Product Innovation and Differentiation, Intra-Industry Trade and Growth

A thesis submitted in fulfilment of the requirements
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by

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Table of Contents

List of Tables

List of Diagrams and Figures

Abstract

This thesis deals with one aspect of the economics of differentiated goods. Innovative goods are considered to be new goods created by a deliberate innovative process motivated by an anticipated demand for the new good. The proposition is that, amongst the developed economies, the higher the level of production of innovative goods within a country, the higher the GDP growth rate, all else being equal. In the presence of barriers to entry, this would provide economic justification for policies designed to increase the national level of production of innovative goods.

The proposed mechanism is as follows. With continuing product innovation the share of expenditure on innovative goods will increase, resulting in an increasing import demand for, and consequent increasing exports of, innovative goods. All else being equal the higher the innovative good content of a country's exports the higher the export growth rate and the higher the GDP growth rate consistent with balanced trade which can be maintained.

The theory behind this mechanism is developed and explained. A method of identifying innovative goods is developed, and using this method a number of hypotheses derived from the proposed mechanism are empirically tested using trade data from 25 countries. All four hypotheses are supported by the results, and it is concluded that the growth rate of developed economies is increasing in the level of production of innovative goods.

The implications of this result is discussed, including potential barriers to entry into the production of innovative goods and examples of policies designed to overcome these barriers. It is concluded that such policies can be considered as being in the national interest.

This thesis contains no material which has been accepted for the award of any other degree or diploma in any university. To the best of my knowledge and belief this thesis contains no material previously published or written by another person, except where due reference is made in the text of the thesis.

I consent to this thesis being made available for photocopying and loan if accepted for the award of the degree.

Geoffrey Peak

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To

Sean

and

Rebecca

1. Introduction

This thesis is concerned with the influence that the production of innovative goods has on the economic growth rate of a country. Innovative goods are new goods, brought into being by a deliberate process of product innovation, motivated by profit expectations. The innovation process itself is not considered, and neither is the contribution of that process to economic growth. The objective is to demonstrate that a higher level of production of innovative goods can, through the consequent effect on trade, have a positive influence on a country's economic growth rate.

The proposed mechanism is as follows. With continuing product innovation, the share of expenditure on innovative goods will increase, leading to an increasing global import demand for innovative goods and, consequently, increasing exports of innovative goods. All else being equal, the higher the innovative good content of a country's exports, the higher the export growth rate and, therefore, the higher the GDP growth rate, with balanced trade, that can be maintained.

The propositions concerning the growth in trade in innovative goods, and the effect on both export growth and GDP growth of the level of innovative goods in a country's export composition, are examined using trade data from a number of countries; predominantly member countries of the OECD. To enable such an investigation, a method of identifying innovative goods is required; ideally, one which reflects the broad definition of innovative goods given in the opening paragraph. Innovative goods are identified on the basis of the degree to which individual trade categories exhibit the expected characteristics of trade in innovative goods; the basis of these expected characteristics being independent of the hypotheses being tested. A substantial part of this thesis, including Chapters 4, 5 and 6, is spent on addressing this issue.

There is a perception, in at least some sectors of the community, that a country's future prosperity lies in the development of sectors variously described as "high tech", "biotech", "high value added", "R&D based" and, more recently, "the information industries". The mechanism by which the expansion of these sectors will contribute to national prosperity has not been clearly articulated but, nevertheless, such perceptions seem to be shared by the governments of many developed economies, as evidenced by policies designed to increase the size of the innovative goods sector. Examples of such policies are subsidies or tax concessions for research and development, the recasting of taxation arrangements to enhance the availability of venture capital, various "Science Parks" and "Technology Parks", and industry specific schemes[1]. At the time of writing there is a "National Innovation Summit"[2] in progress in Australia.

If it can be shown that increased production of innovative goods is in the national interest, and that there are barriers to entry into this sector, then there is justification for policies designed to increase the national output of innovative goods. This thesis will concentrate on the former of these two requirements; barriers to entry are discussed only briefly. Innovation itself is relevant in this study only as a necessary precursor to the production of innovative goods, and the location of innovation relevant only to the degree to which it influences the location of production of the consequent innovative good.

Basing the study on this one specific view is not to imply that this is the only significant aspect of innovation, but rather to enable a sharper focus on one possible mechanism by which innovation can influence country specific economic growth. This has made it possible to test a number of specific hypotheses; hypotheses concerning trade at the individual trade category level, aggregate trade by country, and economic growth by country. At the same time, the decision to base the analysis on the production of innovative goods was not an arbitrary one. There is a general perception that the success of innovation can be measured by the commercial success of the ensuing product. An expressed objective of the "National Innovation Summit" is to "identify what needs to be done to accelerate the rate at which new ideas are translated into commercially successful products and services in Australia".[3]

In addition to concentrating on this one particular role for innovation, there are several other features which distinguish this study from others concerned with innovation and

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[1] Examples within Australia include: the "Factor F" scheme, designed to encourage research within Australia by pharmaceutical companies, subsequently replaced by the Pharmaceutical Industry Investment Programme (PIIP); the "Partnership for Development Programme" designed to encourage greater development and production within Australia by firms within the information technology industry.

[2] Sponsored jointly by the Business Council of Australia and the Commonwealth Government, held in Melbourne February 10th-11th 2000.

[3] Press release 00/1 10th January 2000, Department of Industry Science and Resources

growth. One is the argument that, with continuing product innovation, the share of expenditure on innovative products will be increasing over time. This argument cannot be examined independently, but only through the expected effect on trade. The other distinctive feature is that the empirical analysis does not rely on measurements of specific inputs into the innovation process but, rather, is based on the output of the innovative process, the innovative good.

The thesis is organized as follows. Chapter 2 analyzes the existing literature on growth based on innovation and trade driven by product differentiation. Chapter 3 further develops the arguments outlined above and establishes the theoretical foundation of the thesis. Chapters 4, 5 and 6 deal with the question of identifying innovative goods. Chapter 4 analyzes the literature on intra-industry trade, and examines the extent to which intra-industry trade can be used as a proxy for product differentiation. Chapter 5 uses econometric estimations to examine the major criticisms of the significance of measured intra-industry trade. The results do not support the criticisms being examined. In Chapter 6, econometric estimations are used to examine the usefulness of several measures of intra-industry trade as proxies used for identify innovative goods. The results support the use of these measures in this way.

In Chapter 7, the proposition, that trade growth is higher for innovative than for other goods, is examined with a number of econometric estimations. The argument, that trade growth is higher for innovative goods than for other goods, is tested with econometric estimations with the growth in the import to GDP ratio and the export growth rate, both at the individual trade category level, as dependent variables. The argument, that the higher the innovative goods content of a country's exports, the higher the export growth rate for that country, is tested with an econometric estimation using the export growth rate by country as the dependent variable. The proposed effect of this on a country's economic growth rate is examined with an econometric estimation, using the growth rate of per capita GDP, by country, as the dependent variable. In all cases, the results support the proposed arguments.

Chapter 8 discusses some of the implications arising from the results in Chapter 7, including barriers to entry into the innovative goods sector. Chapter 9 provides the concluding remarks. The conclusion is that the results of the econometric estimations reported in Chapter 7 support the proposition that, on average, the higher the innovative goods content of a country's exports, the higher the country's economic growth rate. The results also support the suggested reasons, described earlier, why this might be the case.

2. Innovation and Growth: Literature Review

2.1 Introduction

Trade based on product differentiation is an important element of the economics of product innovation. For this reason, the starting point for this chapter is a review of the literature on trade based on product differentiation, in (2.2). The effect of including transport costs is briefly reviewed in (2.3). Section 2.4 analyzes the literature on trade driven by product differentiation where there is also an "outside", or undifferentiated, good.

Section 2.5 reviews the literature on innovation and growth, with particular attention paid to the model of Grossman and Helpman (1991c). It is shown that the conclusion of this model - that, with trade, the benefits of product innovation are distributed evenly across countries, regardless of the location of production of the innovative goods - is reliant upon the Cobb-Douglas utility function used. The effects of product innovation on the returns to factors of production are reviewed in (2.5.3). Those models restricting innovation to just one country show higher wages in that country. The model of Grossman and Helpman (1991c), which is more applicable to trade between similar countries, produces factor price equalization across countries.

