman rules out Ricardian explanations of trade.

The results show that the proportion of new goods to old goods is a function of both the rate of innovation, which is proportional to the number of goods already in existence, and the rate of technology transfer. The rate of technology transfer is simply the rate at which new goods become old goods, which is assumed to be a constant function of time. Thus, because all goods are produced with one unit of labor and wages are lower in the South, only the South will produce old goods.

Krugman derives a steady-state equilibrium in which the wage gap is constant and the North produces and exports new

goods. In this steady state the ratio of new to old goods, the ratio of Northern to Southern goods, is constant, although the pattern of production and trade is continually changing.

The most intriguing feature of the model is that the relative wage and the terms of trade depend on the proportion of goods produced in each region. Whenever a production technology is available to Southern producers, the commodity will be produced in the South. This finding implies that in the absence of innovation, the North-South wage gap will fall over time and the North must continually innovate to maintain its relative wage advantage.

Moreover, the results indicate that lower Southern labor costs induce Northern industries to transfer their production to the South. However, the model does not account for the impact of economies of scale on the pattern of trade. Recall that Vernon (1966, 1979) stresses that production transfers will occur when economies of scale are fully exploited in the North, and not merely when the technology becomes available to Southern producers as in Krugman's model. In Vernon's theory it is possible for the lower wage in the South to be offset by the economies of scale in the North so that production of the commodity remains in the North though the technology is public knowledge.

Dollar (1986) extends Krugman's model of the product

life cycle by developing a model of trade, innovation, and technology transfers with two factors of production, capital and labor, two countries, and many goods. He assumes that wages are higher in the North and that through capital mobility the return to capital is equalized across countries. The innovative feature of the model is that the rate of technology transfers is not assumed to be a function of time as in Krugman (1979), rather it is an endogenous function of differences in production costs between the two regions.

As in Krugman (1979), Dollar derives a steady-state equilibrium in which the wage gap is constant, the North produces and exports new goods and the proportion of goods produced in each country is fixed over time. The wage gap, which is a positive function of the ratio of goods produced in each country, is directly related to the rate of innovation. Because the return to capital is equalized across countries, lower Southern labor costs initiate the product cycle. As the North innovates, the relative wage rises in its favor generating an increase in Northern costs of production and a transfer of production to the South.

In Krugman's model an increase in the size of the Southern labor force leads to both a rise in the demand for Northern goods and an increase in the North-South wage gap. However, he assumes that the rate of technology transfer is constant; consequently, growth in the Southern labor force

does not alter the rate of transfer. In contrast, growth of the Southern labor force causes the wage gap to decrease in favor of the South in Dollar (1986) because he assumes that the rate of technology transfer is endogenous and capital is mobile. As a result, when the Southern labor force grows capital migrates to the South and the rate of technology transfer increases lowering the demand for Northern labor.

Moreover, by making the rate of technology transfer endogenous and adding a second factor of production, Dollar captures an important feature of the product cycle not found in Krugman's model. Specifically, Dollar finds that since the capital-labor ratio is higher in the North, the North produces capital-intensive products although their technology is freely available to the South. Nevertheless, as in Vernon (1966) and Krugman (1979), Dollar concludes that lower Southern wages triggers the product cycle.

It is important to note that both Krugman (1979) and Dollar (1986) assume that both the rates of innovation and technology transfer cannot be altered by the diversion of labor from current production into product development in the North or imitation in the South. Conversely, in the next two papers reviewed in this section the North can choose the rate of innovation by shifting labor from current production into R&D and in the same manner the South can alter the rate of production transfer.

First, Jensen and Thursby (1986) develop a two country, North and South, one input and many good model of innovation, technology transfers and international trade to study the product cycle. As in Krugman (1979) and Dollar (1986), there are two kinds of goods, old goods and new goods, labor is equally productive in the two regions, only the North can innovate and labor is paid a relatively higher wage in the North.

The authors are interested in deriving the steady state properties of a Nash equilibrium game in which a Northern monopolist chooses the rate of innovation and a Southern planner sets policy on the rate of technology transfer. Jensen and Thursby use an "open-loop strategy" in which the players do not take into account the response of their rivals to their present action. Thus, neither the monopolist nor the planner can make their entire decisions ex ante. The novel feature of the model is that it examines how the rates of innovation and technology transfer are "strategically related" in a dynamic context and determines the optimal rates of innovation and technology transfer.

As stated above, Jensen and Thursby (1986) assume that both innovation and technology transfers require the diversion of labor from current production. In essence, the Northern monopolist chooses the rate of innovation by diverting labor from current production into R&D. Similarly,

the Southern planner determines the rate of technology transfer by diverting labor from production into reverse engineering. Reverse engineering is defined as, "the process in which the South learns to produce a new good by dismantling and studying it" (p. 272). However, there is a minimum rate of technology transfer which is independent of the diversion of labor into reverse engineering. Similar to Krugman (1979), this assumption implies that if the North does not innovate then the ratio of Southern produced goods will expand and the wage gap will fall in favor of the South. It is therefore always optimal for the North to divert some labor into product development.

The monopolist's objective is to choose an optimal input of labor for innovation in order to maximize its discounted future stream of profits. Likewise, the planner's objective is to pick an optimal input of labor for reverse engineering to maximize the present discounted value of its future stream of utility. Because the quantity of labor diverted into new product development or imitation enter both the monopolist's and the planner's reaction functions, the optimal rate of innovation depends on the rate of technology transfer and vice versa. This is not surprising since the South diverts resources into technology transfers to catch up with the North. If the North increases its rate of innovation, then the South will divert more resources into

technology transfers. Conversely, the North shifts resources into innovation to maintain its relative wage advantage over the South. Consequently, the North will raise its rate of innovation if the South expands its rate of technology transfer.

The findings suggest that there exists an optimal rate of innovation and technology transfer. As the North allocates a greater amount of resources into R&D, as the rate of innovation increases, the South will boost its rate of technology transfer in order to keep up with the North. Hence, the North will retain monopoly control over the new commodity and profits from its sale for a shorter period of time. The optimal rate of innovation in the North is chosen to equate the North's marginal revenue product of labor between current production and innovation.

To conclude, Jensen and Thursby (1986) find that the steady state Nash equilibrium is characterized by both a constant ratio of new goods to old goods and a constant ratio of innovation to technology transfer. Furthermore, the model generates a product cycle in which the North innovates and produces new goods which over time are transferred to the South.

These results conform with those of Krugman (1979) and Dollar (1986). In all of these papers the lower Southern wage initiates the product cycle and the steady state is

characterized by the production of a fixed proportion of goods in each region and a constant relative wage. It is therefore interesting to note that while Krugman (1979) assumes that both the rate of innovation and technology transfer are exogenous and Dollar (1986) assumes that only the rate of innovation is exogenous, Jensen and Thursby (1986) derive very similar results by assuming that both of these rates are determined endogenously.

Similarly, Grossman and Helpman (1989) develop a model of the product cycle with endogenous innovation and technology transfers in which all goods are produced with one input, labor, wages are lower in the South and innovation takes place in the North. However, unlike Jensen and Thursby (1986), they do not restrict innovation to a single monopolist and decisions on technology transfers to a single planner. Rather, they assume that oligopolists direct resources into product development and reverse engineering (imitation). Innovation and imitation create country specific by-product benefits in the form of knowledge which add to the productivity of future efforts. Hence, countries become relatively more efficient at product development and imitation over time.

Grossman and Helpman (1989) assume that firms behave as Bertrand competitors. When two Northern firms produce the same commodity, or a Northern firm copies the innovator,

price is set equal to marginal costs and neither firm makes a profit. As a result, firms cannot recoup their sunk costs; consequently, two firms will never produce the same product. By a similar argument, two Southern firms will never produce the same commodity. However, when a single firm produces the product profits are modeled as a mark-up over costs implying that an increase in output leads to a rise in profits.

The model depicts a steady state which is similar to that of the previous three papers outlined in this section. In the steady state, both the rate of innovation and the rate of technology transfer are constant, or the ratio of Northern goods to Southern goods is fixed. Northern firms innovate when the expected present value of their future stream of profits exceeds the cost of innovation. Once the South produces the commodity, the North ceases to manufacture it since wages are lower in the South and Southern producers sell the commodity at a lower price. As in Jensen and Thursby (1986), the initial stage of the product cycle, the period in which the North produces the commodity and earns oligopoly profits, depends on the South's desire to imitate.

Furthermore, Grossman and Helpman go beyond the Jensen and Thursby analysis by examining the factors which determine the profitability of innovation and the North's desire for innovation. Grossman and Helpman show that if the resource base in the South increases, or if productivity in the South

improves, the steady-state rates of innovation and technology transfer expand. In this case, the South can divert more resources into imitation and the period for which the North earns oligopoly profits, the initial stage of the product cycle, shrinks. One would normally expect the North to respond by reducing its rate of product development. However, because a rise in rate of technology transfer implies that the North produces fewer commodities, Northern labor is spread more densely over a narrower range of commodities generating an increase in firm output. Since profits are a mark-up over costs, profits rise and the North can afford to channel more resources into product development.

These findings differ from those found in both Krugman (1979) and Dollar (1987). In Krugman's model the rates of innovation and technology transfer remain constant when the South's labor force expands. In contrast, Dollar (1987) finds that the rate of technology transfer increases when Southern wages fall but the rate of innovation remains constant. The unique feature of the Grossman and Helpman (1989) paper is that they are able to capture the relationship between the rate of technology transfer and the rate of innovation. In particular, they find that the North does not remain passive when the South begins to increase its rate of imitation and vice versa.

Finally, the authors show that trade increases the welfare of both countries. Trade enables the North to expand its existing output and divert resources from manufacturing into product development. When the North trades, it produces a narrower range of goods but serves a larger market. As a result, output rises across all Northern firms and both the rate of profit and the rate of innovation increase. Likewise, trade leads to a welfare improvement in the South because the imitation of Northern goods requires less resources than their own product development. Recall that the South is better at imitation than product development. Consequently, the South can produce a narrower range of commodities, its output expands across all firms and both the profit rate and rate of imitation rise in the South.

To summarize, Grossman and Helpman (1989) find as do the other papers reviewed in this section, that the product cycle is driven by lower Southern labor costs. The innovative feature of their model is that they are able to identify the factors which determine the length of the initial phase of the product cycle, rather than assuming that the length is set exogenously. In addition, they conclude that trade raises the steady-state growth rate because it allows both countries to divert a greater amount of resources into expanding their product base. This link between trade and growth is not made in the other papers reviewed in this

section. For example, in Krugman (1979) and Dollar (1987) the rate of innovation is exogenous so that there is no feedback between trade and innovation.

The first four papers surveyed in this section analyze the impact of innovation on the pattern of trade within a dynamic framework. However, Flam and Helpman (1987) present a static model of North-South trade which generates results which are consistent with those of the product cycle theory.

Flam and Helpman (1987) assume that there are two goods, a homogeneous product and a vertically differentiated product, differentiated according to quality. Also, wages are higher in the North and one unit of labor produces one unit of the homogeneous product, while the required labor input per unit of the differentiated product varies across countries. The North is assumed to have a comparative advantage in the production of higher quality products and the South manufactures the lowest quality varieties and the homogeneous product.

Each consumer maximizes their utility by choosing a level of the homogeneous product and a specific variety of the differentiated product subject to their income constraint. Utility increases with quality and consumers in different income classes demand different varieties. Specifically, high income consumers purchase the relatively expensive high quality varieties.

Trade occurs because neither country produces a range of varieties that can satisfy domestic demand. In other words, both regions have consumers in each income class and since incomes are higher in the North, it exports the high quality varieties and the South exports the low quality varieties and the homogeneous product.

Especially important is the fact that Flam and Helpman's model generates a quality-based product cycle. Specifically, when the South's population grows, and assuming that population growth is distributed evenly among all income classes, the relative wage will increase in favor of the North because demand for Northern products expands in relation to Northern supply. The rise in the relative wage, in turn, causes the relative price of Northern goods to increase. Therefore, Northern varieties become relatively more expensive and consumers in the lower income classes shift their consumption from comparatively lower quality Northern varieties to the cheaper Southern varieties. Note that the low quality Northern goods are still of higher quality than any Southern varieties. However, because it is assumed that population growth is distributed evenly among all income classes, there is now a larger number of high income consumers, and hence, the demand for highest quality Northern varieties expands. As a result, Northern producers abandon their production of lower quality varieties in favor

of higher quality varieties. Similarly, there is a greater number low income consumers so that Southern producers expand their production to include the varieties abandoned by the North.

In conclusion, the model generates a quality-based product cycle in which the North abandons its lowest quality varieties and simultaneously, the South begins to produce these varieties. In addition, the product cycle is triggered by the rise in the Northern wage.

To summarize, this section reviewed a series of papers on the product cycle. The common feature in these models is that lower Southern labor costs induces Northern producers to transfer their production to the South. All the papers, with the exception of Flam and Helpman (1988), generate a dynamic product cycle in which the rate of innovation and the rate of technology transfer are constant in the steady state. Each author however, models innovation and technology transfers in a slightly different manner. For example, Krugman (1979) assumes that both are exogenous, whereas Grossman and Helpman (1989) model innovation and technology transfers endogenously. Finally, none of these papers use economies of scale to justify the length of the initial stage of the product cycle whereas Vernon (1966) and (1979) stressed the importance of this factor.

2.3 Testing the Product Cycle

Empirical tests of trade theories are concerned primarily with answering questions concerning the composition, the direction and the volume of trade. Deardorff (1984) states that while empirical tests have been carried out on these questions, trade theory deals mainly with the composition of international trade.

This section presents a review of empirical tests of the product cycle theory of trade. In most of the papers surveyed in this section, U.S. trade data is used to not only explain the pattern of U.S. trade, but also to identify the factors that determine the destination of its trade.

In their 1967 paper Gruber, Mehta and Vernon conduct an empirical study to determine the importance of R&D on international trade and international investment by U.S. industries. Using 1962 U.S. data and a two digit S.I.C. industrial classification for 19 industries, the authors test for the correlation between industrial expenditures on R&D and export performance at the industry level.¹ Their results indicate a strong positive correlation between R&D as a percentage of total sales, and export performance of U.S. manufacturing industries. Moreover, they find that those industries most heavily investing in R&D in the United States accounted for 84.4% of the nations R&D expenditures and 72% of the nations exports of manufactures, although they were

responsible for only 39.4% of total domestic sales of U.S. manufactures.²

Second, the authors examine the characteristics of research-intensive industries in the United States. They conclude that research effort is positively correlated with new product development. In addition, research-intensive industries employ a large complement of scientists and engineers in production and sales, contain large economies of scale in production, and are generally not intensive in physical-capital. As in the theory of the product cycle, these results indicate that product development is an important stimulus for U.S. exports.

Thirdly, Gruber, Mehta and Vernon disaggregate the data into U.S. trade with European countries and U.S. trade with non-European countries. They conclude that there is no evidence to suggest a significant correlation between research effort and trade with Europe by U.S. industries. These results are not surprising since research-intensive European industries, in particular those in Germany and the United Kingdom, are in direct competition with their American counterparts. For example transport, machinery (non-electrical) and electrical machinery industries, in the United Kingdom, Germany and the United States compete in similar markets. In contrast, the data indicates that there exists a strong positive correlation between research effort

and export performance with non-European countries.

Finally, the study tests for the relationship between export performance and foreign investment expenditures on plant and equipment by U.S. industries. Using data for 1958 to 1964, the findings suggest that there is a greater tendency for research-intensive U.S. industries to actively invest in foreign subsidiaries. These findings imply that industries not engaged in research are in the late stages of the product cycle, having almost completely transferred their export production abroad. In other words, non-research-intensive industries are no longer expanding their foreign subsidiary base. In contrast, research-intensive industries in their early stages of the product cycle are in the process of moving their manufacturing to foreign locations; consequently, they are investing heavily in foreign subsidiaries.

In conclusion, Gruber, Mehta and Vernon suggest that their results imply "the existence of national markets, in which economies of large scale and barriers to entry stem from the requirements of successful innovation and successful marketing, rather than from capital intensity" (p. 28). Moreover, their findings demonstrate that there is a strong correlation between investment in R&D and export performance by U.S. industries. However, while research-intensive industries rely upon exports and foreign investment, other

industries depend on sales of their foreign subsidiaries rather than exports to penetrate foreign markets.

Keesing (1967) also tests for the impact of R&D on the trade performance of U.S. industries. In particular, he investigates whether the competitive position of the United States can be attributed to its ability to introduce new products into the market. The study uses 1960 and 1961 data on the percentage of scientists and engineers in total industrial employment as a proxy for R&D.

He begins by testing for the correlation between R&D effort and the competitive position of U.S. industries, measured by "U.S. exports in each industry as a percentage of total 1962 exports of the leading industrial countries" (p. 38).³ The results suggest a strong positive correlation between R&D effort and the competitive position of U.S. industry. Research-intensive U.S. industries tend to have a higher ratio of exports to total industrial production.

Furthermore, Keesing examines the link between R&D effort and three variables which have been associated with successful export performance, physical-capital requirement, labor-skill requirement, and economies of scale. Data for the United States indicate that the physical-capital requirement is negatively correlated with R&D effort and trade performance. This may suggest that the Leontief paradox still holds because the degree of standardization of

new products is low and mass production using capital-intensive techniques is not possible. In contrast, labor-skill requirement and economies of scale are positively related to R&D effort. R&D is found to require large inputs of scientists and engineers and thus, is only undertaken when there are prospects for large scale production.

In conclusion, Keesing's results support those of Gruber, Mehta and Vernon (1967) and the theory of the product cycle. His study suggests that the comparative advantage of U.S. industry is in its ability to develop and market new goods produced in relatively skill-intensive industries that exhibit large economies of scale in production.

In Vernon's theory of the product cycle, newly-invented goods are initially produced and exported by the innovating country. However, as the production process becomes more standardized production is transferred to low wage countries. Hufbauer (1970) investigates whether early manufacturing of new goods and technological sophistication lead to the export of differentiated products. The study uses 1965 trade data for twenty-four countries which make up ninety-five percent of the manufactured exports from non-socialist countries.

To compute the degree of differentiation in the production process, Hufbauer assumes that standardized products imply standardized production processes, since these goods are often mass produced. At the three-digit SITC

industrial classification, the results indicate that across all goods the rank correlation between product differentiation and the age at which an industry first exports its product is not significant. The reason for this is that goods begin their lives with varying degrees of differentiation; consequently, there is no direct correspondence between product age and product standardization across goods. However, when eighteen industries with much higher or lower degrees of differentiation than their first trade dates suggest are deleted from the analysis, the rank correlation between product age and standardization increases significantly.

The results of Hufbauer's study also suggest a strong positive correlation between the degree of product differentiation and the skill ratio of the labor force. Industries with relatively high skilled to unskilled labor ratios export differentiated products. Generally, differentiated products require more skills in manufacturing and thus, tend to be produced in DCs.

Finally, it should be noted that Hufbauer finds a strong positive link between per capita GNP and the degree of differentiation embodied in a country's exports.⁴

To summarize, Hufbauer's findings show that an advanced nation with a large ratio of skilled to unskilled labor will tend to produce and export differentiated products.

In their 1974 paper Hufbauer and Chilas study the effect of protectionism on the pattern of specialization and the pattern of trade amongst industrialized countries. Using three-digit SITC industrial groups, they measure the degree of specialization by comparing the ratio of net exports in an industry to manufacturing value added.

The authors divide all commodities into three categories:

(i) Ricardo goods, defined as goods characterized by the importance of natural resources in their production. Examples of Ricardo goods are, dairy products, livestock products, wood, minerals, and oil and petroleum.

(ii) Heckscher-Ohlin goods, commodities produced with standard technologies and manufactured with constant returns to scale in labor and capital. Types of Heckscher-Ohlin goods are, beverages, tobacco, paints, paper articles, textiles, and furniture.

(iii) Product-Cycle goods, defined as high technology goods produced with large know-how rents. Product-Cycle goods are, chemicals, medicinal products, power machinery, communications equipment, and aircrafts.

Hufbauer and Chilas hypothesize that industrialized countries protect Heckscher-Ohlin goods, causing the pattern of specialization in these countries to shift towards Ricardo

goods and Product-Cycle goods.

In general, governments are hesitant to restrict trade in scarce natural resources and technology - that is, in Ricardo goods or Product-Cycle goods - because these are often intermediate goods. However, by protecting Heckscher-Ohlin goods, DCs can attract capital by inducing MNCs to produce in the host country. In other words, the MNC evades the tariff barriers by establishing plants in the home market.

To estimate the extent of specialization in the absence of trade barriers, the study compares data for U.S. interregional trade, trade among four regions in the United States, to U.S. international trade data. The results show that the ratio of interregional trade to value added is highest for Heckscher-Ohlin goods and somewhat lower for Ricardo goods and Product-Cycle goods. Alternatively, the ratio of international to interregional trade is highest for Ricardo goods, somewhat lower for Product-Cycle goods and very small for Heckscher-Ohlin goods. Five Product-Cycle goods, chemicals, aircrafts, power machinery, office machines and watches and clocks, ranked among the top ten U.S. international exports.

The authors conclude that the importance of Heckscher-Ohlin goods in interregional trade is a direct result of the lack of domestic trade barriers. Nevertheless,

Product-Cycle goods remain an important component of U.S. international trade.

The first four papers reviewed in this section examine the determinants of international trade at one point in time. In contrast, Stern and Maskus (1981) analyze changes in the structural determinants of U.S. trade at different points in time. As in Hufbauer and Chilas, they distinguish between Ricardo goods, Heckscher-Ohlin goods and Product-Cycle goods.

Stern and Maskus use 1958 to 1976 three-digit SIC industry data for U.S. net exports of manufactures to test a three-factor version of the Heckscher-Ohlin model. To derive the determinants of U.S. international trade, the authors regress net exports of all three categories of goods on three factors of production;

$$(2.1) \quad NX_{\tau}(t) = f(K_{\tau}(t), H_{\tau}(t), L_{\tau}(t))$$

where: $NX_{\tau}(t)$ = U.S net exports for industry τ at time t ;

$K_{\tau}(t)$ = total stock of physical capital in industry τ at time t ;

$H_{\tau}(t)$ = the stock of human capital in industry τ at time t ; and,

$L_{\tau}(t)$ = industry employment at time t .

It is assumed that this model applies across all U.S. industries.

The results of the regression analysis imply that $L_{\tau}(t)$ is inversely related to $NX_{\tau}(t)$, reflecting the relative

scarcity of unskilled labor in the United States. The stock of human capital H_t , is directly related to NX_t because of the relative abundance of human capital in U.S. net exports. In contrast, K_t is negatively related to net exports in 1958 but positively correlated in 1972. This demonstrates that the Leontief paradox was no longer relevant in 1972.

In addition, Stern and Maskus plot the movement of U.S. net exports of manufactures from 1958 to 1976. Figure 2.1 reproduces the results found in their paper. It clearly illustrates that between 1958 and 1976 U.S. net exports of Heckscher-Ohlin goods have steadily declined, falling to a minimum -\$13.3 billion in 1976. Note that the authors also show that U.S. net exports of Ricardo goods, not shown in Figure 2.1, remained fairly constant until 1973 and declined thereafter to -\$9.2 billion in 1976. Conversely, U.S. net exports of Product-Cycle goods increased continuously during this period, reaching a maximum of \$31.8 billion in 1976.

Finally, Stern and Maskus test for the importance of technological factors on U.S. trade in manufactures. Since annual data were not available to construct a technological measure, 1960 and 1970 U.S. census data for both the number of engineers and scientists as a percentage of total employment in an industry and the industry-level expenditures on R&D as a percentage of value added are used. The

regression results demonstrate that technological inputs are a relatively more important component of U.S. net exports than unskilled labor and physical capital. Likewise, there is some weak evidence to suggest that the coefficient on unskilled labor became smaller and the coefficient on R&D grew larger between 1960 and 1970.

To summarize, Stern and Maskus conclude that technological influences in U.S. trade of manufactures are becoming more pronounced over time. The United States tends to export goods with a high component of skilled labor and R&D. These findings are consistent with the predictions of the product life cycle theory and the empirical tests outlined in the first four papers surveyed in this section.

As in Stern and Maskus (1981), Bowen (1983) analyzes the changing structure of U.S. exports. He compares the distribution of factor inputs across thirty-four countries. The results indicate that in terms of capital per worker endowment, the United States ranked first among the thirty-four countries in 1963 but fell in rank to sixth in 1975. Other countries whose ranking worsened were Germany and the United Kingdom. In contrast, Japan, France, Norway and Turkey improved their ranking. In terms of the ratio of skilled to unskilled labor endowment, once again the rank of the United States dropped from second to seventh. Likewise, Canada, Belgium and Hong Kong fell in rank, while Finland,

Denmark, and Norway improved their ranking.

The data also imply that U.S. exports of skill-intensive goods, or Product-Cycle goods, declined after 1971, although U.S. exports of Product-Cycle goods to LDCs rose during this time period. This conforms with Gruber, Metha and Vernon (1968) study. Similarly, the ratio of skilled to unskilled labor embodied in U.S. exports to DCs decreased after 1971.

Finally, Bowen regresses net exports on physical capital and three classifications of both land and labor. The regression results for five separate time periods show that skilled labor is positively related to net exports, unskilled labor and land are inversely related to net exports, while the relationship between physical capital and net exports is less clear. The sign on the capital coefficient shifted from negative in the first two periods to positive in the last three periods suggesting the possible existence of the Leontief paradox in the early years of the sample.

Bowen's results are consistent with those of Stern and Maskus (1981). The study concludes that the changing pattern of resource endowments in the world has lead to a changing pattern of international trade. Specifically, relatively slow growth in the ratio of skilled to unskilled labor in the United States has caused a decline in U.S. exports of

Product-Cycle goods. Nevertheless, skilled labor embodied in U.S. net exports remains the most important component of U.S. trade.

In conclusion, the papers reviewed in this section demonstrate that R&D, skilled labor and economies of scale are important factors in determining the pattern of U.S. trade, whereas capital is far less important. As a result, the United States has a positive trade balance in Product-Cycle goods. However, as the rate of growth of R&D expenditures and of the ratio of skilled to unskilled labor in the United States has slowed, the United States has lost some of its comparative advantage in Product-cycle goods. Moreover, because Europe and Japan now compete with the United States in the market for Product-Cycle goods, LDCs have become the primary importers of these goods from the United States.

2.4 Case Studies

There are numerous case studies of the product life cycle. In this section, the product cycles of color televisions, petrochemicals, textiles and clothing are reviewed.

2.41 Color Televisions

The theory of the product cycle is often used to explain trade in the color television receiver (CTV)

industry.⁵ CTV technology was first invented and produced in the United States. However, because of high U.S. labor costs and the introduction of standardized production technologies, production of CTVs was transferred initially to Japan and later to South Korea and Taiwan.

Public color television broadcasting began in the United States in 1954. By the early 1960s the majority of broadcasts were in color and by 1966 annual sales of CTVs had reached five million in the United States. In 1967 approximately 6% of U.S. sales, or 300,000 CTVs, were imported, primarily from Japan, into the United States. By 1971, imports had increased to 1.3 million sets, or 19% of the U.S. market.

Three factors which distinguished the Japanese industry from its U.S. competitor accounted for the success of the Japanese firms in penetrating the U.S. market. Firstly, Japanese labor costs were 25% below U.S. costs. Secondly, Japanese firms innovated and introduced solid-state components in advance of U.S. firms. Finally, U.S. firms concentrated on the production of large sets while the Japanese produced smaller sets thereby benefiting from careful selection of their product market.