2.2 Trade in Differentiated Products

Krugman (1979) demonstrates trade arising from product differentiation alone, there being no difference in factor endowments or technologies between the two countries. Trade relies on a utility function which gives increasing utility from increased product variety, at constant prices and income. If all varieties have the same price, the utility maximizing consumer will consume an equal quantity of each variety. This, combined with the restriction that any one variety is produced in only one country, is the basis for trade. In order to restrict the production of any one variety to one country, a production function giving increasing returns to scale is employed. The equilibrium number of varieties available is that consistent with a zero profit equilibrium under monopolistic competition.

The utility function used by Krugman (1979) gives an elasticity of demand that is decreasing in per capita consumption. This gives the following result. With the number of varieties available increasing with trade, per capita consumption of each variety decreases, with a consequent decrease in the elasticity of demand. With constant marginal cost, the profit maximizing price is reduced, and the equilibrium zero profit quantity increased.

The increased quantity per variety in the zero-profit equilibrium means that while, as expected, the equilibrium number of varieties is an increasing function of population (or labour force), it is a strictly concave function. With trade, the equilibrium number of varieties is less than the aggregate number of varieties under autarky. The other effect is that price with trade is less than price under autarky. Consequently there are two benefits from trade - an increase in utility arising from increased number of varieties, and an increase in the real wage arising from the reduction in price.

This result can be contrasted with that obtained using the Dixit and Stiglitz (1977) constant elasticity of substitution utility function, which yields demand functions of constant elasticity. Therefore the increased variety arising from trade does not lead to a price decrease and consequent increase in real wage. Benefits from trade are confined to increased utility arising from increase in variety, as shown in Krugman (1980).

The Lancaster (1980) analysis of trade based on product differentiation uses a utility function based on the concept of each consumer having an "ideal variety" rather than embracing a "love of variety". An undifferentiated good is also incorporated, the effects of which will be discussed below. With the characteristics of the ideal good being uniformly distributed over the population, and the available varieties being "equally spaced", equal aggregate consumption of each variety can be assumed. Increased variety increases utility because, with increased variety, the consumer should be able to acquire a variety with characteristics more closely resembling those of his "ideal variety". Economies of scale in the production of each variety means that the number of varieties is determined by population. The effect of trade is to increase the aggregate population, increase the number of varieties available to each consumer, reduce the average "distance" between the ideal and nearest available varieties, and thereby increase utility.

Lancaster (1980) does not explicitly specify a utility function, but argues that the elasticity of the differentiated good will be decreasing in the number of varieties.

Accordingly, the price with trade will be lower than the price under autarky, providing an additional benefit from trade. With two unequal size countries, the pre-trade price will be lower in the larger country. Gains from trade from both sources - increased utility and decreased real price - will therefore be greater for the smaller country.

This difference in price of the differentiated product between two unequal sized countries, in the absence of trade, is described by Lancaster (1980) as "false comparative advantage", because it is not based on different costs. This same effect could be expected from the Krugman (1979) model, but not from those based on a CES utility function.

2.3 Transport Costs

The above analyses have been based on the assumption, *inter alia*, of zero transport costs. Krugman (1980) introduces transport costs in the "iceberg" form, such that the cost of transport is borne by the consumer. Under these conditions, a balance in merchandise trade requires that the wage in the smaller country is less than that in the larger country. The analysis is not clear as to whether the wage in the smaller country is less or greater than that before trade; it may be indeterminate. Because this model is based on the CES utility function, prices are equal in both countries before and after trade in the absence of transport costs. Post-trade, with non-zero transport costs, both countries have increased utility from the increases in variety, the smaller country experiencing the greater increase. However, this greater benefit for the smaller country is offset to some degree by lower wages than the larger country after trade.

Although the Krugman (1980) analysis is in terms of transport costs, it may have more general implications where the incremental costs in supplying export markets over that of domestic markets are greater for some countries than for others. This issue is not developed in this thesis.

2.4 Trade in Differentiated Products and an "Outside Good"

The incorporation of a composite undifferentiated good (referred to as an "outside" good) into the analysis by Lancaster (1980) allows additional issues to be considered. The author argues that, if the elasticity of substitution between the outside and differentiated good is greater than one, a consumer whose ideal good is further from the nearest available good will consume more of the outside good. From this it follows that, because trade increases the variety of differentiated goods and therefore reduces the "distance" between "adjacent" varieties, the average distance between consumers' ideal and nearest available varieties will decrease. Consequently, the aggregate consumption of the outside good would be expected to diminish.

Compounding this, there is the effect of the lower relative price of the differentiated good arising from the reduction in elasticity with increased variety. If, as is suggested, the elasticity of substitution between the two types of goods is greater than one, then for both of these reasons the share of expenditure devoted to the differentiated good would increase. This change in expenditure share between the two types of goods can have implications for the balance of trade. Lancaster (1980) analyzes the implications of including an undifferentiated good for balanced merchandise trade under a variety of conditions, initially for two economies of equal size. The conclusion is that, where the outside good exhibits diminishing returns to scale at the economy level (e.g. agriculture), balanced trade can occur only with an equal number of varieties produced in both countries.

If the outside good exhibits constant returns to scale, then it is argued that multiple equilibria are possible, and the income elasticity of demand must be considered to determine which, if any, are stable. If this is equal to one then all possible equilibria are stable. This would also apply where incomes are constant. However, if the income elasticity of demand of the differentiated good is greater than one, the only stable equilibrium, where income is rising, is that where an equal number of varieties is produced in the two economies. Extending this analysis to two economies of unequal size, it is concluded that the only stable trade equilibrium is that where each country produces a number of varieties proportionate to its population, with no trade in the outside good.

It is argued that this will be achieved through exchange rate adjustment and reallocation of resources into (away from) the differentiated goods industry in the deficit (surplus) country. Mobility of resources and freedom of entry into the manufacture of differentiated goods are implicitly assumed.

2.5 Innovation and Growth

The demonstration of growth from innovation relies on the production or utility functions employed, usually one or the other. The use of production functions, for the most part, considers the output of a single representative undifferentiated final consumption good, with the output of innovation being incorporated into the production function in a variety of ways. These include an expanding range of horizontally differentiated intermediates, with output increasing in the number available (Romer (1987,1990a), Rivera-Batiz and Romer(1991a,b), Grossman and Helpman(1991a)); a finite range of horizontally differentiated intermediates where output increases with the quality of such intermediates (Grossman and Helpman(1991c)), or one single intermediate where output is increasing in the quality of that intermediate (Aghion and Howitt(1992)).

The utility functions used include the Dixit and Stiglitz CES utility function, incorporating horizontally differentiated products (Grossman and Helpman (1989,1991c), Smulders and van der Klundert(1995)); a finite range of horizontally differentiated products where utility is increasing in quality (Grossman and Helpman(1991a)); and a range of products increasing in their content of characteristics (Stokey(1988,1995)).

The production function approach has the advantage that it demonstrates growth in a manner which is consistent with the commonly used empirical measure of growth (an increase in GDP at constant prices). However, because there is only one consumption good, trade in consumption goods is not possible, although intra-industry trade in intermediate goods, or inter-industry trade of intermediate goods for the consumption good, is possible.

The use of a utility function incorporating differentiated goods allows both intra-industry trade and inter-industry trade between the differentiated and undifferentiated goods (where both are included), but the utility function approach can demonstrate growth only in the form of increased utility. Grossman and Helpman (1991c) argue that their model, based on a CES utility function, can be construed as demonstrating growth in real GDP. This argument is based on a hedonic price index, which will decrease with innovation as greater utility is derived from consumption of the same quantity of goods. If this price index is used to adjust GDP over time to "real" GDP, then real GDP will increase over time. This is effectively comparing GDP over time on the basis of utility produced, rather than the volume of goods (and services).

2.5.1 Innovation Without Considering Trade

Romer (1986) considers innovation in terms of the production of knowledge, both firm specific and non-appropriable, as an abstract entity, and the contribution of this knowledge to the production of an undifferentiated good. Trade is not an issue. This model is further developed in Romer (1990a), where innovation results in a range of differentiated intermediates. These are incorporated into a CES production function of an undifferentiated consumption good, and non-excludable knowledge used as input into subsequent innovation. There being only one aggregated consumption good, trade can occur only in the differentiated intermediates, and this is analyzed in Rivera-Batiz and Romer (1991a). Trade is considered only between two identical economies. The consequences of increased non-excludable knowledge, and diversity of differentiated intermediates, are analyzed for their impact on long run endogenous growth. A similar model is employed in Rivera-Batiz and Romer (1991b), and again trade only between identical economies is considered.

Aghion and Howitt (1992) employ a model where innovation produces an intermediate good of increasing quality. Only the highest quality (latest) intermediate good is employed in the production of an undifferentiated consumption good. Output is increasing in the quality of the intermediate good. Again, trade is not considered.

2.5.2 Innovation and Trade

Grossman and Helpman (1989) analyze trade driven by product differentiation. The utility function is Cobb-Douglas, incorporating both an undifferentiated good, and differentiated goods within a CES formulation. The Cobb-Douglas format gives constant expenditure shares between the two types of goods, the significance of which is discussed in the conclusions to this chapter.

In this model (Grossman and Helpman 1989), differentiation depends upon innovation. Unlike the previous models of trade driven by product differentiation, varieties come into existence only as a result of innovation. The output of innovation is totally excludable, giving the innovating firm monopoly power over the innovative product. With successive innovations, the market share for each variety diminishes so that, with the cost of innovation remaining constant, the profitability of each innovation is correspondingly diminished and, in the steady state, the rate of innovation is zero.

In Grossman and Helpman(1991c), the output of innovation is still excludable for the purposes of manufacture of the differentiated good, but is non-excludable as an input into all subsequent innovative activity. The result is that the cost of innovation is decreasing with previous cumulative innovation, so that the profitability of innovation does not decline, and consequently will continue indefinitely.

The utility function used in this analysis gives instantaneous utility U as

$$U = \sigma \log C_Y + (1-\sigma)\log C_Z \qquad 0<\sigma<1$$

where C_Z is the consumption of an undifferentiated good Z, and C_Y is a sub-utility function defined over the differentiated good, given by

$$C_Y=[\int_0^n x(j)^{\alpha} dj]^{\frac{1}{\alpha}} \qquad 0<\alpha<1$$

where x(j) is the consumption of variety j , and n is the total number of varieties. This is a continuous version of the Dixit-Stiglitz CES utility function.

The elasticity of substitution between any two varieties, ε, can be shown to be $\varepsilon = \frac{1}{1-\alpha} > 1$

In this model each variety of the differentiated good has the same price, p_x. so that equal quantities of each variety are consumed. $x(j)=x, \forall j$.

C_Y can now be expressed as $C_Y = n^{\frac{1}{\alpha}} x$.

If X is the total consumption of the differentiated good, then X=nx, and $C_Y = X(n^{\frac{1-\alpha}{\alpha}})$.

The effect of innovation is to increase the value of n. C_Y can be seen to be increasing in n, and consequently U is also increasing in n. Growth is defined as being the growth rate of n.

Substituting this expression for C_Y into the expression for instantaneous utility gives

$$U = \sigma(\frac{1-\alpha}{\alpha})\log n + \sigma \log X + (1-\sigma)\log C_z$$

The ratio of marginal utilities of the two types of goods is

$$\frac{U_X}{U_Z} = \frac{\sigma}{1-\sigma}\frac{C_z}{X}$$

The effect of innovation is an increase in the value of n, which does not appear in this expression. With the two prices p_x and p_z remaining constant, the relative consumption of the two goods remains constant. Even if relative prices did change, the utility maximizing requirement, that $\frac{U_Z}{U_X} = \frac{p_Z}{p_X}$, will produce constant expenditure shares of σ and $(1-\sigma)$ for the differentiated and undifferentiated goods respectively.

The contribution of innovation to utility can be determined as the marginal utility with respect to n and is given by

$$U_n = \sigma(\frac{1}{n}.\frac{1-\alpha}{\alpha})$$

which does not depend directly on the consumption of the differentiated good but on the expenditure share, σ, which is constant.

With these characteristics of the utility function, the impact of trade is limited. In a static sense it will lead to an increase in n, and therefore in utility. The CES (or equivalent) sub-utility function over the differentiated good ensures that the price of the differentiated good remains constant (as does that of the undifferentiated good). With trade there is therefore no effect on real income or wages, or changes in consumption of either good. Where "public knowledge" arising from previous innovations is assumed to flow freely and without cost between the two countries, there is an increase in the rate of innovation, to the equal benefit of both countries.

The key conclusions from this model, within the context of this thesis, is that trade produces no change in consumption patterns, and neither does ongoing innovation. There are therefore no implications for balance of trade requirements.

2.5.3 Returns to Factors

2.5.3.1 Trade Between Dissimilar Countries

Variously described as "North-South" trade and "Product Cycle" trade, this literature is characterized by the assumptions that innovation occurs only in the North, and that the manufacture of each innovative product occurs only in the North until there is some form of "technology transfer" (such as imitation or the expiration of intellectual property rights), after which time they may be manufactured in the South.

In Krugman (1979b), innovation is exogenous and "new" goods can be manufactured only in North. After some period of time (formally represented as "radioactive decay") "new" goods become "old" goods and can be manufactured also in the South. With a CES utility function, both "old" and "new" goods enter symmetrically into the utility function. The assumption of full employment requires that the relative wage is an increasing function of the ratio of the number of products manufactured in each country, and a decreasing function of the relative labour forces[1].

In Segerstrom *et al* (1990), innovation is endogenized (and confined to North), this time with innovation leading to a higher quality, and again there is a time lag (the duration of intellectual property rights) before the highest quality can be manufactured in the South. Utility is Cobb-Douglas over a finite range of products, with the utility per unit consumption increasing with quality. Prices are set for a Bertrand Nash equilibrium, ensuring that only the highest quality of each product is manufactured. Again, relative wage (N/S) is increasing in the proportion of total products being manufactured in the North, and decreasing in the relative size of the labour force.

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[1] $w_N/w_S=(n_N/n_S)^{1-\theta}(L_N/L_S)^{-(1-\theta)}$, where utility is given by $U=(\Sigma x_i^{\theta})^{1/\theta}$. w is wage, n the number of varieties and L the population. The subscripts N and S refer to North and South.

2.5.3.2 Trade Between Similar Countries

In Grossman and Helpman(1989), declining activity in research and development (R&D) over time leads to reduced wages for human capital, in which R&D is relatively intensive. If one country is more human capital intensive than the other, this can lead to a change in relative average wage. This result is specific to the case of reducing R&D activity.

Grossman and Helpman (1991c, Chapter 7) analyze the requirements for factor price equalization from trade between two countries where rates of innovation are not necessarily equal. The aim of this is to demonstrate that trade will reproduce the integrated economy. The model considers two factors of production, human capital and unskilled labour. It incorporates a three sector economy comprising innovation, differentiated product manufacture and undifferentiated product manufacture, in descending order of requirement of human capital relative to unskilled labour.

Under autarky, the rate of innovation in any country is determined by its relative endowment of human capital and unskilled labour, which is assumed unequal between the two countries. With trade, by imposing steady state restrictions such that allocation of resources to the three sectors remains fixed (and non-zero) which, amongst other things, implies incomplete specialization, then factor price equalization is demonstrated to be a consequence of equal prices. The integrated equilibrium is reproduced, providing that factor intensities in the two countries are not too dissimilar. It is further argued that, as a result of the restrictions imposed on the steady state, each country has the same rate of innovation.

In accord with the Heckscher-Ohlin theorem, the human capital rich country will be a net exporter of innovative products, while the other will export the differentiated product. Different factor proportions therefore produce inter-industry trade. Product differentiation arising from innovation will produce intra-industry trade within the differentiated goods sector, even with identical factor proportions.

2.5.3.3 Conclusions on Factor Proportions

The models of both Krugman (1979b) and Segerstrom *et al* (1990) produce different wages in the two countries by restricting innovation and limiting the rate of "escape" to the other country. This result relies on there being only differentiated products, and is not applicable where there are both types of goods, which is the case being considered in this thesis.

By restricting the level of both human capital and labour in both countries to some non-zero value, Grossman and Helpman (1991c) ensure innovation in both countries, and show that with not too dissimilar factor proportions between the two countries, factor price equalization is achieved. Where there are more extreme dissimilarities in factor proportions, factor price equalization may require that innovation and the production of the ensuing differentiated variety occur in different countries, either through licensing or multi-national enterprises. The degree to which these conclusions depend on the fixed expenditure share, and fixed consumption share, between the two types of goods is not clear.