As sales of U.S. manufactures continued to decline in the early 1970s, the industry became more capital intensive and transferred labor-intensive processes to low wage

countries, specifically to Mexico and South East Asia. By 1974, the percentage of imported components in American CTVs rose from 3% to 16%. In spite of these cost cutting measures on the part of U.S producers, imports grew to 33% of the U.S. market by the end of 1976.

In response to the overwhelming competition from the Japanese, U.S producers began to demand protection against Japanese imports. In 1977, the Japanese government signed the "Orderly Marketing Agreement" (OMA), a voluntary export restraint agreement, with the United States. In spite of the agreement, imports of CTVs into the United States increased in 1978. While the agreement successfully lowered Japanese exports to the United States, reducing Japan's share of U.S. imports from 90% to 50% of the market, imports from South Korea and Taiwan increased rapidly. As a result, the OMA was extended to include both South Korea and Taiwan.⁶

Japanese producers reacted to these restrictions by increasing their R&D effort to both further reduce costs and invent new products. As television technology reached its maturity in the late 1970s and early 1980s, Japanese production of CTVs declined. Figure 2.2 shows that Japanese exports of CTVs were replaced by a growing volume of video-tape recorder (VTR) exports to the United States.

The history of this industry reflects many of the characteristics of Vernon's (1966) theory of the product

cycle. The product was first invented and produced in the United States. The O.E.C.D. (1981) concludes that innovation in the United States initially led to the creation of a domestic CTV industry. As demand for CTVs increased and both the product and the production technology became more standardized, the Japanese took advantage of their lower labor costs to capture a significant share of the U.S. market. As prices started to decline the United States began to subcontract the more labor intensive components of the product to lower wage countries. Unfortunately, rather than continue to innovate and develop new products, the United States turned to protectionism to retain its market share. In fact, it was the Japanese who became the innovators moving into the production of VTRs in the late 1970s and shifting their CTV industry to South Korea and Taiwan. Japanese producers of electronics pursued a product cycle strategy adjusting to changes in their pattern of comparative advantage, while American producers relied on protectionism.

2.42 Petrochemicals

Stobaugh (1971) examines the life cycle of the petrochemical industry. He finds that the United States and Germany are the primary innovators of petrochemical products and that initially production is located in the home market. Essentially, manufacturers try to reduce the risk from the potential collapse of the foreign demand by originally

securing the domestic market.

Furthermore, Stobaugh notes that there is always a lag before a product is exported. Of the nine products reviewed in his study, the average lag in the United States was fourteen years. The petrochemical industry is characterized by large economies of scale and the industry tends to locate in large markets in order to take advantage of the available economies. For example, Stobaugh shows that marketing costs for new chemical products decline from about 23% of total sale price to 2% as the product matures. Locating in large markets further reduces these costs making the United States and Germany ideal locations for early production.

As demand for the petrochemicals spreads to foreign markets, the innovating firm initially services this demand with domestic production. However, when foreign markets can support an efficient-sized plant, plants are constructed abroad and exports from the home country begin to fall. Table 2.1 shows the decline in U.S. exports of petrochemicals as a percentage of U.S. production between 1914 and 1969.

Table 2.2 indicates that the longer is the imitation lag, the greater are U.S exports as a percentage of industry production. The reason for this is that foreign demand continues to rise over time but because imitation is slow to occur domestic exports increase.

Stobaugh finds that on average U.S. exports peak some twenty-five years after the product is initially introduced into the market. This period exceeds the longest imitation lag cited in table 2.2. Essentially, firms continue to export even after imitation begins to occur. In the case of Styrene Monomer, exports to Germany from the United States were worth approximately ten million dollars in 1964 and 1965. Consequently, Germany constructed a new Styrene Monomer plant at this time and U.S. sales in Germany declined dramatically after the plant was completed. Nevertheless, U.S. exports of Styrene Monomer remained constant in 1966 as exports to Germany were substituted for sales to other countries.

In the later stages of the product cycle exports of petrochemicals from the United States and Germany persist because plant size is lumpy. New plants are only built when they can be supported by the size of the local market. Regions in which demand is insufficient to warrant their own plants, rely on imports from the home country.

In summary, Stobaugh (1971) concludes that the petrochemical industry follows a product cycle in which the United States and Germany innovate and initially export the product. Table 2.2 demonstrates that the share of exports in total production is higher for petrochemicals initially produced in the United States. Over time as demand in foreign markets expands and plants are constructed abroad,

exports from the home country begin to decline. One of the important features of the study is that Stobaugh links the length of the initial phase of the product cycle with the level of economies of scale. He finds that the initial phase is relatively long for petrochemicals, fourteen years on average, because petrochemicals have large economies of scale.

2.43 Textiles and Clothing

The history of the textile and clothing industries in Europe and the United States are examined by Walker (1979) and the O.E.C.D. (1985). These studies indicate that high levels of trade restrictions in both the textile and clothing industries in Europe and North America has restricted the degree of foreign competition in these sectors and slowed the transfer of production to low wage LDCs. However, in spite of the trade restrictions, these two industries display characteristics that are consistent with the product life cycle theory. Specifically, both the textile and clothing industries are characterized by a limited amount of product differentiation. The one exception is the high-fashion clothing industry which is highly differentiated. Secondly, the cost structure is determined by labor costs, giving a comparative advantage to low wage countries. Finally, there are weak barriers to entry and exit reflected by the high rates of turnover and low profit rates.

In the 1950s textile exports from Japan to the United States began to grow. By 1957, 52% of U.S. cotton textile imports were from Japan. In 1957 Japan entered into a voluntary export restraint agreement with the United States that lowered the share of Japanese cotton textile exports from 52% to 30% of the U.S. market by 1960. However, as in the CTV industry, the prime beneficiary of this policy was another LDC. Between 1957 and 1960 Hong Kong's exports of textiles grew from 1% to 25% of the U.S. market. In turn, the Japanese responded by increasing their exports of less restricted products such as wool and synthetics. In fact, between 1957 and 1960 Japanese exports of textile products to the United States rose at an annual rate of 10%.

A comparison of costs structures by the O.E.C.D. (1981) demonstrates that production costs in the textile and clothing industries are substantially lower in LDCs. The manufacturing costs in the newly-industrialized Asian countries are estimated to be 30% to 50% lower than in Europe and North America. The ability of the DCs to retain a large share of the world market is therefore, attributed primarily to the protection given to their domestic industries.

In 1953, textile and clothing accounted for 20% of the manufacturing employment in DCs but by 1980 that rate had declined to 13%. This drop in employment is attributed primarily to increases in the capital-labor ratio in the

textile industry, not to a fall in output. In an attempt to cut costs, the textile industry has moved to large automated plants. Furthermore, the United States, Japan and Europe have abandoned the more price oriented market segments and focused on high value added industrial textiles.

In contrast to the textile industry, the capital-labor ratio has not increased significantly in the clothing industry. In the United States the clothing industry's trade deficit increased steadily in the 1970s reaching 8 billion dollars in 1983. The industry has less opportunities for economies of scale and labor substitution. Thus, DCs have had to compete on a cost basis in the clothing industry and none of the cost cutting measures have restored the competitiveness of the industry, even though DCs have been able to move into the high value-added lines of clothing.

In conclusion, both the textile and the clothing industries have followed patterns which conform with the product cycle theory. However, unlike the CTV industry and the petrochemical industry, these two sectors have been highly protected against foreign competition. The trade restrictions have slowed the transfer of production to lower wage LDCs. Pelzman and Bradberry (1980) estimate that a 30% reduction in U.S. textile tariffs would lead to a twenty-five percent increase in U.S. imports.

2.5 Conclusion

In summary, the results generated in the empirical studies presented in this chapter conform with the theoretical models of the product life cycle. Generally, both the theory and the empirical evidence indicate that R&D is an important factor determining the pattern of trade between DCs and LDCs. Initially, DCs produce new goods at home but as foreign demand expands, production is transferred abroad. The results suggest that skilled labor embodied in U.S. exports is the most important component of U.S. exports of manufactures.

Moreover, the studies indicate that the length of the initial phase of the product cycle depends on the relative labor costs between the two regions and the extent of economies of scale. Stobaugh (1971) found that the initial phase of the cycle was relatively long for petrochemicals because of the large economies of scale in this industry.

In addition, it is shown in this chapter that protectionism on the part of the innovating country can slow the transfer of production to LDCs. For example, in the case of CTVs, textiles, and clothing protectionism prolonged the initial phase of the product cycle. Nevertheless, DCs have been unable to gain a comparative advantage in these industries in spite of the fact that measures have been taken to lower production costs. This suggests that the textile

and clothing industries are in the later stages of the product cycle and the high levels of Northern production are a result of the protection accorded to these sectors.

Finally, the theoretical papers reviewed in this section model cost differences between the two regions as solely a function of the wage gap and not economies of scale. Conversely, the model developed in Chapters 4 to 7 extends the analysis on the product cycle by introducing economies of scale into the model. Hence, production transfers are correlated with both the North-South wage gap and the extent of economies of scale in an industry. Moreover, it is assumed in Chapters 4 to 7 that the economies of scale are external to the firm. The next chapter therefore, presents a review of the literature on external economies of scale.

Endnotes

1. Export performance is measured by: (i) exports as a percentage of total sales, and (ii) the excess of exports over imports as a percentage of total sales.
2. The five industries are, transportation, electrical machinery, instruments, chemicals and machinery (non-electrical).
3. The nine countries are the United Kingdom, Germany, Italy, France, The Netherlands, Sweden, Belgium, Japan and Canada.
4. However, in Canada and Australia product differentiation is inversely related to per capita GNP. Hufbauer feels that these results are due to the relatively young age of these two countries.
5. For a more detailed review of this industry see, O.E.C.D. (1985) Costs and Benefits of Protection, (Paris), 149-167.
6. Unlike the case of the Japanese, the OMA was far more detrimental to South Korea and Taiwan. In these two countries there was virtually no domestic demand for CTVs; consequently, the industries suffered under the restrictions.

Figure 2.1
U.S. Trade Balance for All Manufactures
(Billions of Current Dollars)

Figure 2.2
Japanese Exports of Consumer Electronics Equipment
By Product

Trillions of Yen

Trillions of Yen

Table 2.1

**Decline in U.S. Exports as a Percentage of U.S.
Production, Seven Petrochemicals, 1914 to 1969**

<i>Products First Produced in the United States</i>	<i>Year of Export Peak</i>	<i>U.S. Exports as % of U.S. Production, Average.</i>	
		<i>In peak Year</i>	<i>In 1969</i>
Cyclohexane	1967	47%	35%
Ortho-xylene	1960	87%	70%
Para-xylene	1965	25%	22%
	<i>Average</i>	53%	42%
<i>Products First Produced Abroad</i>			
Acrylonitrile	1963	27%	24%
Synthetic Methonal	1964	14%	2%
Synthetic Phenol	1943	16%	1%
Styrene Monomer	1969	18%	18%
	<i>Average</i>	19%	11%

Source: R.B. Stobough (1971), "The Neotechnology Account of International Trade: The Case of Petrochemicals", Journal of International Business Studies, p. 90.

Table 2.2
Imitation Lag and U.S. Export Peak,
Seven Petrochemicals, 1914 to 1969

<i>Products First Produced in the United States</i>	<i>Imitation Lag of U.S. Average for Products in Sample</i>	<i>U.S. Export Peak as a % of U.S. Production.</i>
Cyclohexane	- 7*	47
Ortho-xylene	-15	87
Para-xylene	- 6	25
<i>Average</i>	- 9	53
<i>Products First Produced Abroad</i>		
Acrylonitrile	+ 7	27
Synthetic Methonal	+ 3	14
Synthetic Phenol	+ 7	16
Styrene Monomer	+ 4	18
<i>Average</i>	+ 5	19

Source: R.B. Stobough (1971), "The Neotechnology Account of International Trade: The Case of Petrochemicals", Journal of International Business Studies, p. 93.

* A negative number denotes the imitation lag in the foreign country. A positive number refers to the imitation lag in the United States.

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Chapter 3

External Economies of Scale

The effect of economies of scale on international trade has received widespread empirical and theoretical attention in the literature. In Vernon's original concept of the product life cycle economies of scale are found to be an important factor affecting the pattern of international trade. In Vernon's model, the rate of production transfer is slowed because the existence of economies of scale in the high wage country offsets the impact of lower labor costs abroad. Helpman (1987) concludes that economies of scale can have "a bearing on a host of trade problems such as explanations of trade patterns, gains from trade, commercial policy, multinational corporations, and direct foreign investment" (p. 236).

The model developed in Chapters 4 to 7 extends previous attempts to formalize the theory of the product cycle by incorporating the effect of economies of scale which are external to the firm but internal to the industry into production. The purpose of this chapter is therefore, to review the literature on external economies of scale.

Throughout Chapters 4 to 7, and in the papers surveyed in this section, it is assumed that markets are perfectly competitive. Chipman (1965) shows that external economies of scale are compatible with perfect competition because under

external economies of scale firms view industry output as exogenous. Consequently, firm-level production functions exhibit constant returns to scale.

Furthermore, since the theory of the product cycle and the model presented in Chapters 6 and 7 are dynamic in nature, this chapter also reviews papers which study the impact of external economies of scale within a dynamic framework. These models suggest that it is possible for the economies of scale in an industry to be increasing over time.

The chapter is divided into four parts. Section 3.1 examines the nature of external economies of scale. The papers surveyed in this section include those by Stigler (1951), Meade (1952), Arrow (1962), J.S. Chipman (1965), Silberston (1972), Herber (1979), Oakland (1987), Helpman (1987), Stiglitz (1989) Lindert (1991), and Krugman and Obstfeld (1991).

Section 3.2 explores some theoretical models using external economies in production. The papers outlined in this section are by Jones (1968), Melvin (1969), Kemp (1969), Herberg and Kemp (1969), Eaton and Panagariya (1979), Manning and Mcmillan (1979), Markusen and Melvin (1981), Choi and Yu (1984), and Markusen and Melvin (1984). These papers are primarily concerned with the gains from trade when production exhibits increasing returns to scale.

Section 3.3 analyzes the relationship between economies

of scale and growth. The papers reviewed in this section are by Silberston (1972), Romer (1986), Lucas (1987), Stokey (1988), Milgrom and Roberts (1990) and Milgrom, Qian and Roberts (1991). Finally, Section 3.4 concludes the chapter.

3.1 Sources of External Economies of Scale

External economies of scale refer to economies of scale which are external to the firm but internal to the industry. Helpman (1987) states that the assumption of external economies rests on the view that "a larger industry takes better advantage of within-industry specialization, as well as better advantage of conglomeration, indivisibilities, and public intermediate inputs such as roads" (p. 329). In essence, higher industry output generates more intra-industry specialization which improves the productivity of all firms within the industry.

As in Helpman (1987), Stigler (1951) believes that geographical concentration can lead to external economies of scale. Agglomeration, for example, lowers transport costs, communication costs and so on. Furthermore, complementary and auxiliary industries co-operate better with the parent industry when they are located in close proximity to one another, thereby reducing the costs of production.

Likewise, Meade (1952) felt that the "creation of atmosphere" generates external economies affecting production. He made the distinction between the factors of

production and the atmosphere of production. Atmosphere is a fairly stable condition influencing the extent of economies of scale in an industry. For example, the provision of public intermediate goods, the creation of atmosphere, provides economies which are external to the firm but internal to the industry.

Herber (1979) and Oakland (1987) expand on Meade (1952) and show that the provision of public intermediate goods generates economies which are external to the firm. They find that public intermediate goods can lower a firm's marginal costs of production, even though the firm produces with constant returns to scale technology. In this case, the industry or the economy as a whole will exhibit increasing returns to scale. The extent of the external economies in any particular industry depends on the appropriateness of the intermediate goods to the needs of the industry and the geographic location of the industry with respect to the intermediate good. Consequently, it is entirely possible that different industries exhibit varying degrees of economies of scale.

Production can also exhibit economies of scale when there is learning by doing. Arrow (1962) finds that as a firm or industry gains experience, which he models as a positive function of cumulative output, marginal costs of production will begin to fall.

Stiglitz (1989) believes that if knowledge is a public good, external economies of scale can be justified in the case of learning by doing. Specifically, if firms cannot successfully keep information private then the returns to knowledge are shared across the entire industry. When the production of knowledge or learning by doing is a function of cumulative output as Arrow (1962) suggested, the industry will exhibit external economies of scale. In this case, the learning of any individual firm is shared across the entire industry thereby lowering each firm's marginal costs of production.

The types of external economies mentioned above occur because of an unappropriated spillover from knowledge production or the provision of public goods. However, it is important to note that the assumption of perfect competition rests on the fact that knowledge is entirely public. If it were possible for an individual firm to take advantage of its learning or of the public good and lower production costs below those of its competitors, perfect competition could not be maintained.

Lindert (1991) suggests that in knowledge-intensive industries new knowledge spreads quickly from firm to firm; information is not firm specific. He contends that the closer the links between the various firms in an industry, the greater is the transmission of information between them.

For instance, the degree to which skilled workers shift between firms, influences the rate at which information is disseminated across the industry. Note that this is consistent with Helpman's view that there are external economies of agglomeration and Chipman's belief that each firm contributes a small amount to the process of change.

According to Lindert (1991) New York's historic garment industry and California's Silicon Valley semiconductor producers and computer industry are two examples of industries in which firms seem to gain from being located in close proximity to their competitors. Stiglitz (1989) also cites the concentration of computer firms around Route 128 in Massachusetts as a similar example. In all three of these cases firms are continually swapping workers, ideas and often even factories. As the industry grows, the degree of contact between firms expands and thus, their marginal costs decline. As a result, the economies of scale are external to the firm.

It should be noted that in the analysis in Chapters 4 to 7, the external economies of scale are not due to either economies of agglomeration, the provision of public intermediate goods, or learning by doing. In Chapters 4 to 7 the economies of scale are, in part, a positive function of current industry output. However, the benefits from the provision of public intermediate goods or prior learning are

not a function of current industry output. Nevertheless, there are still some important similarities between the current analysis and that of Chapters 4 to 7. For example, in both cases markets are perfectly competitive. Moreover, as in Herber (1987) and Oakland (1979), it is assumed in Chapters 4 to 7 that industries exhibit varying degrees of economies of scale. Finally, similar to Arrow (1962), the extent of economies of scale can increase over time.

One of the problems with the assumption of external economies of scale, as Helpman (1984) points out, is that the process by which higher industry output produces greater intra-industry specialization is not adequately dealt with in the literature. Chipman (1965) feels that the case for external economies rests on the belief that expansion of industry output generates a further division of labor or it creates a new category of technicians. Each firm adds very little to this process and so it does not account for the contribution of its own output to the new division of labor. Consequently, the economies of scale are external to the firm.

Similarly, Stigler (1951) and Silberston (1972) argue that external economies of scale can arise from greater intra-industry specialization generated by vertical disintegration. Industries often take on many processes so that external economies of scale exist when a firm ceases

production of a particular input or process and turns it over to specialists who produce at a lower cost. However, the entire industry, or a large number of firms, must cease to manufacture the input before the specialists can produce it at a lower cost than the firm. Hence, each firm in the industry benefits from the external economies generated by vertical disintegration.

As in the model used Chapters 4 to 7, the economies of scale referred to by Chipman (1965), Stigler (1951) and Silberston (1972) are directly related to current industry output and reversible. The reversibility of these economies is justified on the grounds that "the division of labor is limited by the extent of the market". Stigler (1951) argues that as an industry contracts in size, input supplying industries, which are also subject to economies of scale, will move up their average cost curves raising input prices. This leads to a rise in firm costs and a reduction in the extent of economies of scale.

Most of the empirical studies on variable returns to scale attempt to prove the existence of internal rather than external economies of scale. However, Caballero and Lyons (1990) test for external economies of scale using an index of two digit manufacturing industries for thirteen industries in four European countries, West Germany, the United Kingdom, France and Belgium.

Their findings indicate that there is strong evidence of the existence of external economies of scale in all four countries. Cross-country evidence shows that France and Belgium exhibit the strongest degree of external economies, while the external effects in West Germany and the United Kingdom are somewhat weaker. Only three industries exhibited any degree of internal economies of scale, whereas external economies were observed in the remaining industries. Note that the three industries were, agricultural and industrial machinery in Germany, rubber and plastic products in both United Kingdom and Belgium and mineral products in Belgium.

While the Caballero and Lyons (1990) study is unique in the sense that it verifies the existence of external economies, it provides no insights as to the source of these economies. Despite the problems associated with the explanations of external economies of scale, Helpman (1984) concludes that it remains an important concept in the theory of international trade. Specifically, the assumption of external economies is useful because, as Chipman (1965) points out, competitive conditions can be maintained under external economies of scale in production. Firms producing in industries with external economies face upward slopping marginal cost curves which shift downwards as industry output expands. If a firm's output is small relative the collective output of its competitors, a rise in firm output is perceived

as a movement along its marginal cost function and not a shift in the entire function. Thus, the industry will not be monopolized.

3.2 External Economies of Scale and International Trade:

Static Models

The structure of the two-sector trade model under external variable returns to scale was initially explored in Jones (1968), Herberg and Kemp (1969) and Melvin (1969). All three of these papers use a two good, two factor and two country model of trade in which the variable returns to scale are reversibly linked to output. Each of these authors is specifically concerned with the shape of the production possibilities frontier when production exhibits external economies of scale.

Melvin (1969) summarizes the results for the case in which both goods are produced under increasing returns to the industry but constant returns to the firm. Note that he also assumes that both countries are identical in all respects so that their production possibilities curves are the same. He finds that the shape of the production possibilities frontier depends on two factors: (i) differences in factor intensities in the production technologies which tend to make it "bowed out" and, (ii) returns to scale which tend to make it "bowed in". The final shape of the curve is a function of the relative strengths of these two factors.

In his 1969 paper Melvin assumes that the increasing returns are sufficient to insure that the curve is "bowed in". As a result, he shows that in this case each country will completely specialize in production - there is a corner solution - and that increasing returns will generate international trade.

However, these models cannot determine either the pattern of trade or the distribution of the gains from trade. As Kemp and Negishi (1970) explain, the gains from trade cannot be identified in a model with increasing returns to scale without a clear specification of the technology and preferences. The reason for this is that the pattern of comparative advantage cannot be defined unless the scale of production, which is a function of preferences and the technology when both countries are the same size, is determined. In contrast, in a model with constant returns to scale the pattern of comparative advantage is not related to the scale of industry output.

Kemp and Negishi (1970) extend Melvin's analysis by developing a model in which there are a large number of industries divided into two groups, (i) those with less strongly increasing returns to scale and (ii) those with more strongly increasing returns. They find that if trade causes output of industries in group one to not expand and output of the industries in the second group to remain constant or

increase, then the gains from trade depend on two factors; (i) the difference between the rise in marginal costs in the contracting industries versus the fall in marginal costs in the growing industries and (ii) the relative size of group one industries to group two. In other words, it is necessary for a country to gain a comparative advantage in those industries with the largest economies of scale in order to gain from trade.

Given the limited ability of the above mentioned models to determine the gains from trade, a number of papers, for example Eaton and Panagariya (1979), Markusen and Melvin (1981), Choi and Yu (1984) and Markusen and Melvin (1984), attempt to derive the exact conditions under which a country will gain from trade in the face of external economies of scale. These papers therefore, clearly specify the production technologies and preferences.

When economies of scale are assumed to be solely a function of current industry output the industry production function is often specified as follows:

$$(3.1) \quad X_{(h)} = f(a_{j(h)}, (X_{(h)})^{\tau})$$

where: $X_{(h)}$ = output in industry h ;

$a_{j(h)}$ = vector denoting the industry specific employment levels of factor j ;

τ = scaling factor, $0 < \tau < 1$.

The extent of economies of scale in any industry is given

by $(X_{(h)})^T$. The external economies are modeled as a positive function of industry output $X_{(h)}$ and a scaling factor τ . Industries with comparatively larger potential external economies of scale are characterized by higher values of τ .

In addition, the external economies are assumed to be reversibly linked to industry output; they are positively related to current industry output. As argued by Stigler (1951) the reversibility of these economies is justified on the grounds that "the division of labor is limited by the extent of the market".

However, because the economies of scale are external to the firm an increase in firm output will have no effect on the amount of economies of scale, $(X_{(h)})^T$. Firm-level production functions therefore exhibit constant returns to scale and are given by:

$$(3.2) \quad x_{(h)}^i = f(a_{(h)}^i, (X_{(h)})^T)$$

where the superscript i denotes the firm. Firms perceive industry output as being constant. Moreover, paying factors their firm level marginal products just exhausts total output.

It is important to note that in Chapters 4 to 7 the model employs firm and industry production functions which are similar to those specified in equations (3.1) and (3.2). In fact the economies of scale are represented in the exact

same fashion, although the model in Chapters 4 to 7 assumes that there is only one factor of production and is more concerned with explaining the pattern of trade between DCs and LDCs rather than the gains from trade.

In Eaton and Panagariya (1979) it is assumed that there are $N+1$ industries, M factors of production, and that social welfare is represented by a differentiable quasi-concave utility function which is increasing in each argument. Given equations (3.1) and (3.2), they are able to derive an expression which measures the impact of trade on welfare under conditions of external increasing returns to scale. This of course represents a significant improvement over the Kemp and Negishi (1970) results.

The findings suggest that for a comparatively small change in the terms of trade, the gains generated by growth in output for industries exhibiting relatively larger economies of scale outweigh the losses experienced when industries with smaller economies of scale contract. However, this condition does not hold when the free trade equilibrium is very close to autarky - the volume of trade is small- or industries with small returns to scale expand while those with larger economies of scale contract. In these two instances, the increased export revenue is insufficient to compensate for the decline in economies of scale resulting from the change in the pattern of trade.

Using a very similar approach, Choi and Yu (1984) derive results which conform with those of Eaton and Panagariya (1979). Choi and Yu (1984) construct a two good, two factor and two country model with external economies of scale to analyze the gains from trade. Their findings suggest that a country can be made worse-off under free trade when trade causes the high scale industry to contract so that the impact of higher marginal costs of production in the industry outweigh the consumption gains from the improvement in the country's terms of trade. Moreover, they extend the Eaton and Panagariya (1979) model to demonstrate that when trade makes a country worse-off, the optimal policy is a production tax-cum subsidy that causes factors to be transferred from the lower scale sector to the high scale industry.

A slightly different approach is taken by Markusen and Melvin (1981). They develop a two country, two factor, and two good model of trade in which only one good, good X, is produced with external increasing returns to scale, while the other good, good Y, is produced with constant returns to scale. Furthermore, they assume that one country has a larger endowment of both factors, though the relative factor endowments in the two countries are equal. Because good X exhibits increasing returns to scale and the large country has a greater supply of both factors, it will produce a

greater amount of good X at a lower relative cost than the small country. The large country will therefore, export the good with increasing returns to scale. Thus, the pattern of trade is influenced by the size of a country when production exhibits increasing returns to scale.

If the small country's terms of trade worsen, then it will be made worse off since in addition to the worsening of its terms of trade, it experiences an efficiency loss associated with a reduction in the size of its domestic industry with economies of scale.

Unlike traditional Heckscher-Ohlin models, Markusen and Melvin's model also predicts that the equalization of commodity prices does not lead to the equalization of factor prices. Since productivity is directly related to the level of industry output, factor prices are not only a function of product prices but are positively related to the economies of scale in production. Trade generates a relatively larger increase in the output of good X in the large country and thus, the relative price of the factor used intensively in good X is lower in the small country. Recall that the product life cycle models also conclude that trade will not necessarily equalize factor prices.

Markusen and Melvin (1984) conclude that a sufficient condition for a country to gain from trade in the presence of external economies of scale is that trade generate a

rise in output across all industries with increasing returns to scale (IRS). This result conforms with Eaton and Panagariya (1979), Markusen and Melvin (1981) and Choi and Yu (1984). According to Markusen and Melvin (1984) "what is required is that trade have a certain "rationalizing" effect on the increasing returns to scale industries. By this we mean that the proportion of output of the IRS production eliminated by trade is less than the proportional increase in output of the surviving IRS industries" (p. 15 and 16).

Trade between DCs and LDCs is also affected by economies of scale. Stiglitz (1989) contends that LDCs often have trouble reproducing technologies developed in the North and tend to produce and export goods with lower economies of scale. Stigler (1951) believes that this is due to the extent of their markets. Specifically, LDCs do not have access to the complementary industries, skilled labor, education system, transportation or communication networks and so on available in DCs. The newest processes, with the most advanced technologies, are often too specialized to be economical for LDCs.

Stiglitz (1989) suggests that market failures in LDCs constrain them from attaining the scale of production found in DCs. The main problems facing LDCs is the acquisition of information about technology and imperfect capital markets. The large scale of DCs and the number of industries located

in DCs allow them to reap the benefits from undertaking "overhead information acquisition activities". As a result, the environment in LDCs limits the growth of productivity. As in Meade (1951), the atmosphere of production affects the extent of economies of scale.

To summarize, external economies of scale have been used extensively in the international trade literature. In general, the use of external economies is expedient because it is consistent with the existence of competitive markets. The models presented in this section are developed within a static framework in which the economies are positively related to industry output and are fully reversible.

The ability of a country to take advantage of economies of scale is therefore, a critical factor in determining whether it will gain from international trade. In theory, when there are external economies of scale in production, the first country to enter the market can gain a comparative advantage though another country, i.e. a LDC, could produce at a lower cost if it controlled the market. Hence, history plays an important role in determining the pattern of international trade.

The findings indicate that trade will improve a country's welfare if it leads to an expansion of output in the industry with relatively large economies of scale. Otherwise, if trade causes output in the sector with high

economies of scale to decline, the optimal policy is a production tax-cum subsidy which shifts factors into the industry with comparatively larger economies of scale. Furthermore, the results show that when production is subject to IRS, trade will not equalize factor prices.

3.3 Dynamic External Economies of Scale

Some of the most important external economies are dynamic in nature and derive from the accumulation of knowledge. Learning by doing occurs when one firm improves upon the production technique or the commodity through experience. However, since knowledge is freely available other firms in the industry will also benefit from the invention. In other words, the economies are external to the firm.

Arrow (1962) assumes that for a given level of inputs a firm's production is an increasing function of the cumulative aggregate investment for the industry. As the industry gains experience, the spillovers of knowledge cause the firm's costs of production to decline. Spillovers of knowledge production are often represented by a learning curve which relates unit costs to cumulative industry output. Krugman and Obstfeld (1991) point out that the main difference between economies of scale and economies of learning by doing is that costs are negatively related to the level of experience rather than industry output.

Spence (1981) theorizes that in principle both external economies and learning by doing could be present at the same time. He believes that the learning model is formally very close to a situation based purely on economies of scale. For example, Spence suggests that one should think of small intervals of time as market segments. Learning is a result of economies of scale across multiple market segments. Costs could be negatively related to both accumulated output and current output. The firm optimizes by setting marginal costs equal to marginal revenue where marginal costs decline with total output and accumulated output. However, while economies of scale are reversible, learning is not. Essentially, economies are reversible within a market segment but not across segments so that the extent of the reversibility is limited by history.

The vast majority of the papers that use economies of scale in the context of open economy dynamic models treat the economies as learning-by-doing. In contrast, it is assumed that the state of technology is constant in the static equilibrium analysis. Silberston (1972) points out that the average cost curve, or the scale curve as he refers to it, assumes a given state of technology and has a date on it. Thus, in a dynamic model one must carefully determine the relationship between the state of technology and the extent of economies of scale.

Arrow (1962) models the relationship between increasing returns and economic growth as a function of the rate of technological change, which is driven by an exogenous rate of population growth. Conversely, Romer (1986) assumes that technological change is spurred by the accumulation of knowledge which is endogenous in his model.

In Romer (1986) the growth of knowledge occurs when forward-looking, profit-maximizing agents transfer labor from current production into technological change. Moreover, it is this accumulation of knowledge that initiates economic growth. In Romer (1986) the production function is similar to equation (3.1) except that knowledge replaces industry output as the scaling factor. Romer suggests that production of knowledge by one firm will positively affect other firms in the industry since "knowledge cannot be perfectly patented or kept secret"(p. 1003). Recall that Stigler (1951), Stiglitz (1989) and Lindert (1991) expressed similar views. The production technology thus, exhibits increasing returns to scale which are external to the firm, firm profits are zero, and a competitive equilibrium exists.

Romer (1986) shows that as knowledge accumulates over time, the extent of external economies will be continuously rising. However, if this new knowledge does not spillover onto older industries, then newer industries will attain higher external economies of scale than older ones.

The results of Romer's model suggests that the competitive equilibrium is suboptimal in the absence of government intervention because the social marginal product of knowledge production exceeds the private marginal product. In general, firms do not account for the spillover benefit of knowledge production so that they underallocate resources to this activity.

In contrast to Romer (1986) who examines the role of external economies within the context of a closed economy, Lucas (1988) constructs a Ricardian model of international trade with external economies of scale modeled as industry specific learning-by-doing to study the mechanics of economic development.

Lucas (1988) assumes that there are two goods which are produced with the following Ricardian technology:

$$(3.3) \quad X_{\tau}(t) = h_{\tau}(t)u_{\tau}(t)N_t$$

where: $X_{\tau}(t)$ = production of good τ at time t ;

$h_{\tau}(t)$ = human capital specialized in good τ at time t ;

$u_{\tau}(t)$ = share of the work force devoted to good τ at time t ;

N_t = total work force at time t ; and $\tau = 1$ and 2 .

Human capital represents the general level of skilled labor in the industry. In this production function, output depends on both the level of human capital in an industry and the share of labor devoted to the production of the good. The

variable $h_t(\tau)$ captures the external economies that are the result of learning-by-doing.

Economic growth is driven by growth in human capital, $h(\tau)$. The rate of change in $h_t(\tau)$ is given by:

$$(3.4) \quad \dot{h}_t(\tau) = \delta(\tau)h_t(\tau)u_t(\tau)$$

where: $\delta(\tau)$ = the rate of growth of human capital for good τ , determined exogenously.

Lucas assumes that good 1 is the high technology good and good 2 the low technology good so that $\delta(1) > \delta(2)$. This implies that industry one accumulates knowledge at a faster rate than industry two and is analogous to dividing goods into those with low and high economies of scale as in Eaton and Panagariya (1979), Choi and Yu (1984) and Markusen and Melvin (1984).

The rate of change in human capital, $\dot{h}_t(\tau)$, permits the inheritance of human capital in new goods. That is to say, as innovation takes place old learning is incorporated into new goods, or $\dot{h}_t(\tau)$ increases. This is similar to Romer (1986) in that knowledge accumulates over time.

Essentially, Lucas (1988) is interested in developing "an environment in which new goods are continually being introduced, ..., and with human capital specialized to old goods being inherited in some way by new goods" (p. 28). Human capital, consequently, is not only industry specific but is a function of history; there is a direct relationship

between time and the skill level in an industry. As shown by Silberston (1972), the average cost curve has a time dimension. Thus, new goods tend to exhibit higher external economies of scale than older goods.

Lucas suggests that as new goods are developed there is a "fall-off" in the learning rates of older industries, $\delta(\tau)$ is higher in new goods. In a model with a continual introduction of new products this implies that the age of a good is negatively related with the level of economies of scale in the industry, $\dot{h}(\tau)$ is higher in new industries. As in Romer (1986) this requires that new knowledge not spillover onto older industries.

Lucas (1988) concludes that economic growth is driven by the accumulation of knowledge. As new goods are introduced they exhibit larger economies than old goods which stimulates economic growth.

It is interesting to note that a similar type of approach is taken by Grossman and Helpman (1989). They assume that innovation by the North and imitation by the South create positive externalities in the form of additions to general knowledge which are country specific and not firm specific. As new goods are developed in the North, or as goods are imitated in the South, new knowledge is produced which raises the productivity of labor.

Both Romer (1986) and Lucas (1988) argue that the main

distinction between DCs and LDCs is due to the limits on the ability to transfer learning across borders. LDCs have difficulty acquiring the knowledge created in DCs because of their lack of skilled labor and because the technology is often developed to meet the needs of the North. Note that this point is also made by Stigler (1951) and Stiglitz (1989). Given LDC's initial disadvantage, they find it optimal to specialize in technology or products with lower learning potential, or lower economies of scale.

Similar to Romer (1986) and Lucas (1988), N. Stokey (1988) develops a dynamic general equilibrium model with one factor of production, innovation and learning-by-doing. Stokey (1988) assumes that there is an economy wide accumulation of knowledge attained through learning by doing. Moreover, there is a positive externality associated with the accumulation of knowledge which is external to the firm. As a result, all markets are competitive and goods are manufactured with constant returns to scale.

Unlike Romer (1986), Stokey assumes that the expansion of knowledge is due to growth of production and not from a separate activity requiring the extraction of labor for R&D. This implies that a rise in industry output produces a positive externality in the form of knowledge production. In essence, she combines features of the static variable returns to scale approach and the learning-by-doing model. However,

because the externality is contained in knowledge it is not reversible.

An innovative feature of Stokey's model is that she assumes that only a limited range of goods can be produced in each period. Thus as innovation takes place, production of low quality goods is replaced with the production of higher quality goods. Since low quality goods are the older goods in Stokey's model, she constructs a process by which new goods continuously replace older goods. This represents an important divergence from the models of the product cycle in which the range of goods is continuously expanding.

Finally, Stokey (1988) finds that sustained growth in per capita income is driven by the accumulation of knowledge and the quality of products and not necessarily by the quantity of goods produced in each country as in the models of the product cycle.

As in Lucas (1988), Romer (1986), and Stokey (1988), Milgrom and Roberts (1990) and Milgrom, Qian, and Roberts (1991) stress the importance of history and the accumulation of knowledge in the process of economic growth. In Milgrom and Roberts (1990) and Milgrom, Qian, and Roberts (1991) it is assumed that knowledge is freely available to all firms and that accumulated public knowledge leads to the development of new technologies which reduce the marginal costs of current production and of future technological

improvements. For example, the authors find that as the cost of computer software and hardware has fallen, computer aided designs (CAD) have been adopted by many industries. Some CAD prepare instructions that can be employed by programmable manufacturing equipment (PME). Therefore, one effect of CAD is to reduce the cost of implementing and using PME. Once PME are adopted, the firm can cut back on inventories by scheduling production to quickly respond to consumer demand.

Furthermore, in the cases of CAD and PME, it becomes less costly for firms to increase the frequency of product development. Essentially, the same technology can be programmed to produce a variety of different products. Therefore, there are more frequent product developments at lower costs raising the returns to innovation and the demand for inputs.

The momentum theorem presented by Milgrom and Roberts (1990) and Milgrom, Qian and Roberts (1991) demonstrates that economic growth can be driven by complementarities among different processes. Innovation leads to a fall in the marginal costs of production which in turn, generates a rise in the demand for inputs which produces an increase in investment for complementary techniques further expanding the demand for inputs and so the cycle continues. These types of complementarities are important because they raise the level

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of economic activity and lower the marginal costs of production for the entire industry.

It is important to note however, that unlike Lucas (1988), Romer (1986) and Stokey (1988), Milgrom and Roberts (1990) and Milgrom, Qian, and Roberts (1991) do not specifically emphasize the role of economies of scale in economic growth. Nevertheless, the results of all these papers are similar in that they show that the accumulation of knowledge can generate a fall in marginal costs of production and economic growth. Furthermore, the findings indicate that as long as knowledge is freely available, markets will be competitive.

3.4 Summary and Conclusion

This chapter discussed the role of external economies of scale in international trade and economic growth. Although the means by which greater industry output leads to lower average costs of production is not adequately dealt with in the literature, the assumption of external economies of scale is used extensively in international trade economics. External economies of scale are consistent with the existence of competitive markets and arise as a result of economies of agglomeration, the provision of public intermediate goods, the production of knowledge and the increased specialization of labor.

The extent of the economies of scale in an industry

depends on the level of industry output and the state of technology. Stiglitz (1989) believes that the problem of underdevelopment is due to an inability of LDCs to acquire knowledge about technology. This limits LDCs ability to grow and raise their labor productivity. Thus, LDCs often acquire technologies with lower economies of scale or smaller learning potentials.

Furthermore, if it assumed that external economies of scale are reversible, then a fall in industry output leads to a decline in the extent of external economies of scale. As the size of the market shrinks, input costs begin to increase raising the firms marginal costs of production and lowering the external economies. However, not all economies are reversible. For example, economies contained in knowledge are not a function of current industry output. Nevertheless, as Spence (1979) demonstrates it is possible for economies of scale and economies of learning to be present at the same time.

In dynamic models of trade, the existence of external economies of scale are used to drive economic growth in a competitive framework. In these models, the position of the average cost curve depends on the state of technology. Since technology improves over time, the amount of economies of scale continually expands thereby lowering marginal costs of production and stimulating economic growth.

In the following chapters, a Ricardian model of North-South trade using external economies of scale is developed to explain the product cycle and the pattern of trade between DCs and LDCs. The external economies are modeled as a function of both industry output and time, and they are reversible. The economies of scale are not specifically a result of learning by doing, rather they occur due to technological improvements which lead to the increased specialization of labor. The results show that the pattern of trade depends on production cost differences between the two countries, which is directly related to the North-South wage gap and the extent of economies of scale in an industry.

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Chapter 4

The Static Model

Technological innovation and production transfers are important factors determining the pattern of trade between developed (Northern) and underdeveloped (Southern) countries. Vernon (1966) and (1979) suggests that new products are initially developed and exported by the North but that over time production is transferred to the South. In addition, Vernon hypothesizes that the rate at which production is transferred to the South, depends upon costs differences that arise from differences in factor prices between the two regions and economies of scale in production.

The model developed in this chapter extends previous attempts to formalize the product cycle. Recent reformulations of the product cycle theory by Krugman (1979), Dollar (1986) and Jensen and Thursby (1986) have assumed that production exhibits constant returns to scale so that the rate of production transfer depends solely upon differences in labor costs between the two regions. Conversely, in the present framework it is assumed that production exhibits external economies of scale rather than constant returns to scale.

However, unlike the theory of the product cycle in which innovation generates a continuously changing pattern of trade, the model considered in this chapter examines the

characteristics of the equilibrium at one point in time rather than the dynamic path of that equilibrium. Nevertheless, both the market equilibrium, which is conditional on the history of innovation, and the pattern of trade derived in this chapter are consistent with the predictions of the product cycle theory. In addition, the dynamic process is reintroduced in subsequent chapters. Thus, the product cycle is modeled in two stages; (i) a static version developed in this chapter which determines the equilibrium at a single point in time and, (ii) a second stage which determines the equilibrium at different points in time.

The results derived in this chapter, and in subsequent chapters, suggest that production cost differences between the North and industries in the South are not only positively related to the wage gap, as in the earlier attempts to formalize the product cycle, but also to the extent of economies of scale. The findings indicate that the North has a comparative advantage in the production of goods which are subject to relatively large economies of scale, while the South produces goods with the opposite characteristics. This pattern of trade is due to the North's ability to innovate and take advantage of the external economies in advance of the South. Hence, the pattern of trade is not merely a function of the age of a good, as in Krugman (1979) and

Dollar (1986), but is also related to the economies of scale in production.

The remainder of this chapter is divided into five parts. Section 4.1 introduces the basic assumptions of the model. Sections 4.2 and 4.3 outline the demand and production sides of the model. Section 4.4 examines the allocation of production and production transfers. In Section 4.5 the market equilibrium is derived and Section 4.6 concludes the chapter.

4.1 The Model

As in Dornbusch, Fischer and Samuelson's (DFS) (1977) model, it is assumed there are two countries (North and South) and an infinite number of goods produced with only one factor of production, labor, which is perfectly mobile and homogeneous across industries but immobile internationally. Furthermore, the production technology for each good is different; labor productivity varies across all goods. However, unlike the DFS model it is assumed that each technology embodies a different degree of economies of scale and that the economies of scale are external to the firm but internal to the industry.

In addition, the nominal wage in the North (W_N) is assumed to be greater than the nominal wage in the South (W_S), or the relative wage, ω , is less than one, i.e. $\omega = W_S/W_N < 1$, where n, s denote North and South. In his 1987

paper, Krugman states that it is the ability of DCs to exploit new technologies in advance of LDCs that accounts for their higher wage. In the present model, the wage gap is also justified on similar grounds. Specifically, it is assumed that only Northern firms innovate and produce new goods so that Northern producers take advantage of the economies of scale in advance of Southern firms. This technical advantage provides Northern firms with an initial monopoly in the production of new products and the rent on this monopoly accounts for the higher Northern relative wage. On the basis of these assumptions, the model represents a specialized version of the Ricardian explanation of trade focusing on technological differences in production arising from differences in the degree of economies of scale.

4.2 Demand

The demand side of the model is similar to the DFS model. All consumers in both countries share identical Cobb-Douglas utility functions that result in constant expenditure shares over the continuum of goods, $[0, \tau^*]$, and imply identical tastes between countries, or uniform homothetic demand. The demand side of the model differs from the DFS specification by restricting expenditure shares to being equal across all goods.¹ The fraction of income spent on any commodity (commodities are indexed by τ) is the same in the North and South and amounts to:

$$(4.1) \quad \beta(\tau) = \frac{P(\tau)X(\tau)}{Y} = \beta > 0; \beta(\tau) = \beta \text{ for } \tau \in [0, \tau^*]$$

where:

$\beta(\tau)$ = is the share of world income spent on good τ ;

$X(\tau)$ = total output in industry τ ;

$P(\tau)$ = price of good τ ; and

Y = World income.

The sum of the shares of income spent on all commodities must be equal to one and is given by the integral of expenditure shares over the existing set of goods in the range $[0, \tau^*]$, $\tau^* < 1$:

$$(4.2) \quad \int_0^{\tau^*} \beta(\tau) d\tau = 1$$

The share of world expenditure spent on Southern goods is defined by:

$$(4.3) \quad \beta_S(\bar{\tau}) = \int_0^{\bar{\tau}} \beta(\tau) d\tau = \frac{\bar{\tau}}{\tau^*} > 0$$

where, $[0, \bar{\tau})$ is the range of goods produced in the South. Note that since expenditure shares are constant across all goods, the fraction of world income spent in either country is equal to the proportion of goods produced in a region. All remaining goods, indexed by $[\bar{\tau}, \tau^*]$, are manufactured in the North and the share of world income devoted to Northern goods is simply:

$$(4.4) \quad 1 - \beta_S(\bar{\tau}) = \int_{\bar{\tau}}^{\tau^*} \beta(\tau) d\tau = \frac{\tau^* - \bar{\tau}}{\tau^*} > 0$$

Equilibrium in the market for Southern produced goods requires that labor income in the South, $W_S L_S$, equal the value of world spending on Southern produced goods:

$$(4.5) \quad W_S L_S = \beta_S(\bar{\tau})(W_S L_S + W_N L_N) = \left(\frac{\bar{\tau}}{\tau^*} \right) (W_S L_S + W_N L_N)$$

Similarly, in the market for Northern produced goods the equilibrium condition is given by:

$$(4.6) \quad W_N L_N = (1 - \beta_S(\bar{\tau}))(W_S L_S + W_N L_N) = \left(\frac{\tau^* - \bar{\tau}}{\tau^*} \right) (W_S L_S + W_N L_N)$$

The relative wage, for any hypothetical pattern of specialization, can be determined by dividing equation (4.5) by (4.6) to obtain:

$$(4.7) \quad \frac{W_S L_S}{W_N L_N} = \frac{\beta_S(\bar{\tau})}{1 - \beta_S(\bar{\tau})} = \frac{\bar{\tau}}{\tau^* - \bar{\tau}}$$

or:

$$(4.7.1) \quad \omega = \frac{W_S}{W_N} = \frac{\beta_S(\bar{\tau}) L_N}{(1 - \beta_S(\bar{\tau})) L_S} = \left(\frac{\bar{\tau}}{\tau^* - \bar{\tau}} \right) \left(\frac{L_N}{L_S} \right) = B(\tau; L_N/L_S)$$

Equation (4.7.1) demonstrates that the relative wage is a function of the fraction of world income spent in each country or the proportion of goods produced in each country, determined endogenously in the model, and the relative labor supplies.

Equation (4.7.1) closely approximates equation (10') in the DFS model and is plotted as an upward slopping curve in Figure 4.1. The schedule is an equilibrium locus

representing the demand side of the model. Beginning from a position of equilibrium if the fraction of goods produced in the South increases at a constant relative wage, then the share of world income spent in the South and the demand for Southern labor both rise, generating an excess demand for Southern labor. Equilibrium is restored by an increase in the relative wage, which lowers the demand for Southern labor and production.

Alternatively, the $B(\bar{\tau}; L_N/L_S)$ schedule can be interpreted as a locus of trade balance equilibrium by re-writing equation (4.7) as:

$$(4.7.2) \quad \beta_S(\bar{\tau}) W_N L_N = (1 - \beta_S(\bar{\tau})) W_S L_S$$

Equation (4.7.2) is similar to equation (10'') in the DFS model; it states that balanced trade results when the value of exports equals the value of imports. Increasing the proportion of goods produced in the South at a constant relative wage, leads to an increase in Southern exports, a decrease in its imports and a trade surplus in the South. The resulting trade imbalance is eliminated by a rise in the relative wage which causes Southern imports to expand and its exports to decline.

The slope of the $B(\bar{\tau}; L_N/L_S)$ locus is found by differentiating equation (4.7.1) with respect to $\bar{\tau}$:

$$(4.8) \quad \frac{\partial (B(\tau; L_N/L_S))}{\partial \bar{\tau}} = \frac{(L_N/L_S) (\beta(\bar{\tau}))}{(1-\beta_S(\bar{\tau}))^2} > 0$$

This derivative is strictly positive because the fraction of world income spent in the South increases as its share of the world production grows. Thus, the curve slopes upwards.

(For the derivation of (4.8) see Appendix 1.)

In summary, in this section it is assumed that expenditure shares on all good are constant and equal throughout the world. As a result, national income and the relative wage are a function of the proportion of goods produced in each country. Increasing the share of world production in the South leads to a balance of trade surplus, which is corrected by a rise in the relative wage.

4.3 Production

In any given industry, in the North or South, there are many firms producing a homogeneous product with identical constant returns to scale production functions. The supply of labor is fixed at L_N in the North and L_S in the South. Moreover, it is assumed that all firms within an industry are identical and that firms are operating under conditions of perfect competition, that is, an individual firm's output is small relative to the collective output of the industry. Although an increase in firm output affects industry output, firms regard industry output as exogenous.²

The production function for the firm is given by:

$$(4.9) \quad x_i^{\tau} = [\alpha + (X^{\tau})^{\tau}] l_i^{\tau}$$

where:

x_i^{τ} = total output of firm i in industry τ ;

l_i^{τ} = labor input for firm i in industry τ ; and,

α = an economy-wide technological shift parameter. $\alpha > 0$.

The parameter α is assumed to be constant and equal in both countries so that productivity differences are attributed solely to differences in economies of scale, since the marginal product of labor at the firm level is a function of α and $(X^{\tau})^{\tau}$.³ Note that α is the marginal product of labor when there are no external economies of scale in production. Moreover, because the production technology of each good differs, the index τ represents both the commodity index and the degree of external economies of scale in production. Each industry embodies a different degree of economies of scale ranging over the interval $[0, \tau^*]$, $\tau^* < 1$.

The degree of economies of scale is an important factor in determining the slope of the industry's average cost curve. In particular, the greater the degree of economies of scale the steeper is the slope of the industry's average cost curve. Thus, when two industries utilize the same labor input, the industry with a higher degree of external economies will have lower average costs.

The extent of the external economies is measured by

$(X(\tau))^{\tau}, (X(\tau))^{\tau} > 1$; it enters as a function of the degree of economies, τ , and industry output, $X(\tau)$.⁴ The extent of external economies of scale refers to a point on the industry average cost curve and is directly related to both industry output and the degree of economies of scale. As industry output expands, the extent of economies of scale rises and firm-level average costs decline. However, because firm output is small relative to industry output an increase in firm output, $x(\tau)$, has no effect on the extent of the economies of scale; production functions at the firm level exhibit constant returns to scale.

In addition, it is assumed that the age of a good is inversely related to the degree of economies of scale. In other words, new goods are produced by industries which exhibit comparatively higher economies of scale than older goods. Essentially, new industries are more technologically advanced or more complex than older industries so that new industries contain a greater scope for economies of scale. High-tech goods are assumed to be made up of many distinct parts and the complementary inputs for these goods are highly customized. Therefore, new goods embody technological improvements which necessitate the use of a comparatively larger variety of highly specialized complementary inputs and skills. Pratten (1988) finds that when a series of complex manufacturing operations are required to produce a commodity,

as in the case of high-tech goods, the industry will exhibit comparatively larger economies of scale. In essence, a greater level of industry output is needed to make efficient use of the larger variety of specialized labor skills and inputs.^{5, 6}

Recall that the existence of external economies of scale is supported on similar grounds by Stigler (1951) and Meade (1954). They suggest that external economies of scale exist when higher industry demand for complementary inputs induces a drop in marginal costs. The complementarity between input activities and lower marginal costs is consequently, used to generate external economies of scale and even lower marginal costs.

However, it should be noted that the extent of the economies of scale depends on the size of the market. As demand for a product declines, the cost of the complementary inputs begins to rise. Throughout the paper it is thus assumed that the extent of economies of scale are fully reversible; they are not like the Marshallian "ratchet effect" or Arrow's "learning by doing". Essentially, the division of labor is limited by the extent of the market. However, the degree of external economies, r , is given by technology and is not reversible. In other words, the ranking of high to low scale industries is not altered by a drop in industry output which conforms with Silberston's

(1972) view that the scale curve has a date on it. Accordingly, the model analyzes economies of scale and not economies of cumulative production.

Industry-level production functions are derived by summing output across all firms in a given industry:

$$(4.10) \quad X(\tau) = \sum_i x_i(\tau) = [\alpha + (X(\tau))^T] \sum_i l_i(\tau) = [\alpha + (X(\tau))^T] L(\tau)$$

where:

$L(\tau)$ = is total labor input in industry τ .

Unlike increases in firm output which have no effect on the extent of economies of scale, a rise in industry output leads to an increase in the extent of economies of scale.

With economies of scale external to the firm, the industry's marginal product of labor will exceed that of the firm. The marginal product of labor, from the point of view of the firm, is positively related to the extent of external economies $(X(\tau))^T$:

$$(4.11) \quad \frac{\partial x_i(\tau)}{\partial l_i(\tau)} = (\alpha + (X(\tau))^T)$$

At the industry level the marginal product is:

$$(4.12) \quad \frac{\partial X(\tau)}{\partial L(\tau)} = (\alpha + (X(\tau))^T) + \tau L(\tau) (X(\tau))^{T-1} \frac{\partial X(\tau)}{\partial L(\tau)}$$

This reduces to:

$$(4.12.1) \quad \frac{\partial X(\tau)}{\partial L(\tau)} = \frac{(\alpha + (X(\tau))^T)}{1 - \tau + \alpha \tau L(\tau) (X(\tau))^{T-1}}$$

Because $\tau < 1$, the denominator in equation (4.12) is a

positive fraction. Therefore, as r rises so does the marginal product at the industry level, $(\partial X(\tau)/\partial L(\tau)) > (\partial x(\tau)/\partial l(\tau))$.