The role of factor proportions in different rates of innovation between two countries, and hence in the pattern of trade, is not well established. The analyses based on North/South trade could reflect the situation between developed and developing countries. On the other hand, that of Grossman and Helpman (1991c) would find its parallel more in trade between developed economies, and it is in this case that the role of factor proportions is less apparent. In the analysis on factor price equalization, factor proportions are assumed to be exogenously determined, but in a separate analysis (*ibid.* chpater 5, 5.2) the same authors endogenize the formation of human capital.

In the model of endogenized factor proportions, human capital formation is on the basis of schooling, with the decision to invest in this process being based on anticipated life-time earnings. Equilibrium factor proportions are those proportions where the discounted life-time earnings to both labour and human capital are equal. This equilibrium point will depend, amongst other things, on the relative activity in the innovation, differentiated, and undifferentiated manufacturing sectors (in descending order of human capital intensity). Varying human capital factor intensities across countries would be determined by variations in the intensity of innovation and production of the innovative good across countries, rather than the other way round.

In summary, the contribution of different levels of activity in innovative goods to varying factor incomes is not clear. The North/South models that limit innovation to North can show higher factor incomes in North, but these analyses do not include an undifferentiated good. Where innovation occurs in both countries, and an undifferentiated good is included, then with exogenously determined factor proportions factor price equalization can occur. However, nothing is established as to the relative rewards of the two factors. If factor proportions are endogenized, both factors receive equal life-time discounted income.

2.6 Conclusions

It is informative to compare the results obtained by Lancaster (1980) with those of Grossman and Helpman (1991c). The use of the CES sub-utility function over the differentiated good means that there is no change in price resulting from an increase in the number of varieties, arising either from trade or innovation. The Cobb-Douglas utility function gives a constant expenditure share between the two types of goods - and at constant prices, constant quantities - irrespective of innovation.

Lancaster (1980) does not incorporate innovation, but the effect of trade is to increase the number of varieties of the differentiated good. This is the effect of innovation within the Grossman and Helpman (1991c) model, and so comparisons can be made. Lancaster (1980) argues that, the closer a consumer's ideal variety is to the closest fitting existing variety, the more of the differentiated good and less of the undifferentiated good will be consumed. With trade, or innovation had it been included, and given the assumption of uniform spacing between existing varieties, the average distance between the ideal variety and closest available variety over all consumers must decrease. Consequently, the average ratio of consumption of the differentiated good to that of the undifferentiated good will increase, even at constant relative prices.

The other effect of an increase in the number of varieties, either resulting from trade or innovation, is an increase in the elasticity of demand for each variety of the differentiated good, leading to a decrease in price. This effect by itself, given an elasticity of substitution of greater than one between the two sectors, will increase expenditure share on the differentiated good. Just as increasing income, combined with an income elasticity of demand for the differentiated good greater than one, will lead to an increasing volume and expenditure share for the differentiated good, so too will continuing innovation, for the reasons outlined above, even at constant income. So conclusions as to the requirements for stable trade balance in the former case apply equally as well to the latter.

The conclusions are that the requirement for stable trade balance is the production of equiproportionate number of varieties (based on country size) in each country. This leads to no net trade in either sector, and intra-industry trade within the differentiated goods sector. The mechanism proposed for achieving this condition is currency appreciation (depreciation) in the surplus (deficit) country, motivating the required reallocation of resources between the two sectors. This mechanism requires, *inter alia*, mobility of resources and freedom of entry into the production of differentiated goods. In the absence of either, a trade deficit could be anticipated in the country producing less than its proportionate share of varieties of the differentiated good.

The results therefore depend on the assumptions of the model, and particularly on those of the utility function. Krugman (1980, p953) laments the fact that the use of the CES utility function limits the gains to trade in differentiated goods to increased utility only, and does not capture the effects of increased elasticity of demand arising from the increased number of varieties, as did the utility function employed in Krugman (1979a). This is described as "an unsatisfactory result". The use of the CES utility function is justified on the basis that "it seems worth sacrificing some realism to gain tractability here". The utility function used by Lancaster (1980) does provide the same feature as that employed by Krugman (1979a) - increased elasticity with increased variety - and a corresponding decrease in price.

The use of the Cobb-Douglas utility function, or the log formulation thereof, also contributes to the different conclusions between the two models. This utility function produces constant expenditure share which, with no changes in relative prices, means constant relative quantities. In contrast, the reasoning of Lancaster (1980) is based, in part, on increased consumption of the differentiated good with increasing variety, even at constant relative prices. The attraction of the Cobb-Douglas utility function is its tractability. Perhaps its use here is also "sacrificing some realism to gain tractability".

The Cobb-Douglas utility function represents a separable utility function over various groups of goods, in this case differentiated and undifferentiated goods. Innovation, represented by an increase in the number of varieties of the differentiated good, does not cause any substitution between the two groups. The utility function envisaged by Lancaster (1980), not formally specified, does give substitution away from the undifferentiated good to the differentiated good with increasing variety of the differentiated good.

This substitution can be seen as an efficiency substitution (Lancaster 1966b), where consumers increase their consumption efficiency by obtaining a given set of characteristics from a different set of goods. In the context of innovation, Lancaster (*op. cit.*) argues that the significance of innovative goods is that they provide a more efficient means of acquiring a set of characteristics which previously were obtained from the consumption of non-innovative goods. Consequently, continuing innovation will be accompanied by decreased consumption of non-innovative goods, and increased consumption of innovative goods. It is not too great a step to extend this concept to production efficiency; to argue that the use of innovative producer intermediates and producer durables will enhance production efficiency.

Ultimately it depends on the way in which the effects of product innovation are modelled. The Lancaster "approach to consumer theory" was motivated in part by the perceived need to incorporate "new" goods, those existing and those yet to be invented, into consumer theory. It was an attempt to model a perception of reality, perhaps at the cost of tractability. With this thesis resting more on the results of econometric estimations than on the results of a theoretical model, tractability is less of an issue, and more attention can be paid to capturing elements of reality.

3. Innovation, Differentiation and Growth: The Underlying Logic and Arguments

3.1 Introduction

This thesis develops and examines the proposition that, all else being equal, the higher the proportion of innovative goods in a country's exports, the higher the economic growth rate. The proposed mechanism is as follows. With continuing product innovation there will be an increasing import demand for, and consequently increasing exports of, innovative goods. All else being equal, the higher the innovative good content of a country's exports, the higher the export growth rate, and the higher the GDP growth rate which can be maintained consistent with balanced trade.

This chapter develops and explains this proposition. The concept of innovative goods is further developed, as is the reasoning that expenditure share on innovative goods will increase with continuing product innovation. The relationship between the concepts of differentiated goods and innovative goods is discussed, as is the relationship between trade and economic growth.

The organization of this chapter is as follows. Differentiated goods are discussed first (3.2), followed by innovative goods (3.3), and the relationship between the two in (3.4). A discussion on the role of innovative goods in the economy follows, together with an explanation for the proposed growth in import demand for such goods (3.5). Section (3.6) develops a model of trade in differentiated goods. This is followed by a discussion of the relationship between import and export growth and growth in GDP (3.7). The chapter concludes with some comments on further steps required prior to empirical evaluation (3.8).

3.2 Differentiated Goods

The adjective "differentiated" is the past participle of the verb "to differentiate", the meaning of which is "To observe, note or ascertain the difference in or between; to discriminate between, distinguish." (*OED*). A group of goods is differentiated if the consumer can differentiate between the individual goods produced by each firm, each unique good being produced by only one firm. A good is a differentiated good if it is produced by only one firm; and can be distinguished from the goods produced by all other firms. This is consistent with the concept of product differentiation developed by Chamberlin (1962). "A general class of product is differentiated if any significant basis exists for distinguishing the goods (or services) of one seller from those of another. Such a basis may be real or fancied, so long as it is of any importance whatever to buyers, and leads to a preference for one variety of the product over another." Chamberlin (1962, p56). In summary, a differentiated good is one which can be distinguished from the product of any other firm and is, therefore, unique to one firm.

The significant characteristic of product differentiation, as Chamberlin (1962, p56) describes it, is that "buyers will be paired with sellers, not by chance and at random (as under pure competition), but according to their preferences.". It is this pairing which motivates trade in differentiated goods - if the seller is in one country and the buyer in another, then international trade ensues. It is this consequence of product differentiation which is used by Krugman (1979) in developing a theory of trade driven by product differentiation. This theory of trade can explain trade between similar countries, as distinct from the theory of trade based on factor proportions, where trade is based on the difference between countries. The key point for this analysis is that the theory of trade based on product differentiation enables some predictions to be made about the pattern of such trade. This will be further developed later in this chapter.

A differentiated product group is one which is comprised of differentiated products. It is, however, necessary to consider what defines the "boundaries" of any given differentiated product group. Chamberlin (1962, p81) suggests that such a group would be comprised of differentiated goods which are "close substitutes for each other". Dixit and Stiglitz (1977) also use substitutability as defining a product group, or sector. Lancaster (1980) takes a more conceptual approach, defining a differentiated product group, or product class, as one in which all goods - existing and potential - possess the same characteristics but in different proportions.

Chamberlin (1962, p81) suggests another definition of a differentiated product group; one not necessarily related to substitutability. "The group contemplated is one which would ordinarily be regarded as composing one imperfectly competitive market: a number of automobile manufacturers, of producers of pots and pans, of magazine publishers, or of retail shoe dealers". An example of a differentiated product group for which the constituent differentiated products are not all bound together by a high level of substitutability might be tyres for passenger motor vehicles. For any one vehicle owner the choice of tyres could be expected to be limited to those which fit the vehicle in question. Amongst all tyres which fit that criterion a high level of substitutability could be expected, but between them and tyres of all other sizes there would be a low level of substitutability. Nevertheless, tyres for passenger motor vehicles would normally be considered a differentiated product group.

It is this definition of a differentiated product group which is most applicable to this analysis. Product differentiation will be determined on the basis of the pattern of observed trade. It will be argued (in 5.3.3 "The Criteria for Aggregation") that the criterion for aggregation of individual products into the trade categories employed in the data set to be used in this analysis conforms to this definition of a differentiated product group. The observed pattern of trade will be used to distinguish those categories for which trade is driven by product differentiation from those for which trade has a different motivation. Taking the previous example of tyres, most, if not all, manufacturers would produce tyres of all demanded sizes. It could not seriously be argued that trade would be motivated by each manufacturer specializing in just one tyre size, or that the production of different sizes involved different factor proportions, rather than that trade would be motivated by different consumers preferences for different brands.

Rather than differentiated products within product groups, some authors (for example Helpman, 1987; Grossman and Helpman, 1991c) speak of varieties of the one differentiated good. This terminology seems to have become more popular with the use of the Dixit and Stiglitz (1977) CES utility function, sometimes referred to as the "love of variety" utility function. But the two sets of terminology are effectively interchangeable; differentiated products within a product group, or varieties of a differentiated product.

3.3 *Innovative Goods*

The adjective "innovative" is formed from the verb "innovate" and, consequently, the meaning of the adjective is to be found in the meaning of the verb. The verb has its root in the Latin *innovare*, meaning "to renew, alter", which, in turn, is formed from the verb *novare*, meaning "to make new, change" (*OED*). The contemporary meaning attaching to "innovate" is more in keeping with that of *novare* than that of *innovare*. The *OED* lists the following meanings:

1. *trans*. To change (a thing) into something new: to alter; to renew (*obsolete*, rare after 1750).
2. *trans*. To bring in (something new) the first time; to introduce as new (*obsolete* except in Commercial use).
3. *intr*. To bring in or introduce novelties; to make changes in something established; to introduce innovations.

The only contemporary use of the verb in its transitive form is that described in (2), as used only in commerce, and it is that use which is applicable here.

The *OED* gives the meaning of the adjective innovative as "Having the character or quality of innovating". The full meaning of the adjective in any given use will depend on the form of the verb implied by the context. The expression "innovative good" is more likely to refer to a good which has been innovated than to a good which innovates. Similarly, the expression "innovative person" is more likely to describe a person who innovates than one who is the result of innovation. The literal definition of "innovation" given above (from the *OED*) might seem more applicable to the intransitive rather than the transitive form of the verb. However it is not immediately apparent that one could read into this that the word should only be used in this sense. This definition might be coloured by the fact that the transitive use of the verb is limited, and rare in everyday use. Some dictionaries list only the intransitive form of the verb.

Any confusion could be avoided by using the adjective "innovated" when referring to the object of "innovate" when that verb is used in the transitive form. As "innovated" is the past participle of "innovate", it can apply only to the transitive form. Were this adjective to be used, then in the phrase "firm A innovates product B", A could be described as an innovative firm and B as an innovated good. The problem with using the word "innovated" is that its use is rare. The only *OED* examples refer to "the innovated Idolatry and Superstition" and the "innovated world". Neither of these examples seem applicable to the use in commerce contemplated in meaning (2) but, rather, appear to be applicable to meaning (1), which is now obsolete. *The Shorter OED* does not include "innovated". The electronic data base of economics publication, *Econlit,* includes only two articles containing the terms "innovated good(s)/product(s)" over the period 1969 to April 2001. Over the same period there are eighteen instances of the terms "innovative good(s)/product(s)". In both cases, all articles were from 1990 onwards. It would, therefore, appear that the word innovative is used more frequently in the economics literature than is innovated. It could be argued that the use of "innovated" would be less ambiguous, but there is no clear authority for the use of that adjective with this meaning. The only authoritative examples of the use of the word "innovated" appears to be based upon a now obsolete meaning of "innovate". The decision therefore, on balance, is to use "innovative" rather than "innovated". Over the same time period (1969-2001), the expression "product innovation" is found in 183 articles, of which 137 are from 1990 onwards. The question of whether to call the end result of product innovation an innovative or innovated good would seem to have been avoided by some authors.

The *OED* gives the meaning of the word innovation, in commercial use, as "The action of introducing a new product into the market; a product newly brought on to the market". As this is quite consistent with the relevant meaning of the word innovate, as in (2) above, further insight into the meaning of innovative, as in "innovative good", can be had by considering the meanings of the word "innovation". The example given by the *OED* for this meaning of the word is "innovation is bringing of an invention into widespread, practical use". Further meanings of "innovation", from other sources, are as follows.

1. "The application of an invention to a process of production or the introduction of a new product". (Rutherford, 1992, p226).
2. "process of applying new ideas and technology. It is the first-time application of new knowledge or a new technique, e.g., the introduction of a new production process". (Stanton and Lander, 1998, p58).
3. "The introduction of something new - either new goods and services or new ways of producing them. Innovation differs from invention in one essential respect; an invention is the discovery of something new, whereas an innovation is the actual introduction or application of something new". (Greenwald, 1983, p237).

4. "Often used as an alternative to 'inventions' and is used to cover both technological advances in production processes as well as the introduction of different ATTRIBUTES and attribute combinations in marketable products. In the latter context innovation is a source of PRODUCT DIFFERENTIATION and is used by producers to create DEMAND and enhance MARKET SHARE (Pearce, 1992, p207). (upper case in original).

Some of these descriptions include innovation in the senses of both process and product differentiation. This thesis is concerned with innovative goods and, hence, only with product innovation.

The word "invention" appears frequently in these meanings; some times to draw the distinction between "invention" and "innovation", but in the sense that the two are closely related. Schmookler (1969) appears to use the word "inventive" rather than "innovative". For example, "We can define 'invention' simply as a prescription for a producible product or operable process so new as not to have been 'obvious to one skilled in the art' at the time the idea was put forward, or we can add to the requirement of novelty the additional one of *prospective utility.*" (*ibid.* p6) (author's italics). There is also a chapter titled "The Role of Demand in Consumer Goods Inventions". The meaning of "invent" provided by the *OED* which is most relevant is "To find out in the way of original contrivance; to create, produce or construct by original thought or ingenuity; to devise first, originate (a new method of action, kind of instrument, etc.).". This can be further developed by considering one of the requirements for patentability, the demonstration of an "inventive step". "The invention must not simply be something which has not previously existed, but it must owe its existence to the exercise of a creative thought process". (Phillips and Firth, 1990, p44), and, with specific reference to the UK Patents Act (1977), "an invention shall be taken to involve an inventive step if 'it is not obvious to a person skilled in the art'". Note that while a patentable product would be an innovative product, it is not being suggested that all innovative products are patentable.