Markusen and Melvin (1981) show that in a model using external economies payments will just exhaust output if factors are paid an amount equal to the firm-level marginal products, since there are firm level constant returns to scale. As a result, all output is distributed in factor payments and there is no adding-up problem. In the present model, paying labor its firm-level marginal product amounts to:

$$(4.13) \quad \frac{\partial x(\tau)}{\partial l(\tau)} l(\tau) = (\alpha + (X(\tau))^T) l(\tau) = x(\tau)$$

Equation (4.13) is equivalent to the firm's production function and verifies that there is no adding-up problem. Note that rearranging (4.13) also shows that average and marginal products of labor are equal. In contrast, paying factors their industry-level marginal product will overexhaust output since the marginal product for the industry exceeds that of the firm:

$$(4.13.1) \quad \frac{\partial X(\tau)}{\partial L(\tau)} l(\tau) > x(\tau)$$

The positive relationship between economies of scale and the marginal product of labor is reflected in the firm's cost function. The firm's cost function is simply:⁷

$$(4.14) \quad c(\tau) = W l(\tau) = \frac{W x(\tau)}{\alpha + (X(\tau))^T}$$

where:

$c(\tau)$ = the total cost of producing good τ for firm i .
Furthermore, unit marginal and average costs at the firm level are given by:

$$(4.15) \quad mc(\tau) = \frac{\partial c(\tau)}{\partial x(\tau)} = \frac{W}{\alpha + (X(\tau))^{\tau}}$$

Firms view industry output as parametric so that marginal costs within an industry are constant across all firms. However, industry output is positively related to the degree of external economies. Specifically, the relationship between $X(\tau)$ and τ , holding the labor input constant across all industries, is:

$$(4.16) \quad \frac{\partial X(\tau)}{\partial \tau} = \frac{L(\tau) X(\tau) \ln X(\tau)}{1 - \tau + \tau \alpha L(\tau) (X(\tau))^{-1}} > 0; X(\tau) > 1.$$

Because $\tau < 1$, the sign of this derivative is positive showing that industry output is directly related to the degree of external economies. Therefore, as τ increases, both industry output and the extent of economies of scale rise. Note that since $(\partial L(\tau)/\partial \tau) = 0$ the expansion in industry output is attributed solely to the increase in the degree of economies of scale and not the industry labor input. Moreover, equation (4.15) demonstrates that marginal costs are inversely related to economies of scale and firms producing in industries with the largest degree of external economies produce at the lowest marginal costs. (For the derivation of

equation (4.16) see Appendix 2).

It is important to note that if industry output is not greater than one, then the sign of the derivative in (4.16) is negative. In this case, industry output declines as the degree of economies of scale increases which is not plausible. Therefore, it is assumed that $X(T) > 1$ at all times.

To summarize, the model developed in this section specifies production functions at both the firm and industry level. Production exhibits economies of scale which are independent of firm output but positively related to industry output. In addition, the marginal product of labor is directly related to the external economies and industry output, whereas marginal costs are a negative function of industry output.

4.4 The Allocation of Production and Production Transfers

The division of goods production and the pattern of trade between the North and the South is determined by differences in production costs arising from economies of scale in each region and wage differentials. As stated previously, all goods are originally developed and produced in the North so that Northern producers initially benefit from the economies of scale to lower their marginal costs of production. Thus, because industry output is directly related to the degree of external economies of scale and

wages are lower in the South, the North will have a comparative advantage in those goods with the highest degree of external economies of scale and the South will produce and export the remaining set of goods.

In general, a firm's decision to transfer its production abroad is based on a comparison of its total costs between the two regions. However, in the current model unit marginal costs between the two regions are compared because average costs are equal marginal costs. Northern firms will shift their production to the South when their marginal costs are lower in the foreign market.

Over the set of Northern produced goods, firm-level marginal costs in the North are:

$$(4.17) \quad mc_N^i(T) = \frac{W_N}{\alpha + (X_N^i(T))^T}$$

and in the South:

$$(4.18) \quad mc_S^i(T) = \frac{W_S}{\alpha}$$

Due to the Ricardian nature of the model countries specialize in production, that is, $X_S^i(T)=0$ for Northern produced goods. In addition, both W_S and α are constant across all Southern industries; hence, firm-level marginal costs, for goods produced in the North, are the same over all Southern industries. Consequently, firms compare their marginal costs in the North with a fixed marginal cost in the South.

Northern firms will begin to transfer their production to the South when $mc_N^{\{T\}} > mc_S^{\{T\}}$, whereas production remains in the North when $mc_N^{\{T\}} \leq mc_S^{\{T\}}$. When costs are equal in the two countries, it is assumed that production remains in the North because of a small cost of transferring production.⁸

It is important to note that Northern firms calculate their marginal costs in the South on the assumption that their competitors do not follow them and also move to the South. In other words, firms are myopic and set $(X_S^{\{T\}}) = 0$ when measuring marginal costs in the South. However, all firms within an industry are identical; thus, the action of one firm mirrors that of the entire industry. When $mc_N^{\{T\}} > mc_S^{\{T\}}$, the entire industry migrates to the South and $(X_N^{\{T\}})$ falls to zero. Likewise, if $mc_N^{\{T\}} \leq mc_S^{\{T\}}$, the industry remains in the North. Consequently, for each industry international transfers of production are an all or nothing basis.

Alternatively, the efficient pattern of specialization, for a given relative wage, can be determined by comparing the firm-level unit labor requirements in the two countries. Because the average and marginal products of labor are identical, the unit labor requirement is given by the inverse of the firm-level marginal product of labor equation (4.11) and amounts to:

$$(4.19) \quad a_N^{\{T\}} = \frac{1}{\alpha + (X_N^{\{T\}})^T}$$

in the North and:

$$(4.20) \quad a_s^{(\tau)} = \frac{1}{\alpha + (X_s^{(\tau)})^\tau}$$

in the South. The relative unit labor requirement is given by:

$$(4.21) \quad A(\tau) = \frac{a_N^{(\tau)}}{a_s^{(\tau)}}$$

It follows that for a given relative wage $\bar{\omega}$, $\bar{\omega} < 1$, a commodity will be efficiently produced in the North when:

$$(4.22) \quad W_N a_N^{(\tau)} \leq W_S a_s^{(\tau)}$$

or:

$$(4.23) \quad A(\tau) \leq \bar{\omega}$$

Note that ω also denotes the factoral terms of trade or the relative price of Southern to Northern labor.

Equation (4.22) is equivalent to comparing the marginal costs in the two countries. The borderline commodity of comparative advantage $\bar{\tau}$, is defined by:

$$(4.24) \quad A(\bar{\tau}) = \bar{\omega}$$

Since good $\bar{\tau}$ has the lowest economies of scale and the highest marginal cost in the North, all goods with $\tau > \bar{\tau}$ have higher economies of scale and good $\bar{\tau}$ represents the borderline commodity of comparative advantage. By a similar argument, the South specializes in all goods with $\tau < \bar{\tau}$. Over this range:

$$(4.25) \quad A(\tau) \geq \bar{\omega}$$

or:

$$(4.25.1) \quad W_N a_N(\tau) \geq W_S a_S(\tau)$$

which shows that the marginal costs of producing goods with $\tau < \bar{\tau}$ are lower in the South. Therefore, if the relative wage is $\bar{\omega}$ the North will efficiently produce goods $[\bar{\tau}, \bar{\tau}]$ and the South goods $[0, \bar{\tau}]$.

The efficient pattern of specialization and the $A(\tau)$ function are represented graphically in Figure 4.2. The $A(\tau)$ schedule represents a ranking of comparative advantage and portrays all the combinations of ω and τ for which:

$$(4.26) \quad \omega = A(\tau)$$

The distribution of production is formulated conditional on a given labor allocation to each industry. That is to say, the level of output in the borderline industry $X(\bar{\tau})$, and the position of the $A(\tau)$ schedule, implicitly depend on $L(\bar{\tau})$ which is endogenously determined. By substituting the industry production function (4.10) and the marginal cost pricing equation (4.17) into the constant and equal expenditure share property (4.1), it follows that the Northern labor requirement for the borderline industry is:

$$(4.27) \quad L_N(\bar{\tau}) = \beta(\bar{\tau}) [L_N + \omega L_S]$$

This shows that the labor allocation is a function of the relative wage. As the proportion of goods produced in the

North declines, the relative wage rises to clear the labor market and thus, the labor allocation to the borderline industry rises. Essentially, the Northern labor supply is distributed across a narrower range of industries. As a result, industry output and the extent of economies of scale increase in the borderline industry so that the marginal cost of producing the borderline good in the North declines and the $A(\tau)$ schedule in the range of Northern produced goods shifts downwards.

The slope of the $A(\tau)$ schedule over the range $[\bar{\tau}, \tau^*]$ is given by:

$$(4.28) \quad \frac{\partial A(\tau)}{\partial \tau} = - \left[\frac{1}{(\alpha + (X_N(\tau))^\tau)^2} \right] \left(\alpha (X_N(\tau))^{\tau-1} (\tau (X_N(\tau))^{-1} \frac{\partial X_N(\tau)}{\partial \tau} + \ln X_N(\tau)) \right) < 0$$

Since industry output is positively related to the degree of economies of scale, $(\partial X_N(\tau)/\partial \tau) > 0$, the sign of this derivative is negative and the curve slopes downwards.

The schedule slopes downwards in the range $[\bar{\tau}, \tau^*]$ showing increasing Northern comparative advantage. Over this set of goods the value of the relative marginal product of labor is less than one:

$$(4.29) \quad A(\tau) = \frac{\alpha}{\alpha + (X_N(\tau))^\tau} < 1$$

As the degree of economies of scale, τ , increase, industry

output and the marginal product of labor both rise in the North, while the marginal product in the South remains constant. Consequently, both $A(\tau)$ and the relative marginal cost of producing in the North decrease, or the North's comparative advantage is increasing over this range.

The slope of the $A(\tau)$ curve in the range $[0, \bar{\tau})$ amounts to:

$$(4.28.1) \quad \frac{\partial A(\tau)}{\partial \tau} = \frac{1}{\alpha} \left((X_S(\tau))^T (\tau(X_S(\tau)))^{-1} \frac{\partial X_S(\tau)}{\partial \tau} + \ln X_S(\tau) \right)$$

The sign of this derivative is strictly positive and the curve slopes upwards because $(\partial X_S(\tau)/\partial \tau) > 0$.

The schedule slopes up in the range $[0, \bar{\tau})$ and shows increasing Southern comparative advantage. Over this range:

$$(4.29.1) \quad A(\tau) = \frac{\alpha + (X_S(\tau))^T}{\alpha} > 1$$

An increase in τ generates a rise in the marginal product of labor in the South, while Northern industry output remains the same so that $A(\tau)$ increases and the relative marginal cost of producing in the South falls. Hence, the South's comparative advantage is improving over this range.

However, the ranking of comparative advantage is not continuous over the range $[0, \bar{\tau}]$. The discontinuity occurs because the marginal product of labor is a positive function of industry output and international production transfers are on an all or nothing basis for each industry.^{9, 10}

As another way of understanding the derivation of the $A(\tau)$ schedule suppose that all goods over the range $[0, \bar{\tau}]$ are produced in the North. The ranking of comparative advantage is now represented by equation (4.29) and portrayed by the $A_N(\tau)$ schedule in Figure 4.3. Similarly, if all goods are produced in the South, it is represented by equation (4.29.1) and portrayed by the $A_S(\tau)$ schedule in Figure 4.3. Because the marginal product of labor is a function of industry output and international transfers of production are on an all or nothing basis, the value of the relative marginal product, $A(\tau)$, rises from $(\alpha/(\alpha+(X_N(\tau))^T))$ to $((\alpha+(X_S(\tau))^T)/\alpha)$ when a good is transferred to the South. Consequently, the ranking of comparative advantage is not continuous. If good $\bar{\tau}$ represents the borderline commodity, then the ranking of comparative advantage for goods produced in the North is depicted by the $A(\tau)$ schedule in Figure (4.2).¹¹

In summary, the model shows that the efficient pattern of specialization in the world depends on the relative wage and industry economies of scale. Production transfers are determined by firm-level differences in production costs between the two countries. Moreover, the marginal cost of production is inversely related to the extent of external economies. As the relative wage falls and Northern labor costs rise, goods with the lowest economies of scale in the North are transferred to the South.

The ranking of comparative advantage is however, not continuous. This occurs because the marginal product of labor is positively related to industry output and a country either does not produce a specific commodity or it completely specializes in production thereby taking advantage of the external economies. Because wages are lower in the South, the discontinuity implies that when an industry is transferred to the South and its marginal cost decline, the industry will not be returned to the North unless wages are higher in the South.

4.5 Market Equilibrium

Assuming that α , $\beta(\tau)$, and L_N/L_S are constant, and given a range of economies of scale indexed by $[0, \tau^*]$ there exists an equilibrium that determines the relative wage and efficient pattern of specialization in production and trade. Algebraically, balanced trade is represented by:

$$(4.7.1) \quad \omega = \frac{\beta_S(\bar{\tau}) L_N}{(1 - \beta_S(\bar{\tau})) L_S} = B(\tau; L_N/L_S)$$

and efficient specialization is given by:

$$(4.26) \quad \omega = \frac{a_N^{(\tau)}}{a_S^{(\tau)}} = A(\tau)$$

Equating (4.7.1) with (4.26) generates a relative wage at which both countries are efficiently specialized, and there is balanced trade and full employment. The market

equilibrium condition is:

$$(4.30) \quad \omega = \frac{\beta_S(\bar{\tau}) L_N}{(1-\beta_S(\bar{\tau})) L_S} = \frac{a_N(\tau)}{a_S(\tau)}$$

or:

$$(4.30.1) \quad \omega = B(\tau; L_N/L_S) = A(\tau)$$

There are however, two relative wages and patterns of specialization which satisfy the equilibrium condition specified in equation (4.30). In the hypothetical case that all goods are produced in the North, the $A(\tau)$ schedule is represented by the $A_N(\tau)$ curve in Figure 4.3. Because the relative wage is higher in the North, industries with comparatively smaller economies of scale, $[0, \bar{\tau}]$ in Figure 4.3 will have lower marginal costs of production in the South. In other words, there is a trade imbalance and this pattern of trade cannot be maintained. Therefore, Northern firms begin to migrate to the South. In equilibrium, portrayed in Figure 4.4 at point A, the relative wage is ω_1 , $\omega_1 < 1$, the North produces and exports goods $[\bar{\tau}, \tau^*]$, and the South produces goods $[0, \bar{\tau})$.

Moreover, a second equilibrium which satisfies equation (4.30) can also be derived. In the supposed case that all goods are initially produced by the South then the $A(\tau)$ schedule is represented by the $A_S(\tau)$ curve in Figure 4.3. Southern industries are now the first to take advantage of

the external economies of scale in production and the relative wage is higher in the South. As a result, this pattern of trade cannot be maintained and Southern industries with low economies of scale begin to transfer their production to the North. In equilibrium the relative wage is now greater than one, $\omega > 1$, and those goods with the highest degree of economies of scale are produced in the South with the remaining set of goods produced in the North.

It is interesting to note that in both of these cases the relative wage is higher in the country with a monopoly in the production of new goods. However, in the current model it is assumed that only the North innovates and originally produces all new goods so that the equilibrium with $\omega > ((1+\alpha)/\alpha)$ is ruled out.¹² Therefore, as long as free trade prevails and given the restriction that $\omega < ((1+\alpha)/\alpha)$, the equilibrium is at the intersection of the $B(\tau; L_N/L_S)$ schedule and the $A(\tau)$ schedule.¹³

Industry labor inputs, industry output, and prices can be computed given the efficient pattern of specialization and the equilibrium relative wage determined above. The industry labor input, $L(\tau)$, is derived by using the production function, equation (4.10), and the expenditure share equation from the demand side, equation (4.1). Within a country the relative labor input between any two industries, $\tilde{\tau}$ and $\hat{\tau}$, is constant:

$$(4.31) \quad \frac{L(\hat{\tau})}{L(\tilde{\tau})} = 1 ; \tilde{\tau} \neq \hat{\tau}$$

(For the derivation of equation (4.31) see Appendix 3)

This is expected given that expenditure shares are the same across all goods and both marginal costs and prices are inversely related to the degree of economies of scale in production. An equal value of income spent on each good also implies that the physical quantity of output demanded increases as the degree of economies of scale rises and prices fall. However, industries with the largest economies of scale have the most productive labor; an equal quantity of labor in each industry will generate continuously higher levels of output as the degree of economies of scale expands. Hence, the same labor input in each industry will satisfy demand which is increasing with τ .

Although within a country the industry labor input is equal across all industries, it varies between regions. For example, the relative labor input for any two industries $\hat{\tau}$ in the North and $\tilde{\tau}$ in the South, derived in a similar manner to equation (4.31), is given by:

$$(4.32) \quad L_N^{\hat{\tau}} = \frac{W_S}{W_N} L_S^{\tilde{\tau}} ; \tilde{\tau} \neq \hat{\tau}$$

Since $W_S/W_N < 1$, equation (4.32) implies that Southern industries use relatively more labor in production. In other words, due to the higher economies of scale in the North,

Northern labor is relatively more productive. (For the derivation to equation (4.32) see Appendix 4).

The equilibrium levels of industry output, $X(\tau)$, can now be computed. Using the assumptions that in each country the supply of labor is fixed, α , $\beta(\tau)$, and the degree of economies in each industry are known, each industry receives an equal share of the total labor supply and the labor market always clears, $X(\tau)$ can be derived.

Finally, the equilibrium price level in each industry is equal to the marginal cost of production. The price level for any industry is:

$$(4.33) \quad P(\tau) = \frac{W}{\alpha + (X(\tau))^{\tau}}$$

which can be computed given industry output.

In summary, the unique market equilibrium relative wage and pattern of specialization are determined by the technology, the relative size of the two countries, the range of goods in the world, the structure of demand, and economies of scale. Assuming that $\omega < (1 + \alpha/\alpha)$, the equilibrium occurs at the intersection of the $B(\tau; L_N/L_S)$ schedule and the $A(\tau)$ curve. In this equilibrium, the North produces goods with relatively higher economies of scale than the South. Moreover, the industry labor inputs in each country are equal across all industries. However, economies of scale are higher in the North so that its industry labor inputs are relatively

lower, or labor is more productive in the North.

The efficient pattern of specialization in which the North produces goods with higher economies of scale than the South rests on four assumptions used in the model. Firstly, all goods are initially produced in the North. If both countries had access to a technology at the same time, production of new goods would occur in the South, since its labor costs are lower. Secondly, external economies of scale are not internationally transferable rather, they are dependent on the level of local production. Thirdly, firms act independently of one another, they are price takers, thereby setting industry output equal to zero when measuring production costs in the South. If firms did not act independently the entire industry would move to the South, thereby lowering their production costs by taking advantage of the external economies. Finally, since r is inversely related to the age of a good, old goods have lower labor productivity and their marginal costs are higher in the North. Taken together, these four assumptions result in a pattern of specialization in which the South produces and exports goods with the lowest economies of scale and the North produces and exports goods the remaining set of goods with the opposite characteristics.

4.6 Conclusion

The theory of the product cycle describes a dynamic

process in which the pattern of trade is continuously changing. Initially, commodities are developed and produced in the North but over time production migrates to the South and eventually the North imports the good.

The model developed in this chapter although not dynamic in nature, determines a pattern of North-South trade which is consistent with the predictions of the theory of the product cycle. The model extends previous attempts to formalize the product cycle by assuming that there are external economies of scale in production. Moreover, the findings indicate that higher wages in the North trigger production transfers to the South, a result which is derived by Vernon (1966), Krugman (1979), Dollar (1986) and others. Furthermore, the model conforms with the empirical studies of the product cycle (e.g. Vernon (1966) and Wells (1969)) in which the innovating country, the North, produces those goods with the highest economies of scale.

It is important to note that the structure of production and the resulting pattern of specialization in the present model differ from those found in Krugman (1979) and Dollar (1986). Krugman assumes that the marginal product of labor is the same across all goods and that there are no technological differences between countries. Northern industries transfer their production to the South whenever the commodity's technology is public knowledge because wages

are lower in the South. Conversely, the unit labor requirements are not constant across all industries in the present model; rather, due to external economies of scale the unit labor requirements are a decreasing function of industry output. A firm producing in an industry with relatively large economies of scale will have a lower marginal cost of production. Unlike Krugman (1979) and Dollar (1986), the pattern of specialization now depends on economies of scale and not solely the availability of the technology to Southern producers. In fact, the North can produce commodities whose technology is available to Southern industries.

Furthermore, because marginal costs are negatively related to industry output and wages are lower in the South, production does not migrate back to the North once it is transferred to the South. In essence, the South can take advantage of the external economies in production to gain a permanent cost advantage in the production of the commodity.

In the subsequent chapters the current model is used to analyze comparative statics, innovation and trade policy. In Chapter 5, three comparative static exercises are conducted, (i) an increase in the South's labor force, (ii) a rise in the demand for Northern goods, and (iii) a technological improvement in the South. The model is also extended to include innovation in Chapter 6 and a dynamic product cycle, similar to Vernon's theory is generated by that model.

Finally, Chapter 7 examines trade policy, specifically, a production subsidy in the South within the context of both the static model and the dynamic model.

Endnotes

1. The purpose of this paper is to analyze the effects of economies of scale on North-South trade. Consequently, by restricting expenditure shares to being constant and equal across all goods, the model rules out differences in demand as an explanation for trade. Moreover, this assumption can be relaxed without significantly altering the results of the model.
2. This assumption is also made by Chipman (1965), Kemp (1969), Melvin (1969) and Markusen and Melvin (1981).
3. One can easily relax this assumption without significantly altering the predictions of the model. Moreover, it is interesting to note that unlike the present analysis, Krugman (1979) assumes that all goods are produced with the same technology and there are no economies of scale so that the marginal product of labor is the same across all industries.
4. This specification of economies of scale is from Markusen and Melvin (1981).
5. Recall that Lucas (1988) allows for newer industries to build upon the already existing economies in older industries so that newer goods have higher economies than older goods.
6. Note that in general one would expect some spillovers, in the form of technological improvements, from new industries to older industries. For example, computer technology is

used to make older industries such as textiles more cost efficient. In the current model however, it is assumed that technology is industry specific. Stiglitz (1989) notes that the innovating firm or industry usually experiences a larger benefit from new innovations. Allowing for spillovers in the present analysis only reduces the variance in marginal costs between old and new industries it does not completely eliminate the gap or significantly alter the results. Thus, it is assumed that there are no technological spillovers.

7. Equation (4.14) is derived as follows:

$$c(t) = Wl(t) \text{ s.t. } x(t) = l(t)(\alpha + (X(t))^T).$$

Solving the constraint for $l(t)$ yields:

$$l(t) = x(t) / (\alpha + (X(t))^T)$$

and substituting into $c(t)$ obtains:

$$c(t) = Wx(t) / (\alpha + (X(t))^T).$$

8. There is an extensive literature on the conditions necessary for successful transfers of technologies to the South. See for example, F. Stewart "International Technology Transfers: Issues and Policy Options". World Bank Staff Working Paper 344, (1979). Stewart concludes that LDCs must attract industries in which they can become internationally competitive without the aid of long term protectionism. The technologies embodied in these industries should take advantage of the relative strengths of a country. In general, industries in LDCs tend have a better chance of

success when the technology is labor intensive and makes use of the lower labor costs in the South.

9. In Dornbusch, Fischer and Samuelson (1977) the marginal products of labor are not a function of industry output. Consequently, when production is transferred between countries the $A(\tau)$ values do not change, or the ranking is continuous.

10. Note, it is not necessary to assume that all goods are produced with increasing returns to scale. It is possible for a range of goods to be produced with constant returns to scale. In this case, the $A(\tau)$ curve would be flat over this range and these goods would be produced in the South.

However, it is necessary for Northern goods to be produced with increasing returns to scale, otherwise costs would be lower in the South.

11. Note that the natural route is for goods to move from the North to the South. In the unlikely event that goods are transferred from the South to the North, marginal costs in the South must exceed those in the North or:

$$\frac{W_S}{\alpha + (X_S(\tau))^{\tau}} > \frac{W_N}{\alpha}$$

This would require that the Northern wage exceed the Southern wage. Therefore, like Krugman (1979) and Dollar (1986) this case has been ruled out not only because it is unrealistic but because it is not consistent with the intent of the

model which is to explain production transfers from the North to the South.

12. If goods are transferred from the South to the North then it is good $r=0$, the good with the lowest economies of scale in the South, that is the first to move. The relative marginal product of labor for this good is $(1+\alpha)/\alpha$ and thus, the relative wage must rise above $\omega > ((1+\alpha)/\alpha)$ in order for any Southern goods to be transferred to the North.

13. While it is theoretically possible to have an equilibrium in the discontinuous region, the equilibrium will be at the intersection of the $A(\tau)$ and $B(\tau; L_N/L_S)$ curves because the present model is conditional on the history of innovation. In other words, it depicts the equilibrium at one point in time in the midst of ongoing innovation on the part of the North. In a model with innovation, the equilibrium always tends towards the intersection of the $A(\tau)$ and $B(\tau; L_N/L_S)$ curves because innovation induces the borderline good in the North to be transferred to the South.. (For complete details of this case see Chapter 6).

Appendix 1

To derive the slope of the $B(\tau; L_N/L_S)$ schedule, differentiate the right hand side of equation (4.7.1) with respect to τ . Recall equation (4.7.1) is given by:

$$(4.7.1) \quad \omega = \frac{\beta_S(\bar{\tau}) L_N}{(1-\beta_S(\bar{\tau})) L_S} = \left(\frac{\bar{\tau}}{\tau - \bar{\tau}} \right) \left(\frac{L_N}{L_S} \right) = B(\tau; L_N/L_S)$$

Differentiating equation (4.7.1) with respect to τ yields:

$$(A1.1) \quad \frac{\partial B(\tau; L_N/L_S)}{\partial \tau} = \frac{(L_N/L_S) (\partial \beta_S(\bar{\tau}) / \partial \tau) [(1-\beta_S(\bar{\tau})) + \beta_S(\bar{\tau})]}{(1-\beta_S(\bar{\tau}))^2}$$

which simplifies to:

$$(A1.2) \quad \frac{\partial B(\tau; L_N/L_S)}{\partial \tau} = \frac{(L_N/L_S) (\beta(\bar{\tau}))}{(1-\beta_S(\bar{\tau}))^2} > 0$$

It is assumed in the model that the fraction of income spent on any good is constant so that the share of world income spent in a country is positively related to the range of goods produced in that country. Therefore, as the range of goods produced in the South rises, the share of world income spent in the South will also, increase. In other words, the $B(\tau; L_N/L_S)$ curve slopes upwards.