The words and terms from the above which best apply to the use of the word "innovative", as used here in the term "innovative goods", are: "something new", "first devised", "original thought", "creative thought", "not obvious" and "different attributes and attribute combinations in marketable products". An innovative good is one which embodies these characteristics. Any good exhibiting these characteristics would be expected to be differentiated from all previously available goods, but the term "differentiated good", as commonly employed, does not necessarily carry with it the connotation of "innovative good".

The discussion relating innovation to invention might give the impression that the new characteristics of combination of characteristics are an intrinsic part of the innovative good - that is, can be seen or objectively measured in that good. This need not necessarily be the case. The essential point is that the consumer derives these characteristics from consumption of the good. One example of this is the characteristics associated with, in the mind of the consumer, a brand or brand image. This was nicely summarized in a recent article in the popular press[1]. It was suggested that up to the 1960s, advertising was along the lines of "my brand is better than yours because" . . . Advertising then developed into "my brand is better than yours because" . . .and it will give you a nice warm feeling" and, subsequently, into "my brand is better than yours because" . . .and it will give you a nice warm feeling and will give you something rewarding to believe in.". To which, it is suggested, could be added characteristics such as feelings of passion, excellence, achievement, or success. These additional characteristics result not from the product itself but from the association, in the mind of the consumer, of these characteristics with the product. This association is brought about by advertising, sponsorship, or some other form of marketing activity. Nevertheless the end result is much the same; the consumer acquires these characteristics through consumption of the good. The process of adding these characteristics is innovation, and the result is an innovative good. The attributes of such an innovative good are much the same as those described above.

The objective in producing an innovative good is an economic one. The production of an innovative product requires product innovation, and product innovation incurs a sunk cost. Firms will incur this sunk cost only if they expect that, at the very least, it will be recovered. In other words, there must be an economic incentive. Schmookler (1969, p199) argues that the "stimulus for inventions" (innovations) is "..the recognition of a costly problem to be solved or a potentially profitable opportunity to

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[1] *The Australian Financial Review* 27th July 2001 pp10-11. A review, by M. Milgate, of *No Logo*, by N. Klein.

be seized; in short, a technical problem or opportunity evaluated in economic terms". The sunk cost of innovation can only be covered by the excess of revenue over production costs. Taking, for the sake of simplicity, production costs as given, the maximum value of revenue over production costs is determined by the demand curve for the innovative product[2]. This demand curve is not a given; it depends, *inter alia*, on the characteristics embodied in the innovative good which, in turn, depend on the results of the process of innovation. The objective of a profit maximizing firm will be to embody those characteristics which will, for any given level of expenditure on innovation, produce a demand curve such that the excess of revenue over production costs, at optimum price, is maximized. Because the innovative good is a new good, the revenue from its sale can come only from an expenditure switch from previously existing goods. Innovating firms will be aware of this, and therefore will direct the process of innovation towards producing a good which will achieve an expenditure shift of sufficient magnitude. If any part of this expenditure switch comes from goods which would not be considered innovative, then the result will be an increased expenditure share on innovative goods. This is further developed in (3.4). These arguments are not inherent in the concept of differentiated goods, as generally understood.

It should be noted that any good which is, at some time, considered innovative, need not necessarily and, in all probability will not, remain so indefinitely. What was once "new" will not always be so. There is no one clear criterion by which a once innovative good loses that status. The elapse of sufficient time such that the good becomes "obvious to a person skilled in the art" might be one way, and the innovation of a new good which is in every way superior another. As an example, the original typewriter, when it first became available, might well have been considered an innovative good. Even had there been no further development since then, it is unlikely that it would now be considered so. However, the first typewriter was made obsolete by a number of innovations, including the electric typewriter and the golf-ball typewriter. Subsequently, the typewriter has been largely made obsolete by the word-processor which was, at one time at least, an innovative good.

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[2] This requires that the firm has some monopoly power over the product, and faces a downwards sloping demand curve. This is a property of product differentiation (one firm per unique good). This aspect is dealt with in 3.4.2.

3.4 *Innovative and Differentiated Goods*

The purpose of this section is to clarify the relationship between innovative goods and differentiated goods. It will be argued that innovative goods are differentiated goods, and that differentiated goods are expected to be innovative goods. This being the case, the distinction might, at first sight, appear inconsequential. There is, however, a valid reason for making the distinction. If it can be argued that innovative goods are differentiated goods, then aspects of existing theory relating to differentiated goods can be applied to innovative goods. Of particular significance is the theory of trade driven by product differentiation. At the same time, the argument, that with ongoing product innovation there will be an increasing expenditure share on innovative goods, cannot be attributed to the property of product differentiation. There is nothing in the concept of product differentiation, as generally understood, that could suggest an increasing share of expenditure over time on differentiated goods, all else remaining constant. While the increasing expenditure share argument relies on the concept of innovative goods, the predicted pattern of trade in innovative goods is based on the concept of product differentiation and the relevant existing theory.

3.4.1 Innovative and Differentiated - The Distinction

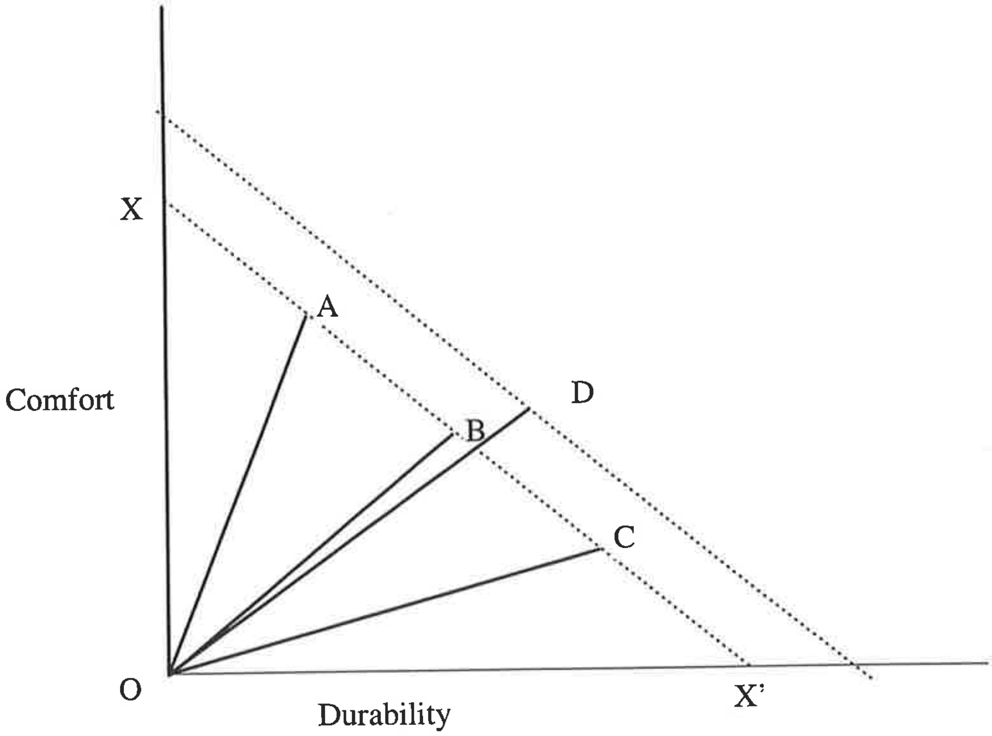
The development of the concept of product differentiation was based on the observation that product differentiation did exist, and could be observed to exist at any point in time. Product differentiation is therefore essentially a static phenomenon, or at least has no need to be more than that. On the other hand, the concept of product innovation is a dynamic one. It is based on the observation that, for example, the set of goods available now differs from that of fifty years ago which, in turn, varies from that of a hundred years ago. Further, that firms fifty years ago would have been unable to produce many of the goods which are available today. The process by which firms have acquired the ability to produce these goods is referred to as product innovation. The effects of product innovation are dynamic, and can be observed only over time. Analyses based on product differentiation are concerned with static effects, and those based on product innovation with dynamic effects. In this thesis both play a part. Product differentiation is used to predict patterns of trade, including intra-industry trade, while innovation is used to predict the dynamic effects which provide the primary focus of this thesis.