Appendix 2

To derive the relationship between industry output and economies of scale, differentiate the industry level production function with respect to τ . This production function is specified as:

$$(4.10) \quad X(\tau) = (\alpha + (X(\tau))^{\tau}) L(\tau)$$

Differentiating equation (4.10) with respect to τ , gives:

$$(A2.1) \quad \frac{\partial X(\tau)}{\partial \tau} = \tau L(\tau) (X(\tau))^{\tau-1} (\partial X(\tau)/\partial \tau) + L(\tau) (X(\tau))^{\tau} \ln X(\tau)$$

which reduces to:

$$(A2.2) \quad \frac{\partial X(\tau)}{\partial \tau} = \frac{L(\tau) (X(\tau))^{\tau} \ln X(\tau)}{1 - \tau L(\tau) (X(\tau))^{\tau-1}}$$

Note that labor inputs are equal across all industries (proved at the end of Section 4.4) so that $\partial L(\tau)/\partial \tau = 0$. In addition, as long as $X(\tau) > 1$ the numerator in equation (A2.2) is positive.

To sign the denominator of equation (A2.2) one must evaluate $\tau L(\tau) (X(\tau))^{\tau-1}$ which can be rewritten as:

$$(A2.3) \quad 1 - \tau L(\tau) (X(\tau))^{\tau-1} = 1 - \tau L(\tau) ((X(\tau))^{\tau} / X(\tau))$$

Furthermore, equation (4.10) is equivalent to:

$$(A2.4) \quad X(\tau) - \alpha L(\tau) = (X(\tau))^{\tau} L(\tau)$$

To calculate the sign of the denominator in equation (A2.2), substitute the solution for $(X(\tau))^{\tau} L(\tau)$ from equation (A2.4) into (A2.3) to obtain:

$$(A2.5) \quad 1 - \frac{\tau}{X(\tau)} \{X(\tau) - \alpha L(\tau)\} = 1 - \tau + \frac{\alpha L(\tau)}{X(\tau)}$$

Since $\tau < 1$, the value of equation (A2.5) is strictly greater than zero.

Finally, substituting equation (A2.5) into (A2.2) produces:

$$(A2.6) \quad \frac{\partial X(\tau)}{\partial \tau} = \frac{L(\tau) (X(\tau))^{\tau} \ln X(\tau)}{1 - \tau + \alpha \tau L(\tau) (X(\tau))^{\tau}}$$

The sign of the derivative in equation (A2.6) is strictly positive. Consequently, as the extent of economies of scale increase industry output expands.

Appendix 3

The relative industry labor input in equation (4.31) is derived by combining both the production and demand sides of the model. On the production side, the labor input in a given industry $\hat{i}$ relative to a numeraire industry $\tilde{i}$, $\hat{i} > \tilde{i}$, is found by dividing the production functions in the two industries and assuming that both goods are produced in the same country:

$$(A3.1) \quad \frac{X(\hat{i})}{X(\tilde{i})} = \frac{(\alpha + (X(\hat{i}))^{\hat{\tau}}) L(\hat{i})}{(\alpha + (X(\tilde{i}))^{\tilde{\tau}}) L(\tilde{i})}$$

which can be re-written as:

$$(A3.2) \quad \frac{L(\hat{i})}{L(\tilde{i})} = \frac{X(\hat{i}) (\alpha + (X(\tilde{i}))^{\tilde{\tau}})}{X(\tilde{i}) (\alpha + (X(\hat{i}))^{\hat{\tau}})}$$

Furthermore, the price ratio in the two industries is equal to the ratio of marginal costs at the firm level:

$$(A3.3) \quad \frac{P(\hat{i})}{P(\tilde{i})} = \frac{(W_N / (\alpha + (X(\hat{i}))^{\hat{\tau}}))}{(W_N / (\alpha + (X(\tilde{i}))^{\tilde{\tau}}))} = \frac{(\alpha + (X(\tilde{i}))^{\tilde{\tau}})}{(\alpha + (X(\hat{i}))^{\hat{\tau}})}$$

Since both goods are produced in the same country and wages are equal across all industries, the relative price ratio is equal to the relative marginal product of labor.

Demand is represented by constant and equal expenditure shares across all goods so that the expenditure share for good $\tilde{i}$ relative to $\hat{i}$ is:

$$(A3.4) \quad \frac{\beta(\hat{T})}{\beta(\tilde{T})} = 1 = \frac{P(\hat{T})X(\hat{T})}{P(\tilde{T})X(\tilde{T})}$$

which reduces to:

$$(A3.5) \quad \frac{P(\hat{T})}{P(\tilde{T})} = \frac{X(\tilde{T})}{X(\hat{T})}$$

Therefore, the price ratio is equal to the inverse of industry output.

Equating the ratio of prices on the demand side, equation (A3.5), to the ratio of marginal costs on the production side, equation (A3.3), amounts to:

$$(A3.6) \quad \frac{X(\tilde{T})}{X(\hat{T})} = \frac{(\alpha + (X(\tilde{T}))^{\tilde{T}})}{(\alpha + (X(\hat{T}))^{\hat{T}})}$$

It states that the ratio of the marginal products is equal to the ratio of industry output. To find the relative labor inputs, substitute the solution for the ratio of the marginal products from equation (A3.6) into equation (A3.2):

$$(A3.7) \quad \frac{L(\hat{T})}{L(\tilde{T})} = \frac{X(\tilde{T})X(\hat{T})}{X(\hat{T})X(\tilde{T})} = 1$$

Equation (A3.7) is equivalent to equation (4.31) and shows that the industry labor inputs within a country are constant and equal across all industries.

Appendix 4

Suppose good $\tilde{r}$ is produced in the North and $\hat{r}$ in the South, then equation (4.32) can be derived as follows. On the production side, the ratio of industry labor inputs is:

$$(A4.1) \quad \frac{L_N(\hat{r})}{L_S(\tilde{r})} = \frac{X_N(\tilde{r}) (\alpha + (X_S(\hat{r}))^{\hat{r}})}{X_S(\hat{r}) (\alpha + (X_N(\tilde{r}))^{\tilde{r}})}$$

The price ratio is equal to the ratio of marginal costs in the two countries:

$$(A4.2) \quad \frac{P_S(\hat{r})}{P_N(\tilde{r})} = \frac{(W_S / (\alpha + (X_S(\hat{r}))^{\hat{r}}))}{(W_N / (\alpha + (X_N(\tilde{r}))^{\tilde{r}}))} = \frac{W_S (\alpha + (X_N(\tilde{r}))^{\tilde{r}})}{W_N (\alpha + (X_S(\hat{r}))^{\hat{r}})}$$

Note that since the relative wage is not equal to one the relative wage does not cancel out as in equation (A3.2).

On the demand side, the expenditure share is equal across all goods, so that the relative expenditure share for the two goods is:

$$(A4.3) \quad \frac{\beta(\hat{r})}{\beta(\tilde{r})} = \frac{P_S(\hat{r}) X_S(\hat{r})}{P_N(\tilde{r}) X_N(\tilde{r})} = 1$$

which is equivalent to:

$$(A4.4) \quad \frac{P_S(\hat{r})}{P_N(\tilde{r})} = \frac{X_N(\tilde{r})}{X_S(\hat{r})}$$

Therefore, the price ratio is merely the inverse of the ratio of industry outputs.

Equating the ratio of prices on the demand side,

equation (A4.4), to the ratio of marginal costs on the production side, equation (A4.2), generates:

$$(A4.5) \quad \frac{X_N(\tilde{T})}{X_S(\hat{T})} = \frac{W_S(\alpha + (X_N(\tilde{T}))^{\hat{T}})}{W_N(\alpha + (X_S(\hat{T}))^{\hat{T}})}$$

To find the relative industry labor inputs between countries, substitute the solution for the ratio of the marginal products from equation (A4.5) into equation (A4.1). This results in:

$$(A4.6) \quad \frac{L_N(\hat{T})}{L_S(\tilde{T})} = \frac{W_S}{W_N}$$

which is equivalent to:

$$(A4.7) \quad L_N(\hat{T}) = \frac{W_S}{W_N} L_S(\tilde{T})$$

It shows that since $W_S/W_N < 1$, Southern industries use relatively more labor in production.

Figure 4.1: Trade balance schedule

Figure 4.2: Index of comparative advantage

Figure 4.3: Complete Specialization in Each Region

Figure 4.4: Market equilibrium; $w < 1$

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Chapter 5

Comparative Statics

A model of North-South trade should provide some insights into the factors which cause changes in the pattern of world trade and the wage gap between DCs and LDCs. The model constructed in Chapter 4, generates a wage gap and a pattern of trade by using a fixed relative labor supply, constant and equal expenditure shares across all goods, and no technological change. However, in practice these factors are continually changing.

In general, LDCs are characterized by comparatively higher rates of population growth than DCs, they export products with relatively low income elasticities of demand (the basis of the Prebisch-Singer theory), and adopt technologies which are originally introduced in the North. This chapter examines three comparative static exercises; one, growth in the relative size of the Southern labor force, two, an increase in the share of world income devoted to Northern goods and three, a technological improvement in the South. While similar issues are examined in the literature on the product cycle, the results generated by the current model differ because of the addition of external economies of scale in production.¹

The comparative static exercises illustrate that an increase in the Southern labor force causes the Southern

relative wage to fall and production to be transferred to the South. These findings are common to many models; for example see Casen (1976), DFS (1977), Krugman (1979), Dollar (1986), Jensen and Thursby (1986) and Helpman and Flam (1987).

Furthermore, the model suggests that a rise in the share of world income devoted to Northern goods leads to a decline in the Southern relative wage or a deterioration in its terms of trade, and a transfer of production to the South. This result is consistent with the predictions of the Prebisch-Singer theory. Finally, a technological improvement in the South reduces the gap in labor productivity between the two countries and leads to a rise in economies of scale in the South. Consequently, Northern goods are transferred to the South and the Southern relative wage increases.

While these results are similar to those found in the literature, they differ because in the present framework the productivity of labor is endogenously determined. In contrast, the productivity of labor is fixed in the DFS (1977) model and other studies of the product cycle; it is not related to the ratio of goods produced in each region since all goods are produced under constant returns to scale. When production exhibits increasing returns to scale, as in the current model, then the proportion of goods produced by each country has an impact upon the extent of economies of scale and thus, the productivity of labor, the wage gap, and

production cost differences between the two region. As Northern industries migrate to the South, the Northern labor supply is spread over fewer industries. Hence, output and economies of scale increase for all Northern industries thereby raising the productivity gap between Northern and Southern labor. In equilibrium, comparatively fewer goods are transferred to the South and the wage gap rises by a larger amount than in the constant returns to scale case.

The remainder of this chapter is divided into four parts. Section 5.1 examines the impact of an increase in the Southern labor force on the wage gap and the pattern of trade. In Section 5.2 the effect of a fall in demand for Southern goods is studied. Section 5.3 analyzes a technological improvement in the South, while Section 5.4 provides a conclusion and summary of the chapter.

5.1 Increase in Southern Labor Supply

Today's world exhibits a demographic dualism with population growth rates considerably higher in the South than in the North.² Casen (1976) finds that because a high rate of population growth expands the size of the domestic market, it can lead to a drop in wages, due to the rise in the supply of labor, and to an increase in economies of scale as production expands to satisfy the growth in demand. In turn, domestic costs of production begin to decline thereby, improving the competitiveness of the country's industrial

sector.

In the current framework an increase in the relative size of the Southern labor force, *ceteris paribus*, generates an excess supply of labor in the South placing downward pressure on the relative wage. Alternatively, one can interpret this disequilibrium as a balance of trade deficit in the South, where the deficit is a result of the South's increased demand for Northern exports. As the relative wage begins to fall to clear the market, demand for Southern labor and production both rise. Figure 5.1 shows that the $B(\tau; L_N/L_S)$ schedule shifts downwards in proportion to the rise in L_S and, in the absence of any production transfers from the North to the South, ω_4 is required to clear the labor market and eliminate the trade imbalance.

A fall in the relative wage, however, will cause Northern industries to transfer their production to the South. At the initial equilibrium at point A, the marginal cost of producing the borderline good is the same in both countries. This implies that a decline in the relative wage will trigger comparatively high cost Northern industries to migrate to the South, since the relative marginal costs of producing in the North increase. As the proportion of goods produced in the South expands, the demand for its labor rises. Thus, a relative wage above ω_4 will clear the labor market.

The combined effect of a drop in the relative wage and a transfer of production to the South serves to eliminate the excess supply of labor in the South. Moreover, the range of goods that is transferred to the South and the magnitude of the decline in the relative wage depend upon the relationship between production transfers and changes in the productivity of labor, or the relative marginal costs of production.

In the DFS model, the marginal product of labor is assumed to be constant (the standard Ricardian assumption); it is not related to the proportion of goods produced in each region. Thus, the position of the $A(\tau)$ schedule, which represents the relative marginal products of labor, does not shift when production is transferred between countries. In this case, the new market equilibrium would be at point B in Figure 5.1, the relative wage at ω_2 and the production of goods $(\bar{\tau}, \bar{\tau})$ would be transferred to the South. Equilibrium is restored because the South now produces and exports a wider range of commodities and imports a narrower range of goods thereby eliminating the South's excess supply of labor and the trade imbalance.

However, point B in Figure 5.1 does not represent the final market equilibrium in the current analysis because there are external economies of scale in production and hence, the marginal product of labor is positively related to industry output. When production is transferred to the South

and the range of goods produced in the North declines, the fixed Northern labor supply is spread across a narrower set of industries. Recall that within a country, labor is distributed evenly across all industries. Consequently, economies of scale and the marginal products of labor rise across all Northern industries. In other words, the relative marginal costs of producing in the North decline, or the $A(\tau)$ schedule shifts downwards in Figure 5.2, partially offsetting the initial loss in the North's comparative advantage.³

Compared to the DFS model, this implies that a narrower set of goods will be transferred to the South. Furthermore, because the North produces a wider range of goods than in the DFS (1977) model and the productivity of labor rises when industry output expands, a lower relative wage will clear the market.

The new market equilibrium is represented by point C in Figure 5.2. In the final equilibrium the $B(\tau; L_N/L_S)$ curve shifts downwards to $B'(\tau; L_N/L_S)$, the $A(\tau)$ curve shifts downwards to $A'(\tau)$, goods $(\bar{\tau}, \hat{\tau})$ are transferred to the South and the relative wage falls to ω_3 . The South now produces a wider set of commodities which generates a rise in the demand for Southern labor and clears the labor market. Likewise, the trade imbalance is eliminated because Southern exports expand, while its imports decline. Moreover, the degree of external economies in the borderline good has increased:

$$(5.1) \quad \omega_3 = A(\hat{\tau}) < \omega_1 = A(\bar{\tau})$$

indicating that the marginal cost of producing the borderline commodity has fallen and is once again the same in both countries. In essence, there is no further incentive for Northern firms to transfer their production abroad, or the world is efficiently specialized.

In summary, an increase in the Southern labor supply leads to a fall in the equilibrium relative wage, a rise in the proportion of goods produced in the South and a new pattern of trade. In equilibrium the North maintains its monopoly on commodities with the highest economies of scale (new goods in the current model), since only goods with the lowest economies of scale in the North (old goods) are transferred to the South.

The decline in the equilibrium relative wage is consistent with the observation of an increasing wage gap between DCs and LDCs. In the current model the reason for this is that the allocation of production, and thus the demand for labor, is a function of the relative wage and the economies of scale in each region. An increase the ratio of goods produced in either region is analogous to a rise in the demand for its labor. When the Southern labor force grows, the South experiences an excess supply of labor which causes the relative wage to decline and induces Northern firms to transfer their production to the South.

However, as the proportion of goods produced in the North declines, the output in each Northern industry and the extent of economies of scale expand; consequently, Northern marginal costs fall and the $A(\tau)$ schedule shifts downwards. In equilibrium, fewer Northern industries migrate to the South and the relative wage falls by a larger amount than in the DFS model because the gap in labor productivity between the North and the South increases by a comparatively larger amount. In some sense, the North realizes greater gains to specialization because of the economies of scale.

It should also be noted that in the other models of the product cycle examined in Chapter 2, the productivity of labor is also independent of the pattern of trade. For example, Krugman (1979) assumes that each unit of labor produces one unit of output. He finds that the wage gap is only a function of the ratio of goods produced in each country and the relative labor supplies. This implies that as production migrates to the South the productivity of labor remains constant. Moreover, when the Southern labor force expands in Krugman's model, the relative wage falls to clear the labor market. However, this does not trigger the migration of production to the South since production transfers are exogenously determined.

5.2 Fall in Demand for Southern Goods

Weak demand for goods produced in LDCs has often been

cited as a reason for the decline in their terms of trade. Hogendorn (1987) and Todaro (1989) show that the development of synthetic substitutes has caused a fall in the demand for raw materials from LDCs. For example, cotton and silk have been replaced, in part, by synthetic fibers, rubber with manmade substitutes, copper with plastic and so forth. Prebisch (1950) and Singer (1950) contend that the secular decline in the South's terms of trade is associated with weak demand for its products and a long-term transfer of income from LDCs to DCs.

Stokey (1988) finds that the demand for old goods usually gives way to demand for new goods. For example, demand for oil and gas lights has been replaced by demand for incandescent bulbs. In the present model the South produces the oldest goods, those goods with the lowest degrees of external economies and thus, a fall in the demand for old goods is equivalent to a drop in the demand for Southern goods.

Since it is assumed that there exists a continuum of goods and that an equal fraction of world income is expended on each good, demand is represented by a uniform density function, see Figure 5.3. This suggests that the share of world income spent in either country is equivalent to the proportion of goods it produces. Areas A and B in Figure 5.3 therefore, represent the fraction of world income spent in

the South and North respectively. Note that the area under the density function must integrate to one.

As demand for Southern goods declines, Northern goods are consumed with a higher density. If there is no change in the pattern of trade, this indicates that the fraction of world income devoted to the North rises, or it falls in the South. The change in the structure of demand is associated with a new density function portrayed in Figure 5.4. Figure 5.4 clearly illustrates that, *ceteris paribus*, the proportion of world income devoted to Southern goods decreases, area C in Figure 5.4 is smaller than A in Figure 5.3.

Algebraically, this is equivalent to comparing:

$$(5.2) \quad \int_0^{\bar{\tau}} \beta(\tau) d\tau > \int_0^{\bar{\tau}} \beta'(\tau) d\tau$$

where, $\beta'(\tau)$ is measured after the shift in demand.

By similar argument, the share of income spent in the North expands, area D is larger than area B.

A decline in the fraction of world income devoted to the South, *ceteris paribus*, is equivalent to a drop in the demand for both Southern commodities and its labor. The South now experiences an excess supply of labor which exerts downward pressure on the relative wage. Moreover, a rise in demand for Northern goods will cause the $B(\tau; L_N/L_S)$ schedule to shift downwards, in proportion to the decline in demand, to $B'(\tau; L_N/L_S)$, see Figure 5.5. As a result, a relative wage

of ω_1 is needed to clear labor market, or the South's terms of trade deteriorate.

As in Section 5.1 the drop in the demand for Southern goods leads to an excess supply of labor in the South. Although different circumstances generate the excess supply of Southern labor in this section compared to Section 5.1, the end result is very similar. In both cases the $B(T; L_N/L_S)$ curve shifts downwards and the relative wage begins to decline. (Refer to Section 5.1 for complete details on the adjustment to equilibrium in this situation.)

As the relative wage falls to clear the labor market, Southern marginal costs decline relative to Northern marginal costs and the North loses its comparative advantage in some industries. Compared to the DFS (1977) model fewer goods are transferred to the South because the productivity of labor in the North rises in equilibrium and thus, the South experiences a comparatively larger deterioration in its terms of trade.

Figure 5.5 shows that at the new market equilibrium is at point C, the relative wage is ω_3 and goods $(\bar{t}, \hat{t})$ are transferred to the South. Note that in the DFS model the final equilibrium would be at point B.

In summary, an increase in the demand for Northern goods results in a drop in the equilibrium relative wage and an increase in the fraction of Southern produced commodities.

Compared to the DFS findings, the current model indicates that a decrease in the fraction of world income devoted to Southern goods leads to both fewer goods being transferred to the South and a proportionately larger decline in the relative wage.

The results derived in this section conform with the Prebisch-Singer thesis which argues that there will be a secular decline in the terms of trade of LDCs because demand for exports from these countries, especially for primary products, grows relatively slower than the demand for DCs' exports. In general, the Prebisch-Singer theory is used to explain the worsening terms of trade for primary product exports from LDCs. Although this section examined a one time drop in demand for Southern goods that does not specifically generate a secular decline in the South's terms of trade, one could easily derive a secular decline in the South's terms of trade by assuming that the demand for Southern goods is continually falling.

Furthermore, although the empirical evidence in support of the Prebisch-Singer theory is mixed, it still remains an important issue for LDCs.⁴ Based on the predictions of the Prebisch-Singer theory, LDCs have called for a redistribution of the gains from trade and a New International Economic Order, see Meier (1984, p. 501-503).

5.3 Technical Change in the South

Technical change can act as a stimulus for economic growth and alter the competitive position of a country, see for example Romer (1986) and Lucas (1988). Gillis, Perkins, Romer and Snodgrass (1987) estimate that ninety percent of the world's R&D expenditures on technology development are made by DCs. However, many LDCs, for instance South Korea, Brazil, Mexico, India and China, have now set up research institutes to promote technological development. Hogendorn (1987) finds that some LDCs are now actually exporting technology to other LDCs. For example, South Korea and Taiwan export technology in the fields of electronics and light manufacturing, Brazil and Mexico in steel, and India in textiles, sugar processing and refrigeration. This section examines the impact of a technological improvement in the South on the North-South wage gap and the pattern of trade.

Suppose that the South experiences a uniform technical improvement. Specifically, the value of α increases by an equal amount for all Southern industries, $\alpha_s > \alpha$ where α is the value of the technological shift parameter prior to the technological improvement. This type of technical change leads to a rise in Southern labor productivity and a reduction in the North-South labor productivity gap. Alternatively, Northern relative marginal costs increase and the $A(\tau)$ schedule shifts upwards in the range of goods

produced in the North.⁵ As a result, Northern industries transfer their production to the South and the Southern relative wage rises.

Over the set of Northern produced goods a uniform technological improvement in the South causes the relative marginal products of labor in the South to increase and Southern marginal costs to decline by a constant amount. Southern marginal costs for goods $[\bar{\tau}, \tau^*]$ are now given by:

$$(5.3) \quad mc_S^{\tau} = \frac{W_S}{\alpha_S} < \frac{W_S}{\alpha}$$

In turn, the $A(\tau)$ schedule in Figure 5.6 shift upwards in proportion to the technological improvement. The $A(\tau)$ curve for goods $[\bar{\tau}, \tau^*]$ amounts to:

$$(5.4) \quad A(\tau) = \frac{\alpha_S}{(\alpha + (X_N(\tau))^{\tau})}; \quad \alpha_S > \alpha$$

At the initial relative wage of ω_1 the North therefore experience a loss of comparative advantage in industries exhibiting relatively low external economies of scale.

Across the range of Northern products, the North's comparative advantage derives from its ability to take advantage of the external economies of scale in production. However, when the South realizes a technical improvement, the North's advantage is partially offset because technological factors now have a larger impact on Southern marginal costs. Ceteris paribus, a higher relative wage is now needed to equate the marginal cost of the borderline commodity $\bar{\tau}$ in

each country. Thus, some Northern industries begin to move to the South.

Similar to the first two comparative static exercises examined in this chapter, production transfers to the South generate a fall in Northern marginal costs reducing the set of industries that migrate to the South. Specifically, the North's labor supply is now spread more densely across fewer industries and so Northern marginal costs decline. The number of industries that migrate to the South depends upon the size of the technical improvement, the relative wage, and the gap in labor productivity between the two regions, or the slope of the $A(\tau)$ schedule.

Moreover, as production is transferred to the South, the demand for Southern labor increases placing upwards pressure on the relative wage. This leads to a balance of payments surplus in the South since Southern exports rise and imports decline.

The new equilibrium is illustrated in Figure 5.6 at point B. It shows that when α_s increases, the $A(\tau)$ schedule in the range $[\bar{\tau}, \tau^*]$ shifts upwards to $A'(\tau)$, goods $[\bar{\tau}, \tilde{\tau})$ are transferred to the South and ω_2 is the new equilibrium relative wage.

Compared to the DFS (1977) model fewer goods are now transferred to the South and the relative wage rises by a smaller amount in the current framework. This is attributed

to the fact that in the present model there are economies of scale in production. Thus, the productivity of labor in the North expands when goods are transferred to the South partially offsetting the North's initial loss in its comparative advantage and thereby reducing the range of industries that migrate to the South.

In summary, a Southern technological improvement leads to an increase in the marginal products of labor in the South. Over the range of Northern produced goods, Southern relative marginal costs of production fall. This occurs because the North relies on the external economies to lower its production costs and the technological shift parameter now has a relatively larger impact upon industry output in the South. As a result, Northern industries begin to migrate to the South forcing the relative wage to increase to clear the labor market.

Furthermore, a Southern technical improvement results in the South producing goods with larger economies of scale, goods $(\tilde{r}, \tilde{r})$ in the current framework. Both Stigler (1951) and Stiglitz (1989) felt that the limited technical capabilities of LDCs reduced the ability of poorer countries to handle products with high economies of scale. However, this section shows that technical progress in the South can expand the capabilities of LDCs to produce goods with relatively higher economies of scale.

5.4 Conclusion and Summary

The three comparative static exercises examined in this chapter illustrate that when production is subject to increasing returns to scale in production, a change in the pattern of world trade will alter the extent of economies of scale and the productivity of labor in each region. In this case, industry output and economies of scale are inversely related to the proportion of goods produced in each country. Any factors which affect the allocation of production will therefore, alter the productivity of labor.

In each of the three exercises conducted above, Northern industries transfer their production to the South causing the productivity of labor in the North to improve. Compared to models incorporating constant returns to scale in production, this results in a narrower set of goods being transferred to the South. Furthermore, because the productivity of labor in the North improves, the North experiences a larger fall in the relative wage, or a greater improvement in its terms of trade, when either the Southern labor force grows or the demand for its products declines. Likewise, a technological improvement in the South leads to a comparatively smaller rise in the relative wage in favor of the South.

These results are consistent with those of the Prebisch-Singer theory and Casen (1976). Essentially, weak

demand for Southern products shifts the relative wage in favor of the North generating a deterioration in the South's terms of trade. Moreover, as in Casen (1976) the findings indicate that population growth in the South will lower Southern wages and induce Northern industries to transfer their production to the South.

However, the present model is still static in nature, whereas Vernon's concept of the product cycle alludes to a dynamic process in which the development of new products in the North triggers the product cycle. In the next chapter, the model is extended to include the introduction of new products. It therefore, more closely approximates Vernon's theory generating a moving equilibrium in which Northern innovation stimulates the transfer of production to the South rather than a static equilibrium.

Endnotes

1. In general, one would also want to be able to analyze the effects on the relative wage and the pattern of trade of (i) growth in the relative size of the North's labor force, (ii) an increase in the share of world expenditures devoted to Southern goods and (iii) an improvement in Northern technology. However, in all three of these cases the equilibrium falls within the discontinuous region and no production is transferred from the South to North.

Essentially, the model is designed to study the transfer of production from the North to the South. Hence, these cases are not analyzed. Note that in the case of (i) and (ii) this is not a major concern because these changes are not consistent with observed events, while case (iii) is studied in Chapter 6.

2. The World Bank estimates that the rate of population growth between 1986 and the year 2000 will average 1.9% in low income less-developed countries, 2.1% in middle-income countries and 0.4% in developed countries. Some examples of the projected rates for low-income countries are, Kenya 3.9%, Zambia 3.4%, Pakistan 3.0% and India 1.8%. In middle-income countries some rates are Bolivia 2.6%, Thailand 1.6%, Brazil 1.9%, and Mexico 2.1%. Finally, the rates for high-income countries are Canada 0.7%, United States 0.6%, Japan 0.5%, and Germany -0.3%.

3. Note that the assumption of full employment is critical. When Northern industries are transferred to the South, the labor employed by each Northern industry expands. However, if the labor is not absorbed by the remaining Northern industries, then the $A(T)$ schedule would not shift so that this equilibrium would be identical to the DFS equilibrium.
4. See Spraos (1980) for a review of the literature on secular decline in the terms of trade of LDCs. He concludes that the evidence points to a deteriorating trend in terms of trade of primary product exports from LDCs. However, he does feel that the statistical series chosen by Prebisch exaggerated the rate of deterioration.
5. Note that this section only deals with changes in the position of the $A(T)$ curve in the range of Northern produced goods since the model deals with transfers from the North to the South.

Figure 5.1: Increase in L_S , no production transfers.

Figure 5.2: Increase in L_S with production transfers.

Figure 5.3: Uniform density function

Figure 5.4: Density function after change in demand

Figure 5.5: Decrease in $B(T; L_N/L_S)$

Figure 5.6: Increase in α

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Chapter 6

Innovation

The introduction of new products plays an important role in determining the pattern of world trade. Vernon's concept of the product cycle stresses that changes in the pattern of world trade result from the development of new products and production transfers. The product cycle is particularly relevant in explaining trade between DCs and LDCs and has been emphasized in both the empirical literature and recent attempts to formalize the product cycle.

This chapter builds upon the model developed in Chapter 4 by introducing innovation into the analysis. The analysis in Chapters 4 and 5 focused on a static equilibrium - the equilibrium at one point in time. However, recent reformulations of the product cycle depict a dynamic process in which the pattern of trade is continuously changing as the North introduces new products. Many products are initially introduced in the North but overtime lower Southern labor costs induce Northern firms to transfer their production to the South.

In this chapter it is assumed that only the North innovates and that all new goods are originally produced in and exported by the North. As in Vernon's theory of the product cycle and similar to Krugman (1979), Dollar (1986),

Jensen and Thursby (1986) and Grossman and Helpman (1989), the model obtains a stable equilibrium which is determined by the rate of innovation and the rate of production transfers. This equilibrium is characterized by a continuously changing pattern of trade and a fixed wage gap between the North and the South.

The distinguishing feature of the model is that it incorporates the impact of external economies of scale into the analysis. The findings indicate that the rate of production transfer is not only a function of international wage differentials, but is associated with the extent of the economies in each region. Furthermore, the model is able to establish the conditions which determine the rate of production transfer and thus, the relative wage and borderline good, $\bar{i}$. Specifically, the rate of production transfer is related to the underlying external economies of scale. Northern firms will transfer their production to the South when the wage differential is large enough to compensate them for the fact they are the only firm producing in the South and the extent of external economies are low.

The remainder of this chapter is divided into four parts. Section 6.1 examines the effects of a one-time burst of innovation on the pattern of world trade and the North-South wage gap. In Section 6.2 the sequential equilibrium is derived, Section 6.3 analyzes the properties of the

equilibrium, while Section 6.4 concludes the chapter.

6.1 Once-and-for-all Innovation

Consider a one-time increase in the set of goods produced in the world. Specifically, suppose that the North innovates and develops a new range of commodities. In keeping with both Vernon's concept of the product cycle and the empirical evidence, it is assumed that the North initially produces and exports the entire set of these goods. This allows the North to take advantage of the economies of scale in advance of the South and gain a comparative advantage in the production of newly developed goods.

As in Chapter 4 it is assumed that the degree of economies of scale is inversely related to the age of a good. Newly developed goods exhibit a higher degree of economies of scale than the initial set of goods $[0, \tau^*]$ and the set of newly introduced products is given by $(\tau^*, \tau^* + n\tau^*)$, where n is a positive constant.

The increase in the range of commodities affects the structure of demand in the model. Recall that the fraction of world income spent on each good is constant and equal across all commodities; demand is represented by a specific uniform density function (see Figure 5.3). Therefore, when the set of commodities expands, world income is spread more thinly, although evenly, over a broader range of goods,

$[0, \tau^{\bullet} + h\tau^{\bullet}]$ versus $[0, \tau^{\bullet}]$, and demand is depicted by a new uniform density function, see Figure 6.1.

The integral of the expenditure shares across the total set of goods, the area under the new density function, still sums to one:

$$(6.1) \quad \int_0^{\tau^{\bullet} + h\tau^{\bullet}} \beta'(\tau) d\tau = 1; \quad \beta(\tau) > \beta'(\tau)$$

Ceteris paribus, the South continues to produce the same range of commodities $[0, \bar{\tau})$ and thus, the share of world expenditure on Southern goods falls to:

$$(6.2) \quad \beta'_S(\bar{\tau}) = \int_0^{\bar{\tau}} \beta'(\tau) d\tau$$

All remaining goods, indexed by $[\bar{\tau}, \tau^{\bullet} + h\tau^{\bullet}]$, are produced in the North and the fraction of world income spent in the North rises to include the newly developed products:

$$(6.3) \quad 1 - \beta'_S(\bar{\tau}) = \int_{\bar{\tau}}^{\tau^{\bullet} + h\tau^{\bullet}} \beta'(\tau) d\tau$$

Essentially, both countries shift an equal proportion of their expenditures from the original set of goods, $[0, \tau^{\bullet}]$, towards the newly developed products, $(\tau^{\bullet}, \tau^{\bullet} + h\tau^{\bullet}]$. The South's labor supply is now allocated over the same range of commodities for which demand is lower; there is a drop in the demand for Southern labor, or a balance of trade deficit in the South. By similar argument, the North obtains a rise in the demand for its labor. Figure 6.2

shows that the introduction of new products causes the $B(T; L_N/L_S)$ schedule to shift downwards to $B'(T; L_N/L_S)$ reflecting the decline in the relative demand for Southern goods.¹ As a result, the relative wage must decrease to clear the labor market.

Innovation also affects the pattern of production because the relative marginal costs of producing in the North rise when the North introduces new products. Northern marginal costs increase for two reasons; (i) the relative Northern wage rises to clear the labor market and, (ii) the size of the external economies are negatively related to the range of goods produced in a country.² Since the North produces a broader set of goods after it innovates, Northern industries with relatively low external economies of scale lose their cost advantage and are transferred to the South.

It should be noted that the increase in Northern marginal costs is represented by an upwards shift in the $A(T)$ curve, while the introduction of new products is depicted by an expansion of the $A(T)$ schedule to include the new goods.

Production transfers however, lead to an increase in the demand for Southern labor and a rise in the relative Southern wage. Thus, while innovation causes the relative Northern wage to rise, production transfers have the opposite effect. In the final equilibrium the relative wage

is determined by the proportion of goods produced in each region. For a given amount of innovation, the relative wage can either (i) remain constant, (ii) decrease or (iii) increase, depending on the range of industries that migrate to the South.

(i) ω remains constant.

If the equilibrium relative wage remains at ω_1 after the North innovates, then both the fraction of world income spent in each region and the proportion of goods they produce will be fixed at their initial levels of $\bar{\tau}/\tau^*$ in the South and $(\tau^* - \bar{\tau})/\tau^*$ in the North.³ Note that Krugman (1979) and Dollar (1986) derive similar results in their papers. To demonstrate this result in the current framework consider the following.

The market equilibrium condition requires that both labor markets clear, world trade is balanced, and the pattern of production is efficient. Prior to the introduction of new products, the balanced trade condition is given by:

$$(6.4) \quad \omega_1 = \frac{\beta_S(\bar{\tau})}{(1 - \beta_S(\bar{\tau}))} \frac{L_N}{L_S}$$

This states that at ω_1 the value of Southern exports is equal to the value of its imports when $\bar{\tau}/\tau^*$ goods are produced in the South, see Figure 4.4 in Chapter 4.

When the North innovates however, world income is spread over a broader range of goods. Thus, if ω_1 is the

relative wage the balanced trade condition amounts to:

$$(6.5) \quad \omega_1 = \frac{\beta'_S(\bar{T}+h\bar{T}) \frac{L_N}{L_S}}{(1-\beta'_S(\bar{T}+h\bar{T})) \frac{L_N}{L_S}}$$

where: $\beta'_S(\bar{T}+h\bar{T})$ = the share of world income spent in the South after innovation takes place.

By equating (6.4) to (6.5) and canceling like terms one finds that the relative wage is constant when the fraction of world income spent in each country remains unchanged:

$$(6.6) \quad \beta'_S(\bar{T}+h\bar{T}) = \beta_S(\bar{T})$$

The reason for this is that both the relative wage and labor supplies are fixed in the current model and hence, the ratio of Northern to Southern national income is constant in equilibrium. Alternatively, a fixed relative wage implies that the same proportion of goods will be produced in each country:⁴

$$(6.7) \quad \frac{\bar{T}}{\bar{T}} = \frac{(\bar{T}+h\bar{T})}{(\bar{T}+h\bar{T})}$$

In addition to balanced trade, the market equilibrium condition also requires that the pattern of production is efficient, or:

$$(6.8) \quad \frac{\alpha}{\alpha + (X(\bar{T}+h\bar{T}))^{\bar{T}+h\bar{T}}} = \omega_1$$

Equation (6.8) shows that the marginal cost of producing the new borderline good, $\bar{T}+h\bar{T}$, is equal in both countries so that

there is no incentive for Northern firms to migrate to the South.

However, if ω_1 represents the equilibrium relative wage, then equation (6.8) also implies that the relative marginal product of labor in the borderline industry remains the same after the North innovates:

$$(6.9) \quad \omega_1 = \frac{\alpha}{\alpha + (X_N(\bar{i} + h\bar{i}))^{\bar{i} + h\bar{i}}} = \frac{\alpha}{\alpha + (X_N(\bar{i}))^{\bar{i}}}$$

where:

$(X_N(\bar{i}))^{\bar{i}}$ = the extent of economies of scale in the borderline industry before innovation; and,
 $(X_N(\bar{i} + h\bar{i}))^{\bar{i} + h\bar{i}}$ = the extent of economies of scale in the borderline industry after innovation.

This is needed for equilibrium because the relative wage is fixed at ω_1 and the South's marginal productivity of labor is constant at α across the range of Northern produced goods. In other words, the South's marginal product of labor is fixed at α in both the $\bar{i}$ and the $\bar{i} + h\bar{i}$ industries when the goods are produced in the North. Therefore, in spite of the fact that the borderline industry exhibits a higher degree of external economies of scale after innovation, $\bar{i} + h\bar{i}$ versus $\bar{i}$, the relative marginal productivity of labor in this industry must be constant.

In order for this to occur in the current model the extent of external economies of scale in the borderline

industry in the North must not change after innovation:

$$(6.10) \quad (X_N(\bar{\tau}))^{\bar{\tau}} = (X_N(\bar{\tau}+h\bar{\tau}))^{\bar{\tau}+h\bar{\tau}}$$

This will happen only when the benefit of producing with a higher degree of economies of scale in the North is exactly offset by the fall in industry output that occurs when a broader range of goods is manufactured in the North; the marginal product of labor in the $\bar{\tau}+h\bar{\tau}$ industry declines by the necessary amount in the North after innovation. Consequently, there is no change in the relative marginal cost of producing the borderline good and the economy is efficiently specialized at ω_1 .

The final market equilibrium is portrayed in Figure 6.2 at point B. In equilibrium both the $B(\tau; L_N/L_S)$ curve and the $A(\tau)$ schedule shift outwards in the same proportion, ω_1 is the relative wage, goods $[0, \bar{\tau}+h\bar{\tau})$ are produced in the South and $[\bar{\tau}+h\bar{\tau}, \tau^*+h\tau^*]$ in the North. Although the ratio of goods produced in each country is constant, the pattern of world trade has been altered. Goods with the lowest economies of scale in the North, their oldest goods, are transferred to the South and the North produces the newly developed products.

(ii) A fall in ω

If, on the other hand, the relative wage declines when the North innovates, then the ratio of goods produced in the

North must rise above its initial level of $(\bar{r}^* - \bar{r})/\bar{r}^*$. This indicates that a larger share of world income will be spent in the North, raising both the demand for Northern products and labor. Hence, a lower relative wage will clear the labor market.

In this case, a narrower set of industries is transferred to the South than in the last example, implying that the North experiences a relatively smaller drop in its marginal products of labor. Specifically, the benefit of producing with a higher degree of economies of scale in the borderline industry is comparatively larger than the effect of producing with less labor. Compared to case (i) the relative marginal product of labor in the borderline industry is higher in the North. Thus, the relative wage is lower; the $A(\tau)$ schedule shifts out by a smaller amount.

Figure 6.3 illustrates that the final equilibrium is at point C, ω_2 is the relative wage and goods $[\bar{\tau}, \hat{\tau}]$ are transferred to the South. Because the proportion of goods produced in the North rises to $(\bar{\tau}^* - \hat{\tau}^* + \hat{\tau}^* + n\bar{\tau}^*)$ from $(\bar{\tau}^* - n\bar{\tau}^* + \bar{\tau}^* + n\bar{\tau}^*)$, Northern exports increase, its imports decrease and a higher relative wage, ω_2 , is required for balanced trade. All goods in the range $(\hat{\tau}, \bar{\tau}^* + n\bar{\tau}^*)$ have higher economies of scale and lower marginal costs than $\hat{\tau}$ so that there is no incentive for Northern firms to transfer any additional industries to the South.

(iii) A rise in ω

Finally, if the relative wage rises above ω_1 , then the South will produce a larger proportion of goods than in the previous two examples. In this case, the fraction of world income devoted to the North and both the demand for Northern products and labor will decline. Consequently, a higher relative wage is needed to clear the labor market.

In equilibrium a broader set of goods is now transferred to the South. Moreover, a higher relative wage indicates that over the range of goods produced in the North, the relative marginal products of labor in the North decrease compared to cases (i) and (ii). As Northern industries migrate to the South, the benefit of producing with a higher degree of economies of scale versus the cost of producing a lower level of industry output is comparatively smaller. In turn, there is a greater drop in economies of scale in the North and thus, a wider set of industries migrates to the South; there is a larger shift in the $A(T)$ schedule.

The new equilibrium is portrayed in Figure 6.4 at point D, the relative wage is ω_3 and good $\tilde{r}$ is the new borderline commodity. Note that in this equilibrium the proportion of goods produced in the South rises from $(\tilde{r} \cdot n\tilde{r} / r^* \cdot nr^*)$ to $(\tilde{r} / r^* \cdot nr^*)$. The world is efficiently specialized at this higher relative wage because all goods in

the range $(\tilde{\tau}, \tau^* + h\tau^*)$ have higher economies of scale and lower marginal costs than $\tilde{\tau}$.

In summary, a rise in the relative Southern wage implies that the extent of external economies in the borderline industry declines in the North. This occurs because the North experiences a comparatively greater fall in labor productivity when it produces a wider set of goods. Hence, compared to cases (i) and (ii) a broader range of goods moves to the South. In contrast, when the relative wage is constant the extent of economies of scale in the borderline industry is unchanged from its initial level in the North, whereas a fall in the relative wage occurs when the extent of economies of scale in the borderline industry rises.

Taken together these three cases show that introducing innovation into the model generates results which are similar to those found in Krugman (1979) and Dollar (1986). In Krugman's model, as in the present model, the relative wage is inversely related to the proportion of goods produced in the North. Innovation raises the share of Northern production leading to a fall in the relative wage, whereas a transfer of production lowers the ratio produced in the South causing the relative wage to rise. In addition, all three models predict that the production of old goods, those with the lowest economies of scale in the North in the

current analysis, will be transferred to the South.

Furthermore, the current model depicts the product cycle mechanism in which innovation triggers the transfer of production from the North to the South. However, the model differs from other attempts to formalize the product cycle because it specifically ties the amount of production transfers to the extent of economies of scale and the productivity of labor.

6.2 Continuous Innovation

Both Krugman (1979) and Dollar (1986) find that continuous innovation is consistent with a stable equilibrium in which the North-South wage gap is constant. In their equilibrium each region produces a constant ratio of goods and because the North is continuously innovating, there must be an ongoing transfer of production to the South. In Krugman (1979) the rate of transfer is assumed to be exogenous, whereas in Dollar (1986) it is a function of the wage gap between the two regions.

The results derived in this section are similar to those found in the literature. The stable equilibrium path is characterized by a constant relative wage and ratio of goods in each region, and by a continuous transfer of production to the South. In equilibrium there is a fixed differential in the relative wage in favor of the North, which is an increasing function of the rate of innovation and

a decreasing function of the rate of production transfer.

Similar to section 6.1 it is assumed that innovation occurs only in the North and that Northern firms take advantage of the economies of scale in production in advance of their Southern competitors. All new goods are thus, initially produced in and exported by the North.⁵ Following Krugman (1979), the rate of innovation is proportional to the number of goods already invented in the world:⁶

$$(6.11) \quad \frac{dr_t}{dt} = \dot{r}_t = nr_t^* ; r_t^* < 1$$

where:

n = the rate of innovation which is assumed to be a positive constant;

$\dot{r}$ = the rate of change in r^* , or the rate of change in the range of products;

t = time, $t=0$ is the initial period; and

r_t^* = the index of the total number of goods produced and the highest economies of scale in period t .

Equation (6.11) illustrates that both the range of goods produced in the world, $[0, r_t^*]$, and the degree of economies of scale in the newest industry, r_t^* , are continuously rising over time. Note that in the initial period the set of goods produced in the world is $[0, r_0^*]$ and ω_1 is the relative wage. In addition, the final level of $r_t^* < 1$ since the model requires r^* to remain less than one at all times.

At any point in time the upper bound to the set of

commodities produced in the world, $\tau_t^\bullet$, is given by the solution to the continuous time first-order differential equation specified in equation (6.11):

$$(6.12) \quad \tau_t^\bullet = \tau_0^\bullet e^{ht}$$

This states that $\tau_t^\bullet$ is a positive function of the initial value of $\tau^\bullet$, $\tau_0^\bullet$, the rate of innovation, h , and time, t .

In Section 6.1 it is shown that a constant relative wage is maintained when a fixed proportion of goods is produced in each region. The results derived in that section can also be applied to the case of continuous innovation. If the relative wage is fixed at ω_1 when the North is innovating on an ongoing basis, then the proportion of goods produced in each country must remain the same at all times. In fact, it must maintain its initial level of $\bar{\tau}_0/\tau_0^\bullet$ in the South and $(\tau_0^\bullet - \bar{\tau}_0)/\tau_0^\bullet$ in the North. However, this requires that there be a steady flow of Northern industries to the South. Specifically, the rate of production transfers will be a constant proportion of the rate of innovation.

The index for the borderline commodity is therefore, a constant fraction of the total number of goods, $\tau_t^\bullet$:

$$(6.13) \quad \bar{\tau}_t = c\tau_0^\bullet e^{ht}$$

where: c = is the constant proportion of goods produced in the South, $\bar{\tau}_t/\tau_t^\bullet$.

The rate of production transfers, in turn, is given by the

derivative of $\bar{r}_t$ with respect to time:

$$(6.14) \quad \frac{d\bar{r}_t}{dt} = \dot{\bar{r}}_t = \text{ch}\bar{r}_0^* e^{ht}$$

or,

$$(6.15) \quad \frac{\dot{\bar{r}}_t / \bar{r}_t}{\dot{r}_t / r_t} = \frac{\text{ch}\bar{r}_0^* e^{ht}}{h r_0^* e^{ht}} = c$$

It states that the rate of production transfers is a constant fraction of the rate of innovation, a result which is consistent with both Krugman (1979) and Dollar (1986).

Moreover, the world is continuously in balanced trade at ω_1 because the proportion of goods produced in each region is constant. As a result, the share of world income spent in each country and the demand for labor are unchanged from their initial values.

Likewise, the pattern of trade is efficient, or the marginal cost of the borderline good is simultaneously equalized across both regions at all times even though the degree of external economies of scale in the borderline industry is continuously increasing. This occurs because the North produces a wider range of goods and the corresponding fall in Northern industry output is exactly offset by the higher degree of economies of scale in the borderline industry. Thus, there is no change in the relative Northern marginal cost of producing the borderline good and the world is efficiently specialized at ω_1 ; the $A(\tau)$ schedule and the $B(\tau; L_N/L_S)$ curve shift outwards by the same amount.

The equilibrium growth path is illustrated in Figure 6.5. Note that it is drawn at the end of each period. It shows that as innovation takes place, the $B(\tau; L_N/L_S)$ curve continuously shifts outwards in the same proportion as the $A(\tau)$ schedule. The equilibrium relative wage is ω_1 , goods $[0, \bar{\tau}_1)$ are produced in the South and goods $[\bar{\tau}_1, \tau_1^*]$ in the North.⁷ Moreover, the relative marginal cost of the borderline industry is constant so that the economy is efficiently specialized at ω_1 , $A(\bar{\tau}_0) = A'(\bar{\tau}_1) = A''(\bar{\tau}_2)$. Similarly, the fraction of world income spent in each country is fixed and the world is in balanced trade at ω_1 , $\beta_S(\bar{\tau}_0) = \beta'_S(\bar{\tau}_1) = \beta''_S(\bar{\tau}_2)$.

In summary, introducing continuous innovation into the model generates a product cycle which is consistent with Vernon's concept of the product cycle, Krugman (1979), Dollar (1986), Jensen and Thursby (1986) and Grossman and Helpman (1989). The model depicts a product cycle in which the North produces the newest goods, those produced goods with the highest economies of scale in the present model, and transfers the production of old goods to the South. As in Krugman (1979) and Dollar (1986) the results indicate that in equilibrium both the relative wage and the proportion of goods produced in each country are constant. The introduction of new products leads to a rise in the relative wage in favor of the North, while production

transfers cause the relative wage to increase in the South's favor. In equilibrium therefore, the rate of technology transfer is a fixed fraction of the rate of innovation.

This model however, goes beyond previous attempts to formalize the product cycle by examining the factors which determine the relative costs of producing in each region and by extending the analysis to include external economies of scale in production. In the current model, the relative wage remains constant when the extent of economies of scale in the borderline industry is fixed in the North.

6.3 Shocks to the Equilibrium

(i) Continuous Growth in the Southern Labor Force

A one time increase in the South's labor force will cause the relative wage to fall and production to migrate to the South, see section 5.1. However, higher population growth in the South is not just a one-time event. Rather, if one considers that the children born today will enter the labor force in fifteen or twenty years and that Southern population growth rates are unlikely to decline dramatically in the near future, then it can be expected that the South's labor force will grow at a faster rate for a number of years. In this section the impact of a higher Southern rate of population growth is examined within the context of the continuous innovation model developed in Section 6.2.

Singer (1950) contends that economic growth in the

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North will generate a higher Northern relative wage since the supply of labor is relatively inelastic in DCs. In contrast, the supply of labor is relatively elastic in LDCs. Lewis (1954) argues that LDCs have a "unlimited supply of labor". Thus, Southern wages rise more slowly. This argument is also made by Findlay (1980) who finds that the South's terms of trade have a tendency to decline as its population increases. However, similar to Lewis (1954), Hogendorn (1987) concludes that while this presents a strong case for reducing population growth, real wages in LDCs will begin to rise as development occurs.

Although it is assumed in the present model that the Southern labor force is growing simultaneously as innovation is taking place, one can examine the effect of these two factors separately. The case of continuous innovation is reviewed in Section 6.2 and the stable path is portrayed in Figure 6.5. It shows that in equilibrium the relative wage is ω_1 when a fixed ratio of goods is produced in each country.

An increase in the the Southern labor force however, leads to a movement from one equilibrium growth path to another. A fall in L_N/L_S , ceteris paribus, generates an excess supply of labor in the South, or a trade deficit as its import demand rises. This is represented by a downwards shift in the $B(\tau; L_N/L_S)$ schedule in proportion to the

decrease in L_N/L_S . As a result, the relative wage begins to decline in order to clear the labor market and restore balanced trade.

When the relative wage declines, Northern marginal costs rise and comparatively high cost Northern industries begin to transfer their production to the South. These transfers are in addition to those already generated by the introduction of new products. Thus, the rate of production transfer expands.

In the initial equilibrium path, the transfer of production was just sufficient to maintain a stable relative wage. However, the range of goods produced in the South now rises above its initial value of $\bar{\tau}_t/\tau_0^* e^{ht}$. This leads to an increase in economies of scale in the North and consequently, a lower relative wage is required for efficient specialization; the $A(\tau)$ schedule shifts downwards.

Figure 6.6 illustrates that at the end of period one the $B'(\tau; L_N/L_S)$ schedule shifts downwards to $B''(\tau; L_N/L_S)$, the $A'(\tau)$ schedule shifts to $A''(\tau)$, ω_2 is the relative wage and the proportion of goods produced in the South rises to $\hat{\tau}_t/\tau_0^* e^{ht}$. Moreover, since the ratio of goods produced in the South has increased, goods indexed by $[\bar{\tau}_t, \hat{\tau}_t)$ are transferred to the South and both labor markets clear at the lower relative wage. The world is also efficiently specialized at the lower relative wage because the relative

marginal cost of producing the borderline commodity declines when production migrates to the South, $A'(\hat{\tau}) < A'(\bar{\tau})$.

If this were a one time increase in the South's labor force, the world would be on a new stable path with a relative wage of ω_2 and a ratio of $\hat{\tau}_t/\tau_0^* e^{ht}$ goods produced in the South. However, in a world with continuous innovation and a higher population growth rate in the South, the wage gap will be continuously rising in favor of the North. Figure 6.6 portrays the equilibrium at the end of three different time periods. Note that this representation does not distinguish between the impact of innovation and that of population growth. It shows that the relative wage will fall and production will simultaneously be transferred to the South when rate of population growth is higher in the South. At the end of each period the relative wage drops from ω_1 to ω_2 to ω_3 and the proportion of goods produced in the South rises from $\bar{\tau}_0/\tau_0^*$ to $\hat{\tau}_1/\tau_0^* e^h$ to $\bar{\tau}_2/\tau_0^* e^{h^2}$.

In summary, a higher population growth rate in the South leads to a fall in the relative wage, a rise in the relative marginal costs of producing in the North and hence, a transfer of production to the South. These transfers are in addition to those already generated by the introduction of new products and so the South produces a wider range of goods; the rate of production transfer is increased. Nevertheless, because the South's labor force has grown the

relative wage still declines to clear the market.

(ii) One-Time Technological Improvement in the
 North with Continuous Innovation

In the current model, a technological improvement in the North is denoted by an increase in the value of the North's technological shift parameter α . Thus, α is no longer equalized across both countries, $\alpha_N > \alpha_S$. An increase in α_N will lead to an improvement in the productivity of labor in the North and a fall in its marginal costs of production; the $A(\tau)$ curve shifts downwards in the range of goods produced in the North.

As the North begins to introduce new products a narrower set of goods will now be transferred to the South. Assume that the drop in Northern marginal costs is not sufficient to induce Southern firms to transfer their production back to the North. Therefore, over time the ratio of goods produced in the North will expand so that a lower relative wage will clear the labor market.

The new equilibrium path is portrayed in Figure 6.7. Beginning from the initial equilibrium at point A, point B would depict the equilibrium at the end of period two had the North not experienced a technological improvement. However, an increase α_N causes the productivity of labor in the North to increase and the $A(\tau)$ curve to shift downwards to $A''(\tau)$. The new equilibrium is therefore, at point C, fewer goods are

transferred to the South, the ratio of goods produced in the South falls below its initial value of c and the relative wage declines to ω_2 .