The concept of product differentiation was used by Chamberlin (1962) in the development of the model of monopolistic competition. It was based on the empirical observation that differentiation existed, be it on the basis of brand name, seller location, or whatever. "A general class of product is differentiated if any significant basis exists for distinguishing the goods (or services) of one seller from those of another." (Chamberlin, 1962, p56). This concept of product differentiation was used to argue for a "middle ground" (*op. cit.,* p5) between the theory of pure competition and that of monopoly. This theory of monopolistic competition predicts, *inter alia*, an equilibrium with prices greater than marginal cost, and the number of firms determined by a zero-profit equilibrium. These are all static concepts. These aspects of monopolistic competition were used by Krugman (1979a) in developing a theory of trade driven by product differentiation. This theory operates within the framework of comparative statics - comparing before and after trade.

Analyses dealing with differentiated product groups require only that the product of each firm be distinguishable from that of all others, and differentiation is presented within as simple a framework as will achieve this end. To have introduced the dynamic concept of innovation into such analyses would have achieved nothing other than unnecessary complication. One such simplifying element was to envisage a "fixed spectrum" of possible varieties within a differentiated product group. Salop (1979) does this by representing varieties as distributed around the circumference of a circle which represents the differentiated product group. Lancaster (1980) considers all varieties within a differentiated product group to contain the same characteristics, but in different proportions. An example of the latter might be shoes, with the two characteristics being durability and comfort. In keeping with the requirement that "no product dominates any other" (Lancaster, 1980, p153), it could be assumed that a higher content of one characteristic could be achieved only with a lower content of the other. The choice of variety, for any firm, is confined to this predetermined product range. An additional variety is "new" only in the sense that it was not previously produced. Any firm could have done so, simply by selecting that variety rather than some other. All varieties within the spectrum are equally capable of being produced; it is just that, with economies of scale, not every possible variety will be produced, and so some are while others are not.

Innovation is not a simple matter of selecting a variety from an existing range. In addition to producing something new, the process of innovation is regarded as including an inventive, or creative, component. This meaning of innovative is not inconsistent with that attaching to it in contemporary usage, and has been discussed in some detail in (3.3). The word inventive might have been used rather than innovative, but for some the word invention is associated with a specific group of goods, whereas the concept of innovation is, as commonly understood, more broadly applicable. As previously discussed, Schmookler (1969) does use the word inventive. However, much of the empirical data presented is based on patent statistics, so it seems likely that he did have a narrower view than that being contemplated here. The inventive aspect is significant because the result of innovation is not confined to a variety within an existing product spectrum. The process of innovation can lead to a firm being able to produce a good which no firm has been previously capable of producing. Schmookler (1969, p188), with specific reference to Lancaster (1966b), argues that "consumer goods inventions can be thought of as changing the quantities of given characteristics, adding or subtracting characteristics, or changing the cost at which a given collection of characteristics obtained". Developing the previous example of shoes, the result of innovation might be a shoe that contains a higher content of both characteristics in combination than any variety previously available or capable of being produced. This is illustrated in Diagram 3.1, which is a minor variation on that presented by Lancaster (1966b).

Diagram 3.1. Product Characteristics and Product Differentiation



The line XX′ shows the previously existing "characteristics frontier". The existing varieties A, B and C lie on this frontier. In the absence of innovation any additional varieties would also lie on this frontier. As a result of innovation shoe D is produced, containing more of both characteristics than shoe B. However, shoe D contains less of the comfort characteristic than does A and less of the durability characteristic than does C. It does not necessarily follow therefore, as has been suggested, that shoe D will be the only shoe purchased and that innovation reduces rather than increases variety. Given widely distributed consumer preferences it is expected that shoes A and C would still be purchased - and it should be realized that consumers will have a different "ideal variety" for different occasions. Whether or not shoe B continued to be purchased might depend on the relative prices of B and D. In any event, it would be expected that further innovation would produce additional varieties lying beyond what was the "characteristics frontier", XX′. Any thought that innovation in footwear leads to reduced variety would be dispelled by observing the stock in, for example, a casual/sporting footwear shop.

Staying with the shoe example, innovation need not be limited to more of existing characteristics. It might be the development of additional characteristics; for example, status or image. One supervisor is inclined to stretch this example, arguing that "if square and round toes are both ‘in’ this year there will be more product differentiation than last year when only square toes were sold, but this is scarcely innovation". This is not the place to discuss the intricacies of the fashion industry. However it should be apparent that what is "in" or "out" is not exogenous - it is not a given. Rather, it relies on some firm being aware that a particular style will appeal to consumers at this time; or by persuading consumers, through advertising or whatever, of the desirability of characteristics associated with a particular style at that time. There is no reason why such activity should not be considered innovation. Firms within the fashion industry who simply pick this year's style out of a hat would not last very long.

The theory of monopolistic competition, based on product differentiation arising from costless differentiation, gives an equilibrium number of varieties in any product group determined by the zero-profit equilibrium. When this point is reached there is no further differentiation. With constant production costs, the number of varieties can increase only as a result of increased income or market size. There is no such constraint on product innovation, which will continue for as long as there is "...a potentially profitable opportunity to be seized...." (Schmookler, 1966, p199). The knowledge gained from previous product innovations might contribute to this, as might the results of purely scientific research, and of greater knowledge of the characteristics from which consumers derive utility. While product differentiation for its own sake is static in equilibrium, product innovation can be expected to be ongoing.

Grossman and Helpman (1991c) use the terms "innovative" and "differentiated" for similar purposes to those here, and make similar distinctions between the two. While the focus of their analysis is product innovation, the characteristics of product differentiation are used to predict the pattern of trade. "...our model predicts the practice of *intraindustry trade,* with firms in each country exporting the unique brands that they have developed. The basis for this type of trade is the same here as in the static models with differentiated products..." (authors' italics). "In the static models the fixed costs are a component of total production costs, whereas here they take the form of up-front research outlays. In either event each partner to trade will have an incentive to import the unique varieties produced abroad rather than incur a second fixed cost to produce these goods locally." (Grossman and Helpman, 1991c, p187).

The argument, that there will be a continually increasing expenditure share on innovative goods, requires the ongoing nature of innovation. The increased expenditure share requires the inventive nature of innovation - that an innovative good will represent a more cost effective manner of acquiring a bundle of characteristics than was previously the case, or may provide one or a number of characteristics not previously available. This is further developed in Section 3.5.

3.4.2 Innovation Leads to Differentiation

For an innovative good to be considered a differentiated good requires only that the variety of the good produced by one firm be distinguishable from that produced by all others. This, as discussed in Section 3.2, is the defining characteristic of a differentiated good. Firms invest in innovation in anticipation of being able to, at least, recover the cost of innovation. This requires that the revenue from the sale of the product exceeds the cost of production, which in turn requires some degree of monopoly power. Such monopoly power will not be present if other firms are able to "free ride" by imitating. Consequently, firms will not innovate unless they can have exclusive ownership of the results. This is the economic justification for intellectual property rights, which represent one mechanism by which the one firm per product relationship can be maintained. Grossman and Helpman (1991c, p43) employ similar reasoning in arguing for the firm specificity of innovative goods. "Entrepreneurs invest resources in order to develop unique goods. .... Product designs are assumed to be proprietary information, either because their details can be kept secret or because patents effectively deter unauthorized users. Each new product substitutes imperfectly for existing brands, and innovators exploit limited monopoly power in the product market.".

3.4.3 Differentiation Requires Innovation

It having been established that innovative goods are differentiated goods, it remains to consider the converse. The requirement for the converse to hold is that there be no differentiation without innovation. Differentiation without some form of deliberate process of innovation implies a random process, without any conscious decision on the part of the firm, and would fit with the example of costless differentiation given earlier in this section. It portrays a collection of firms, each of which, although producing a unique product (or variety), is passive, taking its demand curve as given. Each of these firms, though assumed to be profit maximizing, is unwilling, or unable, to take any action designed to alter the demand curve in such a way as to increase profits. Product differentiation, in the absence of innovation, means a static product group. Once equilibrium is reached new varieties arise only from an increase in market size or increased income.