In conclusion it should also be noted that both DFS (1977) and Collins (1985) study the impact of a country specific technological improvement on the relative wage and the pattern of trade. Both authors conclude that a technological improvement in the home country will lead to a transfer of production from the foreign country to the home country, from the South to the North in the present model, and a fall in the relative wage.

6.4 Conclusion

Many industries in DCs are now losing out to their cheaper Southern competitors. Northern industries such as steel, electronics, automobiles and clothing cannot compete with Southern industries which face considerably lower labor costs. The model developed in this chapter, like other models of the product cycle, portrays a world in which the pattern of trade is continuously changing. New products are initially developed and produced by the North and older Northern products, those produced with comparatively lower economies of scale, are simultaneously being transferred to the South.

The innovative feature of the model is that it not only relates the rate of transfer to the wage differential

between the two regions, but also to the extent of economies of scale in production. This conforms with both Vernon's concept of the product cycle and empirical tests of the product cycle.

Furthermore, similar to both Krugman (1979) and Dollar (1986), the findings indicate that a constant relative wage and terms of trade is maintained when there is a fixed ratio of goods in each country. However, unlike other models of the product cycle, this will only occur when the extent of the economies of scale in the borderline industry is constant in spite of the fact that it is subject to a higher degree of external economies of scale in production. Essentially, the productivity of labor is inversely related to the proportion of goods produced in each region and thus, the productivity of labor in the North declines when it produces a wider range of goods.

Growth in the Southern labor force drives Northern industries to migrate to the South raising the rate of production transfer. In turn, the productivity of labor in the North expands so that the relative wage declines.

Similarly, a technological improvement in the North also leads to a drop in the relative wage by reducing the rate of production transfer and generating an increase in the fraction of goods produced in the North. In equilibrium, the North experiences a rise in labor

productivity and a fall in the relative wage.

Finally, the implications of this model are that the South can obtain an improvement in its terms of trade by increasing the rate of production transfer, *ceteris paribus*. One way for the South to achieve this goal is to subsidize relatively high cost Northern industries to produce in the South. Hence, the next chapter examines the impact of protectionism on the part of the South on the wage gap and the pattern of North-South trade within the context of both the static model and the continuous innovation model.

Endnotes

1. Point A in Figure 6.2 is the point of market equilibrium before the introduction of new products.
2. Economies of scale are fully reversible. When industry output contracts the marginal cost of producing any good in the North rises.
3. Note that although the proportion of goods produced in the two countries is constant, the pattern of trade has changed in the sense that the North produces the new goods and transfers the production of its oldest goods to the South.
4. This can be demonstrated algebraically as follows. Before the North innovates, the ratio of goods produced in the South is:

$$\beta_S(\bar{\tau}) = \bar{\tau}/\tau^*.$$

After the introduction of new products and the resulting production transfers to the South, it is given by:

$$\beta'_S(\bar{\tau}+\lambda) = \frac{\bar{\tau} + \lambda}{\tau^* + n\tau^*}, \text{ where; } \bar{\tau}+\lambda = \text{the new borderline commodity.}$$

Solving for λ by setting $\beta_S(\bar{\tau})$ equal to $\beta'_S(\bar{\tau}+\lambda)$ yields:

$$\frac{\bar{\tau}}{\tau^*} = \frac{(\bar{\tau} + \lambda)}{(\tau^* + n\tau^*)}$$

where $\lambda = n\bar{\tau}$. This states that if $n\tau^*$ new goods are invented in the North and $(\bar{\tau}, \bar{\tau}+n\bar{\tau})$ are transferred to the South, then both the fraction of world income expended in each country and the proportion of goods they produce will maintain their initial values.

5. Both Vernon (1966) and Krugman (1979) also assume that although labor costs are lower in the foreign country production initially occurs in the innovating country.
6. Dollar (1986) models the rate of innovation in a similar fashion, although he assumes that the rate of innovation is proportional to the number of goods produced in the North.
7. It is however, important to note that although the equilibrium path examined in this section maintains a constant relative wage, the model does not explicitly rule out equilibrium paths in which the relative wage increases or decreases.

Figure 6.1: Uniform density function at end of period 1

Figure 6.2: Innovation ω Constant

Figure 6.3: Innovation $d\omega < 0$

Figure 6.4: Innovation $d\omega > 0$

Figure 6.5: Continuous Innovation

Figure 6.6: Innovation and a continuous increase in L_S

Figure 6.7: Technological Improvement in the North

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Chapter 7

Trade Policy

The promotion of exports from LDCs is often considered a major component of any long-run development strategy. The success of the Japanese and the newly industrialized countries in penetrating industrialized markets has been attributed, in part, to the export promotion strategies undertaken by these countries. Infant industries in many LDCs however, have often experienced difficulty in becoming internationally competitive. Johnson (1965) and Corden (1980) suggest that this is primarily due to high start up costs arising from either economies of scale or economies of learning. Corden (1980) believes that in order to become internationally competitive industries with economies of scale may require some form of temporary assistance to take advantage of available economies.

Itoh and Kiyono (1987) point out that the Japanese provided short-term production subsidies to a limited number of industries with the potential of becoming leading exporters. Likewise, Westphal (1978) shows that South Korea used an export promotion strategy to stimulate growth in its manufacturing sector, whereas Kirkpatrick (1987) concludes that Singapore, Hong Kong and Taiwan implemented industrial targeting strategies similar to those of Japan and South Korea to raise domestic production and exports.

In this chapter, the models developed in Chapters 4 and 6 are used to examine the effects of a production subsidy in the South on the North-South wage gap and the pattern of world trade. Itoh and Kiyono (1987) demonstrate that in a continuous good Ricardian model of trade with constant returns to scale, non-uniform production subsidies concentrated on the marginal goods (those that have the potential of becoming the home countries exports) can improve the economic welfare of the subsidizing country. Essentially, the subsidies expand the home regions production by turning marginal goods into exports, thereby improving domestic welfare and shifting the terms of trade in favor of the home country.

Krugman (1984) develops a model in which production exhibits increasing returns to scale and the domestic government limits access to the home market by foreign firms. In Krugman's model protectionism allows domestic industries to take advantage of the available economies of scale by shifting demand towards locally produced goods. Simultaneously, demand for foreign production and the economies of scale in the foreign country decline in the subsidized. As a result, some domestic industries become internationally competitive.

The model developed in this chapter extends Itoh and Kiyono's 1987 paper by introducing economies of scale and

innovation into the model. As in Krugman (1984) and Itoh and Kiyono (1987), the results of the current model suggest that non-uniform production subsidies placed by the South on a set of Northern goods will alter the pattern of trade by increasing the range of Southern exports. In turn, the relative Southern wage rises and the South's terms of trade improve.

However, the current framework differs from that of Itoh and Kiyono (1987) because they assume that all goods are produced with constant returns to scale. In their model the productivity of labor in each industry is fixed and the subsidies must be permanently kept in place. In contrast, the productivity of labor is endogenous in the present analysis. Therefore, when the government of the South subsidizes its producers, output and the marginal products of labor in the subsidized industries begin to increase in the South. When a sufficient amount of production is located in the South, it gains a cost advantage in these industries and the subsidies can be removed.

Furthermore, neither Itoh and Kiyono (1987) or Krugman (1984) allow for innovation in their models. When innovation is introduced into the present framework, the findings suggest that the subsidies only shorten the initial phase of the product cycle, the stage in which the North

produces the product, they do not alter the rate of production transfer. Innovation triggers the transfer of production to the South and even in the absence of any subsidies, the subsidized industries would inevitably migrate to the South. If the South wishes to permanently expand the proportion of goods they produce, it must continuously subsidize a different set of goods with higher degrees of economies of scale.

The remainder of this chapter is divided into three parts. Section 7.1 examines the effect of the production subsidy on the pattern of world trade, the wage gap and the South's welfare within the context of the static model developed in Chapter 4. Section 7.2 uses the dynamic model developed in Chapter 6 to determine the impact of a production subsidy on the wage gap and the pattern of world trade, while Section 7.3 concludes the chapter.

7.1 Production Subsidies in the Static Model

The demand side of the model is similar to DFS (1977), Itoh and Kiyono (1987) and Chapter 4. It is assumed that all consumers have identical Cobb-Douglas utility functions and the share of world income expended on each commodity is the same. Consumers' utility in either country is depicted by the following Cobb-Douglas utility function:¹

$$(7.1) \quad U = \int_0^{\bar{T}} \beta(\tau) \ln c(\tau) d\tau + \int_{\bar{T}}^{\bar{T}^*} \beta(\tau) \ln c(\tau) d\tau$$

where: $c(\tau)$ = consumption of good τ .

Equation (7.1) is identical to equations (2) and (3) in Itoh and Kiyono (1987). The indirect utility function that corresponds to equation (7.1) amounts to:

$$(7.2) \quad V_i(p(\tau), Y_i) = \ln Y_i - \int_0^{\bar{T}} \beta(\tau) \ln p_S(\tau) d\tau - \int_{\bar{T}}^{\bar{T}^*} \beta(\tau) \ln p_N(\tau) d\tau$$

where: i = region, North or South, and

$p_i(\tau)$ = the price of Southern or Northern produced goods.

Equation (7.2) states that utility is directly related to the country's income, $\ln Y_i$. As income increases utility rises since higher incomes allow consumers to acquire larger amounts of goods. In contrast, utility is inversely related to prices, $\int_0^{\bar{T}} \beta(\tau) \ln p_S(\tau) d\tau$ and $\int_{\bar{T}}^{\bar{T}^*} \beta(\tau) \ln p_N(\tau) d\tau$, because higher prices lead to a fall in real purchasing power. Note that equation (7.2) is identical to equations (14') and (15') in Itoh and Kiyono (1987).

The production side of the model is the same as in Chapter 4. However, in order to remain consistent with Itoh and Kiyono (1987) it is assumed that the total labor supply in each country is unitary. While this assumption does not significantly alter the results of the model, it does serve

to simplify the analysis. The initial equilibrium, reproduced in Figure 7.1, is derived in Section 4.3, ω_1 is the equilibrium relative wage and $\bar{r}$ is the borderline commodity.

Especially important is the fact that the North's cost advantage in the production of goods $[\bar{r}, \bar{r}']$ derives from Northern firms' ability to benefit from the external economies in advance of their Southern competitors. If Southern firms wish to compete with Northern producers, industries in the South must expand production to lower their marginal costs of production. This, however, is not possible unless the Southern government offers some form of a subsidy to Southern producers.

As in Itoh and Kiyono (1987) the subsidization takes the form of non-uniform ad valorem production subsidies of $s(\tau)$ offered by the government of the South on a set of Northern goods.² The subsidy levels are set to insure that the marginal costs of producing the subsidized goods in the South are infinitesimally lower than Northern marginal costs. Furthermore, it is assumed that all subsidies are financed by a non-distortionary lump-sum tax and the North continues to engage in free trade, that is, the North does not retaliate by taxing Southern exports or subsidizing its own production in response to the Southern policy.

The exact levels of the subsidies can be derived from the $A(\tau)$ schedule by comparing the relative marginal costs for goods $(\bar{r}, \hat{r})$. Recall that the $A(\tau)$ curve represents all combinations of the degree of economies of scale, τ , and the relative wage, ω , needed to equate marginal costs in the two countries and that the position of the $A(\tau)$ schedule depends on the proportion of goods produced in each region. As production migrates to the South, industry output begins to rise and marginal costs decline across all Northern industries so that the $A(\tau)$ curve shifts downwards. Therefore, the subsidy rates, which are a function of the relative marginal costs between the two regions, must be adjusted in response to a shift in the $A(\tau)$ schedule.

If Northern firms or industries move one at a time, then the subsidy rates must be continuously increased over time to compensate for the fact that Northern marginal costs are falling. To avoid this problem it is assumed that the entire set of subsidized industries shifts at one time. Although this assumption does not significantly alter the results of the model, it does imply that the South incurs a smaller subsidy expense.

Suppose the government of the South wishes to expand Southern production and exports. It can achieve this goal by offering an ad valorem production subsidy schedule of $s_j(\tau)$

to the producers of goods $(\bar{i}, \hat{i})$. The subsidies are applied to a set of commodities close to $\bar{i}$ - the marginal goods - because these goods require the smallest subsidies; the North-South gap in marginal costs is lowest for goods $(\bar{i}, \hat{i})$. Note that the marginal goods represent an infinitesimally small set of goods near $\bar{i}$.

The subscript j on $s_j(\tau)$ denotes an assumed subsidy schedule for the Northern produced goods $(\bar{i}, \hat{i})$ conditional on a given relative wage. Essentially, the subsidy schedule is conditional on the value of the relative wage, since the marginal cost gap between the two regions is a function of the relative wage. Consequently, when the relative wage changes the required subsidy schedule will also change.

At the initial equilibrium, point A in Figure 7.2, the Southern government must offer an infinitesimally higher subsidy rate than:

$$(7.3) \quad s_1(\hat{\tau}) = (\omega_1 - A(\hat{\tau})) / \omega_1 = (\omega_1 - \omega_2) / \omega_1; \quad j = 1$$

to entice producers of $\hat{i}$ to transfer their production to the South. When the relative wage is ω_1 and the ratio of Southern produced goods is $\bar{i}/\tau^*$, the required subsidy for good $\hat{i}$ must be greater than $s_1(\hat{\tau})$ because this rate equalizes the marginal cost in the two countries and the South will only produce a good when its marginal costs are lower.

By similar reasoning subsidy levels can be determined

for each Northern industry. By offering subsidies ranging from $[s_{\hat{\tau}}, s_{\hat{\tau}}]$, $s_{\hat{\tau}} < s_{\hat{\tau}}$, or a subsidy schedule of $s_{\hat{\tau}}$, the South will begin to produce goods $(\hat{\tau}, \hat{\tau})$.

When the government of the South offers subsidies of $[s_{\hat{\tau}}, s_{\hat{\tau}}]$ to the producers of goods $(\hat{\tau}, \hat{\tau})$ the subsidies are only required on a temporary basis. In general, once the South begins to produce a commodity, Southern industries start to benefit from the scale economies thereby lowering their production costs. Simultaneously, Northern production of the subsidized goods declines generating a drop in economies of scale in the North. Since the North's superiority derives from its ability to benefit from the external economies in advance of the South, the increase in Southern production reduces the North's advantage. When a sufficient amount of production is located in the South, Southern producers become cost competitive without any assistance. As in Krugman (1984), the length of time for which the subsidies are needed depends upon the speed with which Southern industries expand.

The new trade equilibrium is depicted in Figure 7.3. In equilibrium the production of goods $(\hat{\tau}, \hat{\tau})$ is shifted to the South, the North produces goods $(\hat{\tau}, \hat{\tau}^*)$, the South $(0, \hat{\tau})$, and the relative wage rises to ω_2 . The rise in the relative wage occurs because the transfer of production to the South

induces an increase in the demand for Southern labor and a drop in the demand for Northern labor. Consequently, the relative wage rises to clear the labor market.

The North now produces a narrower set of goods, and thus more output per industry, at a lower Northern relative wage so that Northern relative marginal costs decline across all industries. The pattern of production is efficient at this point because there is no further incentive for Northern firms to transfer their production to the South. Specifically, the marginal costs of producing goods $[\bar{\tau}, \tau^*]$, the Northern set of goods, are lower in the North. In fact, there is a gap in the marginal cost of the borderline good in favor of the North. In equilibrium this implies that the $A(\tau)$ curve, which includes the subsidy schedule, shifts upwards to $A'(\tau)$ and meets the $B(\tau; L_N/L_S)$ curve at point B in Figure 7.3.

Furthermore, it is important to note that over the original set of Southern goods, $[0, \bar{\tau}]$, prices increase as a result of the subsidies because the South produces a broader set of goods with a given labor force when some Northern production moves to the South. In other words, industry output and the extent of economies of scale contract over the original set of Southern produced goods. The prices of Southern commodities, in turn, rise lowering Southern

utility.

In contrast, the prices of Northern goods, $[\hat{r}, \hat{r}^*]$, decline, since the North now produces a narrower range of commodities with a given labor force. Consequently, Northern industry output expands, the price of Northern goods falls, and Southern welfare improves.

Similarly, the prices of the subsidized goods drop when they are transferred to the South generating a rise in Southern welfare. This occurs because the Southern relative wage is lower and the Southern industry labor input is higher than in the North. (See Appendix 5 for the derivation of this result).³

Itoh and Kiyono (1987) conclude that infinitesimally small subsidies on the marginal goods can make the home country, the South in the current model, better-off than under free trade. This will occur in spite of the fact that the subsidy expense is permanent in their model. Essentially, they find that as long as the South subsidizes only an infinitesimally small set of goods and the subsidy rates are very low, the welfare benefits to the South will outweigh the cost of the subsidy.

However, the results of the current model differ from those of Itoh and Kiyono (1987). In the present model production exhibits increasing returns to scale. Thus, as

Southern production rises, the South gains a permanent comparative advantage in the subsidized industries so that the subsidies, and the taxes incurred to finance the subsidies, are only left in place on a temporary basis. In contrast, the benefits of the subsidies to the South accrue forever. If the economy is infinitely lived, there is a trade-off between the temporary cost of the taxes incurred to finance the subsidies and the permanent benefits of the subsidies.

In the context of the present model, the derivation of the welfare impact of protectionism in the South requires a present discounted value (PDV) calculation of the net benefits. The effect of the subsidies on Southern welfare can be analyzed with a PDV calculation of the indirect utility function specified in equation (7.2). By substituting $p(\tau) = W_S a_S(\tau)$ for $\tau < \bar{\tau}$ and $p(\tau) = W_N a_N(\tau)$ for $\tau \geq \bar{\tau}$ into equation (7.2), the PDV of the indirect utility function for the South can be written as:

$$(7.4) \quad V_S(p(\tau), Y_S) = \frac{1}{r} \left[- \int_0^{\bar{\tau}} \beta(\tau) \ln a_S(\tau) d\tau - \int_{\bar{\tau}}^{\infty} \beta(\tau) \ln a_N(\tau) d\tau + \ln \psi \int_{\bar{\tau}}^{\infty} \beta(\tau) d\tau \right] - \left[\ln w - \ln \psi \right] \int_0^{\bar{\tau}} \beta(\tau) d\tau$$

where:

r = a constant rate of discount;

ψ = the ratio of Southern to Northern income, Y_S/Y_N ; and

$\left[\ln w - \ln \psi \right] \int_0^{\bar{t}} \beta(\tau) d\tau = \text{the single period cost of the subsidy.}$

Note that this is merely a PDV calculation of equation (14'') in Itoh and Kiyono (1987) and recall that $a_f(\tau)$ is the inverse of the marginal productivity of labor. The effect of the subsidies on the share of world income spent by each country, the inverse marginal products of labor, and the relative income are permanent. Equation (7.4) shows that Southern welfare is determined by a PDV calculation of these three variables - the PDV of the future stream of Southern purchasing power which is the same in each period - minus the one-time cost of temporary taxes incurred to finance the subsidy - the ratio of the relative wage to the relative income.

Southern utility is a positive function of the marginal products of labor, since higher marginal products suggest lower prices, and relative Southern income. Conversely, Southern utility is inversely related to the subsidy expense. In essence, utility reflects a country's real purchasing power which is negatively related to prices and the cost of the subsidy, raised through non-distortionary lump-sum taxes, and positively related to relative income.

Relative income (Y_S/Y_N) is given by:

$$(7.5) \quad \psi = \frac{\beta_S(\bar{\tau})}{1 - \beta_S(\bar{\tau})} = \frac{\bar{\tau}}{\tau^* - \bar{\tau}}$$

which indicates that the ratio of Southern to Northern income is equal to the fraction of world income spent in each country. Alternatively, equation (7.5) can be represented by the proportion of goods produced in each region since expenditure shares are equal across all goods. Southern income rises relative to Northern income as the South subsidizes its producers and the fraction of goods produced in the South expands.

The subsidy expense to the South is given by the difference between the relative wage and ratio of Southern to Northern income:

$$(7.6) \quad \omega - \psi = \int_{\bar{\tau}}^{\hat{\tau}} z(\tau) \beta(\tau) (\psi + 1) d\tau$$

where: $z(\tau) = s(\tau)/(1-s(\tau))$.

Since the labor supplies are unitary by assumption, equation (7.6) shows that Southern wages deviate from income by the subsidy expense, or the value of the lump-sum taxes. In other words, the relative wage is equal to the relative income minus the cost of the subsidy, which amounts to the subsidy rate times the value of world expenditures on the subsidized commodities. Equation (7.6) is equivalent to equation (19) in Itoh and Kiyono (1987).

The PDV welfare impact of the subsidies on the marginal industries is given by the derivative of the indirect utility function in equation (7.4) with respect to a change in the borderline good, evaluated at $\hat{\tau}$ because the South subsidizes industries $[\bar{\tau}, \hat{\tau}]$:

$$(7.7) \quad \frac{\partial V_s}{\partial \bar{\tau}} = \frac{1}{\psi} \frac{\partial \psi}{\partial \bar{\tau}} \left(\frac{1}{r} \frac{\bar{\tau} - \hat{\tau}}{\bar{\tau}} - \frac{\hat{\tau}}{\bar{\tau}} \frac{\hat{\tau} - \bar{\tau}}{\bar{\tau}} \int_{\bar{\tau}}^{\hat{\tau}} z(\tau) d\tau \right) +$$

$$\left(\frac{1}{\psi} - \frac{1}{\omega} \right) \frac{\partial \omega}{\partial \bar{\tau}}$$

Equation (7.7) depicts the change in the PDV of Southern welfare near the free-trade equilibrium. It shows that Southern welfare is directly related to the PDV of the change in relative Southern income and inversely related cost of the temporary subsidy expense.

As in Itoh and Kiyono (1987) Southern welfare will improve if subsidy schedule is designed so that the South subsidizes an infinitesimally small set of goods, $[\bar{\tau}, \hat{\tau}]$, requiring infinitesimally small subsidies. In this case, the temporary cost of the subsidy is far exceeded by the permanent benefits of the subsidy. (See Appendix 6 for the derivation of both this result and equation (7.7)).

Essentially, as long as the North produces a wider set of goods than the South in the current model, prices fall over a broader range of goods when the South subsidizes its

producers. Specifically, the prices of Northern goods and the subsidized goods decline and that the prices of Southern goods increase in this case. As a result, the South's terms of trade improve and combined with the fact that Southern relative income rises, Southern welfare improves when the subsidy expense is relatively small.

However, it should be noted that if the South wishes to subsidize an even wider set of industries, the subsidy expense will begin to increase. This occurs because the gap in marginal costs, and therefore the required subsidies between the North and South, are higher across industries with larger economies of scale. Furthermore, since the North would produce a narrower set of goods in this case the additional subsidies would lead to a rise in the relative wage causing the prices of the original Southern goods, $[0, \bar{r}]$, to increase, the prices of the subsidized goods to fall by comparatively less, and the prices of Northern goods to decline by relatively more. Consequently, when the South subsidizes a broader range of goods the benefits to the South will rise by a smaller amount.⁴

In summary, a production subsidy on the part of the South alters the pattern of world trade by causing production to shift to the South. As the proportion of goods produced in the South rises, the relative Southern wage increases and

it gains a comparative advantage in the production of the subsidized industries. Hence, the subsidies need only be applied on a temporary basis. Furthermore, because the North produces a narrower set of goods and the relative wage is higher after the subsidies are offered, marginal costs fall in the North. As a result, the Southern government must offer continually higher subsidies to induce additional industries to shift production to the South.

The South will be made better-off from the subsidies when the real value of its national income increases. This occurs when the South subsidizes a small set of industries and the subsidy expense is relatively small.

Nevertheless it is important to note that the subsidies do not eliminate the distortion that exists in this model, they only move the margin. In Chapter 4 it is shown that because Northern firms act independently of one another, they fail to take advantage of the opportunity to reduce their marginal costs of production by moving the entire industry to the South. In spite of the fact that Southern wages are lower, they continue to produce in the North. It is this distortion that impedes factor price equalization. Therefore, the subsidies, which only induce a small number of Northern industries to locate in the South, do not eliminate the distortion. However, because the subsidies partially

offset the distortion they are only required on a temporary basis so that the policy is more likely to be welfare improving than in the Itoh and Kiyono case.

The issue of subsidizing domestic industries in LDCs is discussed in detail in the literature. For example, Krueger and Truncer (1982) conduct an empirical test of the infant industry argument and find that over time Turkish infant industries have not realized sufficiently large increases in output to warrant the removal of protectionism. Bell, Ross-Larson and Westphal (1984) come to a similar conclusion in assessing the performance of industries in LDCs. Conversely, Fei and Ranis (1975) show that in South Korea and Taiwan where markets are fairly competitive, protected infant industries such as clothing, textiles, and electronics were able to lower their costs of production to become internationally competitive.

In the context of the Krueger and Truncer (1982) and Bell, Ross-Larson, and Westphal (1984) results the present model suggests that industries in LDCs grow very slowly. The assistance provided to these industries must be maintained for a longer period of time thereby reducing the potential benefits to the South.

The current model also provides a possible explanation for these empirical results. It may in fact be the case

that LDCs target infant industries with relatively large economies of scale rather than the marginal industries. These industries must therefore, experience significantly larger increases in output, which could take comparatively longer periods of time, in order to become internationally competitive. For example, Krueger and Truncer (1982) find that in Turkey transport equipment, nonelectric machinery and electric machinery, in which the minimum efficient scale of operation is fairly large, have received very high effective rates of protection. However, in spite of high growth rates in these industries over the period of their study, the industries failed to become internationally competitive. These findings imply that in addition to providing protectionism, LDCs must target the correct industries to maximize their benefits. Note that Krueger and Truncer (1982) concede that their study may not cover a long enough period of time to properly assess the performance of Turkish infant industries.

7.2 Production Subsidies and Innovation

The results in Section 7.1 are derived within the context of the static model in which there is no innovation. That model does not account for the impact of innovation on the relative wage and the pattern of trade. This section in contrast, examines the effect of a production subsidies on

the relative wage and the pattern of trade in a model with innovation.

The model developed in this section only considers innovation of the type that leaves ω unchanged at ω_1 . This implies that in the absence of any subsidies the world remains on its equilibrium path with a constant proportion of goods $\bar{\tau}_t/\tau_t^*$ produced in the South and $\tau_t^* - \bar{\tau}_t/\tau_t^*$ in the North. As in Chapter 6, it is assumed that only the North innovates and produces all new goods, and that the rate of innovation is given by:

$$(7.8) \quad \dot{\tau}_t = n\tau_t^*$$

In the absence of any subsidies on the part of the South, the introduction of new products in the North generates a rise in Northern marginal costs that induces some high cost Northern industries to migrate abroad. This occurs because at the initial equilibrium the marginal cost of producing the borderline good is the same in both countries and any increase in Northern relative marginal costs will lead to a transfer of production to the South.⁵

However, at the start of the period it is assumed that the South offers a subsidy schedule of $s_1(\tau)$ to the producers of goods $(\bar{\tau}_0, \hat{\tau}_0)$. Note that goods $(\bar{\tau}_0, \hat{\tau}_0)$ are the same as $(\bar{\tau}, \hat{\tau})$ in Section 7.1 and Figure 7.3. As a result of these subsidies, production of goods $(\bar{\tau}_0, \hat{\tau}_0)$ migrates to the South

- the North produces a narrower range of goods - and the relative wage begins to rise. Hence, one indirect effect of the subsidies is to reduce the marginal costs of producing in the North; the marginal cost gap rises in favor of the North.⁶

Excluding the effect of the subsidies on the costs faced by subsidized firms in the South, innovation and subsidies therefore, have the opposite effects on the marginal cost gap. Innovation causes the gap to fall in favor of the South while subsidies cause the gap to rise in favor of the North. If the marginal cost gap generated by the subsidies is relatively large then innovation may not induce any Northern industries, in addition to those that have already moved to the South due to the subsidies, to locate in the South. Consequently, at the end of period one, after the subsidies are offered by the South and the North innovates, there are two possible scenarios:

- (i) Over the set of Northern produced goods there still exists a marginal cost gap in favor of the North in spite of the fact that the North innovates and produces a higher proportion of goods. Thus, innovation does not lead to additional production transfers to the South.
- (ii) The initial marginal cost gap, which is comparatively small, is completely eliminated when the North innovates so

that some Northern industries migrate to the South.

In case (i) the effect of innovation does not completely offset the impact of the subsidies on marginal cost gap. In other words, the set of industries that would have moved to the South due to innovation has already been transferred because of the subsidies. Hence, no additional Northern industries locate in the South when new products are developed so that the North produces goods $[\hat{\tau}_0, \tau_1^*]$, where $\hat{\tau}_0$ in Figure 7.4 is the same as $\hat{\tau}$ in Figure 7.3.

Compared to the equilibrium in Section 7.1 in which the South subsidizes its producers but no innovation takes place, the North now produces a wider range of goods. Consequently, a larger share of world income is spent in the North and the relative wage falls below ω_2 ; the demand for Northern labor increases when the North produces a broader range of goods and the $B(\tau; L_N/L_S)$ curve shifts downwards. The fall in the relative wage implies that the marginal cost gap has fallen and the subsidy inclusive $A(\tau)$ schedule shifts downwards. After the introduction of new products, the equilibrium at the end of period one is portrayed in Figure 7.4 at point C.

If the South does not subsidize any additional industries and the North continues to innovate, the initial marginal cost gap will therefore, eventually be eliminated. The reason for this is that as the North produces a greater

proportion of goods and the Northern relative wage increases, Northern relative marginal costs will continue to rise, whereas Southern marginal costs will decline.⁷ When a sufficient amount of innovation has occurred, the marginal cost gap will be completely eliminated and Northern industries will begin to migrate to the South.⁸

In case (ii) for example, it is assumed that the North has developed a sufficiently large set of new goods in period one to cause Northern industries to migrate to the South; the the relative marginal costs of producing some Northern goods are now lower in the South.⁹ As a result, Northern firms begin to transfer their production abroad.

In this case, the equilibrium at the end of period one is portrayed in Figure 7.5. In equilibrium, the $A(\tau)$ curve shifts downwards to $A'(\tau)$, the $B(\tau; L_N/L_S)$ schedule to $B'(\tau; L_N/L_S)$ and goods $(\hat{\tau}_1, \bar{\tau}_1)$ are transferred to the South; the equilibrium moves from point C to E. At the end of period one, the South produces a narrower set of goods than in case (i) and so the relative wage declines. Moreover, the world is now back onto the equilibrium path with a relative wage of ω_1 and a ratio of $\bar{\tau}_1/\tau_1^*$ goods produced in the South.

The return to the stable path occurs because innovation has altered the distribution of production so that the subsidies no longer affect the pattern of comparative

advantage. In essence, the set of industries which would have migrated to the South in the absence of any subsidies now includes the subsidized sectors, $[0, \bar{\tau}_1) \supset [\hat{\tau}_1, \hat{\tau}_1)$. A one period subsidy therefore, only serves to accelerate the transfer of production to the South and temporarily raise the relative wage above ω_1 , it does not permanently alter the pattern of trade.

With ongoing innovation, the PDV benefits of the subsidies would now be much smaller for the South. In a world with innovation, production of the subsidized industries would eventually be shifted to the South as new goods are developed. Consequently, the distribution of production, relative income, and the relative wage return to their initial levels so that the benefits of the subsidies do not accrue forever.

To maintain a relative wage of ω_2 at the start of each period, the Government of the South must continuously subsidize a larger set of industries, but the same percentage of the total number of industries, in each successive time period. In other words, the South must always produce a greater proportion of goods than $\bar{\tau}_0/\tau_0^*$. Recall that the fraction of world income spent on each good declines as the North introduces new products. This implies that unless the Southern government subsidizes a broader

range of industries at the start of each period, the South will experience a continuously smaller increase in labor demand and the relative wage will fall below ω_2 ; the proportion of goods produced in the South will decline.

If the South subsidizes the same percentage of the total number of industries, then the subsidy expense in each period will remain unchanged. The subsidy expense is given by $(\omega - \psi)$ and since both the relative wage and the labor supplies are constant, the relative income and the subsidy expense are constant. This is due to the fact that the share of world income spent on each commodity and industry production decline when the North innovates. Hence, although the South is subsidizing a wider set of industries, the total subsidy cost per industry declines.

This result has implications for Southern welfare. Essentially, the welfare maximization problem collapses to a single-period problem since the benefits and costs of the subsidies are constant. Because the government of the South must incur the constant subsidy expense in each period and the benefits do not accrue forever, the subsidies are much less likely to be welfare improving than in the static model developed in Section 7.1. In this case, the change in Southern utility is no longer a PDV calculation but is given by:

$$(7.9) \quad \frac{\partial V_s}{\partial \hat{\tau}} = \frac{1}{\psi} \frac{\partial \psi}{\partial \hat{\tau}} \left(\frac{\tau^* - \hat{\tau}}{\tau^*} - \frac{\hat{\tau}}{\tau^*} \frac{\hat{\tau} - \bar{\tau}}{\tau^*} \int_{\bar{\tau}}^{\hat{\tau}} z(\tau) d\tau \right) + \left(\frac{1}{\psi} - \frac{1}{\omega} \right) \frac{\partial \omega}{\partial \hat{\tau}}$$

This is equivalent to equation (7.7), with the exception the the benefits are not a function of the discount rate, r .

(See Appendix 6 for the derivation of equation (7.7)).

Therefore, the sufficient condition for Southern utility to improve becomes:

$$(7.10) \quad \int_{\bar{\tau}}^{\hat{\tau}} z(\tau) d\tau \leq 1$$

rather than:

$$(7.11) \quad \int_{\bar{\tau}}^{\hat{\tau}} z(\tau) d\tau \leq (1/r)$$

In this case, the potential welfare gains of the subsidies to the South will be much smaller since the benefits for the South are reduced and the costs are constant.

Finally, it is important to note that Itoh and Kiyono (1987) do not examine the impact of innovation in their paper, their model has no dynamic aspect. Innovation, though, would produce similar results in the context of their model. Specifically, the introduction of new products would lead to a shift in the pattern of comparative advantage which, over time, would allow the South to become internationally competitive in the subsidized industries. As a result, the government of the South could remove the

subsidies.

In summary, the model developed in this section suggests that a production subsidy in the South only induces an interim change in the wage gap and in the proportion of goods produced by each region in the face of ongoing innovation. The subsidies merely accelerate the transfer of the marginal goods from the North to the South, they do not permanently alter the pattern of comparative advantage. Over time, as the range of goods produced in the world increases, the world will return to the initial equilibrium path. The South can nevertheless, maintain a relative wage above ω_1 by permanently subsidizing the marginal industries. This implies that the South will continuously incur the subsidy expense lowering the benefits to the South. With innovation the cost-benefit analysis therefore collapses to a single-period problem because the same costs and benefits are incurred in each period.

Although the subsidies may be welfare improving in the static model, their dynamic impact will eventually be eroded. In particular, if case (ii) holds then the benefits to the South will be obtained for less than one period. Consequently, the welfare gain to the South, if it exists, will certainly be lower in a PDV sense in a dynamic world with innovation.

7.3 Conclusion and Summary

The results derived in this chapter show that the South can raise its production and exports by offering subsidies to the producers of the marginal goods. These subsidies accord Southern industries with the opportunity to expand their output thereby taking advantage of the external economies of scale to lower their marginal costs and become internationally competitive. Consequently, the demand for Southern labor grows and the relative wage rises in favor of the South.

Furthermore, due to the fact that production exhibits increasing returns to scale, the subsidies need only be offered on a temporary basis. This is consistent with Krugman (1984) but differs from Itoh and Kiyono (1987) who assume that there are constant returns to scale in production and the subsidies must be maintained on a permanent basis. However, the length of time for which the subsidies must be kept in place depends upon the speed with which Southern industries expand their output and the degree of economies of scale.

Whether the South is made better-off in this situation depends upon the subsidy expense, relative income and changes in prices. In general, Southern welfare will improve when the cost of the subsidy plus the rise in the price of

Southern goods is offset by the increase in Southern relative income and the fall in the prices of Northern goods and the subsidized commodities. As long as the North produces a large ratio of goods and the South only subsidizes the marginal commodities requiring infinitesimally small subsidies, Southern welfare will improve.

In addition, the subsidy rate is inversely related to the ratio of goods produced in each region since the marginal productivity of labor depends on the level of industry output. Once again this differs from Itoh and Kiyono (1987) who assume that the marginal productivity of labor and therefore, the subsidy rates are constant.

Finally, when the model is extended to include innovation, the findings suggest that unless the South is willing to subsidize a different and growing set of marginal goods in each period, the relative wage and pattern of trade will eventually return to their free-trade levels. Essentially, the subsidies only serve to accelerate the transfer of the marginal goods to the South, they do not alter the rate of transfer or correct the underlying distortion which allows the North to take advantage of the external economies in advance of the South.

Endnotes

1. This utility function was not given in Chapter 4. It is however, specified in this chapter because it is used to analyze the welfare effects of the subsidy.
2. Baldwin (1969) concludes that in the case of an infant industry a production subsidy is more efficient than tariff protection because it is a more direct and selective policy.
3. In general, one would expect the North to produce a wider range of commodities than the South. Recall that the small size of the industrial sector in the South forms the basis of the Lewis model of surplus labor. Most LDCs specialize in a very narrow range of commodities, which implies that prices increase over a small set of goods when the South subsidizes its producers. Consequently, it is likely the South will be made better-off.
4. In industries with larger economies of scale, the marginal cost gap in favor of the North is comparatively higher. Hence, Southern output must expand by a relatively greater amount, which could take a longer period of time, before the South gains a comparative advantage in the product. If there is a positive relationship between the time it takes the South to gain a comparative advantage in a product and the degree of economies of scale in the industry, then the subsidy expense will increase even more

when the South subsidizes goods with higher economies of scale.

5. See Chapter 6 for complete details of this case.

6. Refer to Section 7.1 for details of the effects of subsidies on the relative wage and marginal cost gap.

7. If the South does not offer any additional subsidies at the start of the second period then point C in Figure 7.4 would represent the initial equilibrium at the start of period two.

8. Because the subsidies allow the South to gain a permanent comparative advantage in the marginal goods, the effects of a one period subsidy can potentially carry over for a number of periods. Thus, while the subsidy expense occurs in only one period, the benefits of the subsidy can be carried over for a number of periods.

9. Note that it is still possible for the relative marginal costs of producing the borderline good to be lower in the North at the end of period one. In this instance, no production is transferred to the South in this period, even though innovation occurs in the second period. However, since the proportion of goods produced in the North has increased with innovation, the North-South cost differential is smaller at the end period one. This implies that as the North continues to introduce new products, the gap in

marginal costs will eventually be eliminated and Northern production will migrate to the South. The number of periods it takes for this to happen depends on the rate of innovation and the range of goods that are subsidized in the South. For simplicity, it is assumed that in case (ii) this process occurs in period one.

Appendix 5

To prove that the prices of the subsidized goods decline consider the following. Recall that within a country labor inputs are the same across all industries. The free-trade labor input for any Northern industry, including the marginal industries, is given by:

$$(A5.1) \quad L_N(T) = \omega_1 L_S(T)$$

Due to the higher economies of scale in the North, Northern labor is comparatively more productive and so its industry labor input is lower (see Chapter 4 for the derivation of equation (A5.1)). When the South subsidizes production the industry labor inputs change to:

$$(A5.2) \quad L'_N(T) = \omega_2 L'_S(T)$$

where: $L'_N(T)$ and $L'_S(T)$ = the post-subsidy industry labor allocations.

Since the North produces a narrower set of goods in the post subsidy equilibrium, Northern labor is spread more densely across fewer industries, $L'_N(T) > L_N(T)$. Thus, from equation (A5.1) and (A5.2) it is clear that:

$$(A5.3) \quad \omega_2 L'_S(T) = L'_N(T) > L_N(T)$$

Specifically, because $\omega_2 < 1$, the post-subsidy industry labor input in the South is greater than the free-trade labor input in the North, $L'_S(T) > L_N(T)$. The reason for this is that

industry output and the productivity of labor for goods $(\bar{r}, \hat{r})$ are higher after they are transferred to the South and combined with the fact that relative Southern wage is lower, the prices of the subsidized commodities decline.

Appendix 6

To derive equation (7.7) consider the following.
Southern utility is given by:

$$(7.4) \quad V_S(p(\tau), Y_S) = \frac{1}{r} \left[- \int_0^{\bar{\tau}} \beta(\tau) \ln a_S(\tau) d\tau - \int_{\bar{\tau}}^{\tau^*} \beta(\tau) \ln a_N(\tau) d\tau + \right. \\ \left. \ln \psi \int_{\bar{\tau}}^{\tau^*} \beta(\tau) d\tau \right] - \left[\ln \omega - \ln \psi \right] \int_0^{\bar{\tau}} \beta(\tau) d\tau$$

The derivative of Southern utility with respect to $\bar{\tau}$, evaluated at the post-subsidy equilibrium $\hat{\tau}$, amounts to:

$$(A6.1) \quad \frac{\partial V_S}{\partial \bar{\tau}} = \frac{1}{r} \left[- \beta(\hat{\tau}) (\ln a_S(\hat{\tau}) - \ln a_N(\hat{\tau})) + \right. \\ \left. \frac{1}{\psi} \frac{\partial \psi}{\partial \bar{\tau}} \left(1 - \int_0^{\hat{\tau}} \beta(\tau) d\tau \right) - \ln \psi \beta(\hat{\tau}) \right] - (\ln \omega - \ln \psi) \beta(\hat{\tau}) \\ + \frac{1}{\psi} \frac{\partial \psi}{\partial \bar{\tau}} \int_0^{\hat{\tau}} \beta(\tau) d\tau - \frac{1}{\omega} \frac{\partial \omega}{\partial \bar{\tau}} \int_0^{\hat{\tau}} \beta(\tau) d\tau$$

or:

$$(A6.2) \quad \frac{\partial V_S}{\partial \bar{\tau}} = \frac{1}{r} \left[\frac{1}{\psi} \frac{\partial \psi}{\partial \bar{\tau}} \int_{\hat{\tau}}^{\tau^*} \beta(\tau) d\tau \right] + \left[\frac{1}{\psi} \frac{\partial \psi}{\partial \bar{\tau}} - \frac{1}{\omega} \frac{\partial \omega}{\partial \bar{\tau}} \right] \int_0^{\hat{\tau}} \beta(\tau) d\tau$$

since $\beta(\hat{\tau})$ is infinitesimally small and

$$\left(1 - \int_0^{\hat{\tau}} \beta(\tau) d\tau \right) = \int_{\hat{\tau}}^{\tau^*} \beta(\tau) d\tau.$$

In addition, re-writing equation (7.6) as:

$$(A6.3) \quad \psi = \omega - s$$

where: s = the subsidy expense, $\int_{\bar{\tau}}^{\hat{\tau}} z(\tau)\beta(\tau) \left(\psi + 1 \right) d\tau$.

and taking the derivative of (A6.3) with respect to $\hat{\tau}$ yields:

$$(A6.4) \quad \frac{\partial \psi}{\partial \hat{\tau}} = \frac{\partial \omega}{\partial \hat{\tau}} - \frac{\partial s}{\partial \hat{\tau}}$$

In turn, $\partial s / \partial \hat{\tau}$, the change in the subsidy expense, evaluated at the post-subsidy equilibrium $\hat{\tau}$, is:

$$(A6.5) \quad \frac{\partial s}{\partial \hat{\tau}} = \frac{\partial \psi}{\partial \hat{\tau}} \int_{\bar{\tau}}^{\hat{\tau}} z(\tau)\beta(\tau) d\tau + (\psi+1)z(\hat{\tau}) \int_{\bar{\tau}}^{\hat{\tau}} \beta(\tau) d\tau + \\ (\psi+1)\beta(\hat{\tau}) \int_{\bar{\tau}}^{\hat{\tau}} z(\tau) d\tau$$

where $\beta(\hat{\tau})$ and $z(\hat{\tau})$ are infinitesimally small. Substituting equation (A6.4) and (A6.5) into (A6.2) obtains:

$$(A6.6) \quad \frac{\partial V_s}{\partial \hat{\tau}} = \frac{1}{r} \left[\frac{1}{\psi} \frac{\partial \psi}{\partial \hat{\tau}} \int_{\bar{\tau}}^{\hat{\tau}} \beta(\tau) d\tau \right] + \\ \left(\frac{1}{\psi} - \frac{1}{\omega} \right) \frac{\partial \omega}{\partial \hat{\tau}} - \frac{1}{\psi} \frac{\partial \psi}{\partial \hat{\tau}} \int_{\bar{\tau}}^{\hat{\tau}} z(\tau)\beta(\tau) d\tau \int_0^{\hat{\tau}} \beta(\tau) d\tau$$

From (A6.3) it is clear that $\omega > \psi$, or $\left(\frac{1}{\psi} - \frac{1}{\omega} \right) \frac{\partial \omega}{\partial \hat{\tau}} > 0$ in

(A6.6). Furthermore, relative income, which is equal to the ratio of goods produced in each country:

$$(A6.7) \quad \psi = \frac{\bar{\tau}}{\tau^* - \bar{\tau}}$$

increases when the South subsidizes local production.

Specifically, $\partial \psi / \partial \hat{\tau}$ is positive:

$$(A6.8) \quad \frac{\partial \psi}{\partial \bar{\tau}} = \frac{\tau^{\bullet}}{(\tau^{\bullet} - \bar{\tau})^2} > 0$$

since the South produces a wider set of goods. Therefore, a sufficient condition for Southern utility to improve is the following:

$$(A6.9) \quad \frac{1}{\psi} \frac{\partial \psi}{\partial \bar{\tau}} \left[\frac{1}{r} \int_{\hat{\tau}}^{\tau^{\bullet}} \beta(\tau) d\tau - \int_{\bar{\tau}}^{\hat{\tau}} z(\tau) \beta(\tau) d\tau \int_0^{\hat{\tau}} \beta(\tau) d\tau \right] > 0$$

Since the expenditure shares are constant across all goods, the share of world income spent on any set of goods is equivalent to the proportion of goods i.e. the range:

$$(A6.10) \quad \int_{\hat{\tau}}^{\tau^{\bullet}} \beta(\tau) d\tau = \frac{\tau^{\bullet} - \hat{\tau}}{\tau^{\bullet}}$$

$$(A6.11) \quad \int_{\bar{\tau}}^{\hat{\tau}} \beta(\tau) d\tau = \frac{\hat{\tau} - \bar{\tau}}{\tau^{\bullet}}$$

$$(A6.12) \quad \int_0^{\hat{\tau}} \beta(\tau) d\tau = \frac{\hat{\tau}}{\tau^{\bullet}}$$

Substituting (A6.10), (A6.11) and (A6.12) into (A6.9) yields:

$$(A6.13) \quad \frac{1}{\psi} \frac{\partial \psi}{\partial \bar{\tau}} \left(\frac{1}{r} \frac{\tau^{\bullet} - \hat{\tau}}{\tau^{\bullet}} - \frac{\hat{\tau}}{\tau^{\bullet}} \frac{\hat{\tau} - \bar{\tau}}{\tau^{\bullet}} \int_{\bar{\tau}}^{\hat{\tau}} z(\tau) d\tau \right)$$

As long as the North produces a wider range of goods than the South $\left(\frac{\tau^{\bullet} - \hat{\tau}}{\tau^{\bullet}} > \frac{\hat{\tau}}{\tau^{\bullet}} \right)$ and thus, $\left(\frac{\tau^{\bullet} - \hat{\tau}}{\tau^{\bullet}} > \frac{\hat{\tau}}{\tau^{\bullet}} \frac{\hat{\tau} - \bar{\tau}}{\tau^{\bullet}} \right)$ in (A6.13).

Consequently, the South will experience a welfare improvement if it subsidizes a narrow set of industries requiring infinitesimally small subsidies. A sufficient condition is

that:

$$(A6.14) \quad 1/r \approx \int_{\bar{r}}^{\hat{r}} z(\tau) d\tau$$

In this case:

$$(A6.13) \quad \frac{1}{\psi} \frac{\partial \psi}{\partial \bar{r}} \left(\frac{1}{r} \frac{\hat{r} - \bar{r}}{\tau} - \frac{\hat{r}}{\tau} \frac{\hat{r} - \bar{r}}{\tau} \int_{\bar{r}}^{\hat{r}} z(\tau) d\tau \right) > 0$$

and Southern welfare improves:

$$(A6.14) \quad \frac{\partial V_s}{\partial \bar{r}} > 0.$$

Figure 7.1: Initial Equilibrium

Figure 7.2: Subsidy Level

Figure 7.3: Ad valorem subsidy in the static model

Figure 7.4: Case (i): Ad valorem subsidy with innovation period 1.

Figure 7.5: Case (ii): Ad valorem subsidy with innovation and production transfers period 1.

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Chapter 8.0

Summary and Conclusion

In this dissertation a product life cycle model of trade in which production exhibits external economies of scale is constructed to explain the dynamics of trade between DCs and LDCs. Although the model is different from traditional Ricardian or Heckscher-Ohlin models, it is not intended to replace conventional theories but rather to supplement the existing body of trade theory. The model, which is highly stylized, captures some the important factors influencing the pattern of trade and the wage gap between rich and poor nations.

The main contribution of the model is that it extends previous attempts to formalize the product cycle by incorporating economies of scale into production. The current framework models the product cycle in two stages. In Chapter 4 the equilibrium is determined at one point in time, a static equilibrium, whereas in Chapter 6 a dynamic path of the equilibrium, more closely approximating Vernon's original concept of the product cycle, in which the North innovates is built around the static analysis. The model depicts a world in which the North's ability to innovate and take advantage of the economies of scale in production in advance of the South affects both the North-South wage gap and the pattern of trade.

Dollar (1986) suggests industries such as steel,

electronics, automobiles and textiles are losing out to their Third World competitors and lower Southern wages are central in this process. The results of the current model are consistent with Dollar's findings. In this model new industries are continuously being introduced by the North while older industries are moving Southward in order to take advantage of lower production costs. Innovation causes the relative Northern wage to rise thereby inducing Northern industries to shift their production to the South, whereas production transfers cause the Southern relative wage to increase.

However, although factor costs are lower in Third World countries industrialized nations do not transfer all their products to LDCs. Vernon (1979) finds that subsidiaries of MNCs in LDCs have not acquired all the goods that their parent companies produce. Krugman (1979) derives this result by assuming that the rate of production transfer is exogenously determined so that certain goods cannot be transferred to the South. In contrast, the rate of production transfer is cost driven and endogenously determined in the present model. Unlike other attempts to formalize the product cycle, the length of the initial stage of the product cycle is not only a function of the wage gap but is also tied to the extent of economies of scale in the industry. As long as the economies of scale in the North are

large enough to compensate for the fact that wages are lower in the South, some production will remain in the North. Specifically, industries with comparatively large economies of scale will continue to produce in the North in spite of the fact that the relative Southern wage is lower.

The pattern of trade that emerges is one in which the North produces those goods with the highest economies of scale and the South produces the remaining set of goods with the opposite characteristics. This is consistent with the findings of Stigler (1951), Lucas (1988) and Stiglitz (1989). They conclude that LDCs tend to produce goods with lower economies of scale because they lack the infrastructure and skilled labor necessary to manufacture high-tech goods which are developed to meet the needs of DCs.

Furthermore, in the present model it is the ability of the North to innovate and take advantage of the economies of scale in advance of the South that accounts for its higher relative wage. Thus, if the North is continuously innovating, the North-South wage gap will remain constant only if a constant proportion of goods is produced in each country.

The model consequently, has some important policy implications for LDCs. Specifically, the model highlights the significance of production transfers, technological improvements and product development for LDCs. The findings

indicate that in order to reduce the North-South wage gap and increase national income, LDCs must try to increase the proportion of goods they produce by accelerating the rate of production transfer.

For example, if the South offers production subsidies to the appropriate set of industries - the marginal industries - the relative Southern wage, income and welfare will increase. The reason for this is that production exhibits increasing returns to scale in the current model so that the South gains a permanent comparative advantage in the subsidized industries whereas the subsidy expense is relatively small and temporary. Thus, as the ratio of Southern produced goods expands Southern purchasing power and its welfare increase.

However, protectionism alone will not necessarily raise Southern welfare, rather it is essential that the correct set of industries is targeted. This may, in part, explain why many subsidized industries in LDCs have not become internationally competitive. Industries with relatively large economies of scale have comparatively greater minimum efficient scales of operation. Hence, if the South subsidizes industries with large economies of scale, they must experience significantly larger increases in output, which could take a longer period of time, to warrant the removal of the subsidies. In this case, the subsidy expense

will be relatively high reducing the benefits to the South. Nevertheless, it is important to note that by promoting the appropriate industries countries such as Japan, South Korea, Taiwan, Singapore and Hong Kong have successfully used industrial targeting strategies to expand their base of production and exports.

Likewise, the model shows that subsidizing domestic production is less likely to be welfare improving if the North is innovating. In this case, the benefits to the South will be short lived because the subsidies only temporarily raise the proportion of Southern produced goods they do not alter the steady-state rate of transfer. Therefore, any benefits to the South are not permanent.

In addition to offering subsidies, the model suggests that the South can speed up the rate of production transfer by developing technological improvements that lower their production costs. Firms in India, Mexico, South Korea, China and Brazil for example, have been able to adapt existing products or processes to the specific conditions of their economies. Vernon (1979) suggests that this is the first step before firms in LDCs begin to initiate their own product cycles. The importance of these types of technological improvements is that they partially offset the benefits of the economies of scale to the North. In the context of the current model the world move onto a new equilibrium path in

which both the relative Southern wage and income are higher.

Higher population growth in the South will also accelerate the rate of production transfer. However, while production subsidies and technological innovations raise the relative Southern wage, population growth has the opposite effect. Faster Southern population growth generates a rise in the supply of Southern labor thereby lowering the relative Southern wage and triggering a transfer of production from the North to the South.

The fall in the Southern wage however, hinges on the assumption that the remaining set of Northern industries expands to employ the displaced Northern workers. The current model does not deal with the possible existence of unemployment in either region. Dollar (1987) suggests that in fact Northern production has not expanded quickly enough and that this process partially explains the higher rates of unemployment in DCs over the past decade. If Dollar is in fact correct then one would expect the relative Northern wage to eventually decline to clear the labor market.

Finally, there are several possible extensions to the model. To begin with the current framework assumes that the economies of scale are external to the firm so that firms operate under conditions of perfect competition. It would therefore, be useful to consider the results of the model

under conditions of imperfect competition in which the economies of scale were internal to the firm.

Secondly, the current model assumes that the initial rate of innovation is exogenously determined and that there is no resource cost to product development in the North or imitation in the South. It would be interesting to consider the effects of endogenous innovation and technology transfer, similar to Grossman and Helpman (1989), in which the North expends resources on innovation and the South uses resources for imitation.

Finally, it would be useful to test whether there actually exists a correlation between the degree of economies of scale in an industry and the success of industrial targeting strategies. In particular, one could examine whether the success of the the newly industrialized developing countries can be attributed to their ability to target industries with relatively low economies of scale.

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