Differentiation without innovation is possible in several ways. One is that the ultimate product within the group has already been developed, and cannot be improved upon. This does not seem likely. Another, less improbable, is that the entire product group has been superseded by a quantum technological advancement - for example, the replacement of mechanical calculators with the electronic version. In this case the superseded product group would soon become "extinct", and any existence as a differentiated product group, but one in which innovation is no longer taking place, would be transitory. One source of differentiation which arguably does not require innovation is differentiation by location. But this is, for the most part, discussed as location within a confined area, and would not be expected to contribute to international trade.

In summary, it has been argued that the process of innovation gives rise to goods which are both innovative and differentiated, and consequently it can be expected that the pattern of trade in innovative goods will be that which is expected for differentiated goods. It has also been argued that those goods which trade as differentiated goods can be expected to be innovative goods.

3.4.4 Penicillin

It has been suggested, by one original examiner, that the substitutes for an innovative good should be considered. Penicillin is one example given. The implication is that, in the absence of substitutes, innovative goods might not be differentiated: that there is just the one innovative good which displaces all previously available alternatives and, consequently, trade in such a good would be along the lines of a modified product cycle theory, and there would be no intra-industry trade. It is then suggested that, were this to be the case, measured intra-industry trade would not be a useful proxy for innovative goods. This argument has been endorsed by one supervisor, who interprets it as suggesting that innovation reduces, rather than creates, product differentiation. He then further suggests that the example of penicillin be considered. This section (3.4.4) is a response to these suggestions.

The development of penicillin as a treatment for bacterial infections is summarized in 3.4.4.1, and it is shown that the development of penicillin was not confined to any one firm or any one country, and consequently that the product cycle theory does not apply. The first penicillin is a naturally occurring substance, whose antibacterial properties had been observed well before its use. The recognition of its potential for the treatment of bacterial infections was the earliest contribution of "creative thought" to its development. Innovation by firms was confined to overcoming difficulties in the production of penicillin. Section (3.4.4.2) describes the substitutes for penicillin before, during, and after its introduction. It shows that innovation has increased, rather than decreased, the variety of individual products available for the treatment of bacterial infections. The other requirement for trade driven by product differentiation - the ownership of each individual product by a single firm - is discussed in Section (3.4.4.3). It is shown that the mechanism to achieve this exists, and is widely used.

3.4.4.1 The Development of Penicillin

Fleming is generally credited with being the first to observe the activity of penicillin, in 1928. In September of that year Fleming observed a contaminating colony, obviously a mould, on a plate growing a strain of staphylococci. The more interesting observation was that the staphylococcus colonies in the vicinity of the contaminating colony were transparent in appearance, suggesting that these colonies were being either lysed or dissolved. Details of these observations were published in 1929 (Hobby, 1985, p8). The phenomenon which Fleming had observed, known at that time as antibiosis, had previously been observed by a number of other scientists, including Lister (1871), Roberts (1874), Tyndall (1876), and Pasteur and Joubert (1877) (Stewart, 1965, p4). Hobby (1985, p4) credits Duchesne (1896) and Gratia (1925) with similar observations.

Fleming, realizing the importance of his observation, sub-cultured the contaminant mould. He tested a number of other strains of fungi, including that of *Penicillium*, for similar antibiotic action. The only one which produced a substance with bacteriocidal activity was originally identified as *Penicillium rubrum*, and subsequently correctly identified as *Penicillium notatum*. Fleming studied the bacteriocidal activity, and noted that there was activity against both gram-positive and gram-negative[3] cocci, but no activity against gram-negative bacilli (Stewart, 1965, p5). The first recorded use of the word penicillin was in March 1929, and originally referred to the culture fluids in which the mould was grown. It was subsequently used to describe the antimicrobial substance contained in the culture fluids, and now refers to a group of substances having microbial activity, and derived from metabolic products of *Penicillium notatum* and *Penicillium chrysogenum* (Hobby, 1985, p10).

Fleming made some attempts to purify penicillin, but these were unsuccessful. Little further progress was made over the next ten years. Very little interest was exhibited by medical researchers in the potential of penicillin to treat bacterial infections. This has been attributed, in part at least, to a belief, wide-spread at the time, that chemotherapy was not viable in the treatment of bacterial infections, even though there was already some limited use of chemotherapy for this purpose (Stewart, 1965, p6).

The next major step in the development of penicillin is credited to Florey and Chain, in 1939 and 1940. They were able to increase the growth rate of *Penicillium notatum* and increase the yield of penicillin. In early 1940 they extracted from the culture medium a powder which demonstrated anti-bacterial properties at high rates of dilution. It was also shown to be non-toxic when injected into animals. In May 1940 Chain carried out a controlled trial with penicillin on deliberately lethally infected mice. The results were positive and reported in *Lancet* on August 24th 1940 (Kingston, 2000, p6). Attention was now turned to producing sufficient material for a trial on a human subject. By early 1941 it was considered that this had been achieved and the first clinical trial commenced on 12th February 1941. The administration of penicillin arrested the infection, but after five days the available supply of penicillin was exhausted, the infection continued its course, and the patient died (Stewart, 1965, p10).

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[3] The terms "gram positive" and "gram negative" refer to the affect of gram staining - a widely used technique for classifying bacteria. As the result of gram staining depends on the structure of the cell wall, and the action of penicillin is to inhibit the synthesis of the bacterial cell wall, the correlation between the results of gram staining and the effect of penicillin is not a spurious one.

Within the next few weeks there was enough penicillin produced for the treatment of another five patients, four of them being children who had not responded to sulphonamides. The results were positive, and reported in *Lancet* in August 1941. The major difficulty in further developing these trials was the production of sufficient penicillin. Using the techniques then employed, 2000 litres of fermentation medium was required for the production of sufficient penicillin to treat one person, and this was exacerbated by the limitation that, at that time, *Penicillium notatum* could be grown only as a surface mould. With Britain now being at war, and resources severely limited, Florey concluded that the only viable approach was to enlist the aid of one or a number of US firms (Stewart, 1965, p11).

In the second half of 1941, Florey had discussions with a number of US pharmaceutical firms, amongst whom interest in penicillin had gradually spread. In October, the Committee on Medical Research agreed that penicillin production should be given priority, and, in December 1941, it was agreed that all information arising from research into the production of penicillin in both government and commercial laboratories should be shared, through that committee. During this period small scale production continued at Oxford, with the cooperation of Imperial Chemical Industries Ltd. and Kemball, Bishop and Co. Ltd. By January 1942 there was sufficient material available for trials on almost 200 patients. In this month the National Research Council set up a committee to coordinate further penicillin trials in the US, and in September the General Penicillin Committee was established in Britain to organize and coordinate further trials. It was decided, in both Britain and the US, that the armed forces should be given priority in the supply of penicillin (Stewart, 1965, pp 12-13).

The 1940 *Lancet* publication of Florey and Chain had aroused some interest in the US, and a number of workers set about preparing penicillin. Various trials commenced in October 1941, and the first paper on the results with penicillin were presented to the American Society for Clinical Investigation on May 5th 1941. These results were immediately reported in the popular press, and considerable interest in the potential benefits of penicillin thereby aroused (Hobby, 1985, pp 69-73).

Up to mid 1943, almost all penicillin production in the US was undertaken by five firms: Merck and Co., E.R. Squibb and Sons, Chas Pfizer and Co., Winthrop

Laboratories, and Abbott Laboratories. By May of that year it had been agreed that the production of penicillin needed to be increased, and responsibility for this was given to the War Production Board. A target of 200 billion units of penicillin per month was set. Over the next seven months an additional seventeen firms were given priority for materials used in the preparation of penicillin (Hobby 1985, p171). In April 1944 there was limited distribution of penicillin to 1000 civilian hospitals; this number subsequently being increased to 2700. By March 1945, the production level of penicillin was sufficient to permit hospitals to purchase penicillin through distribution channels (Hobby, 1985, p195). The monthly penicillin production in the US increased from 21 billion units in 1943 to 700 billion units in December 1945 (Hobby, 1985, Table 9.2).

By late 1941 there were five firms in the UK working on penicillin production: ICI, Burroughs Wellcome and Co., Boots Pure Drug Co., British Drug Houses and Glaxo Laboratories. In January 1942 the Therapeutic Research Corporation of Great Britain was formed, with the intent of coordinating research and sharing the results for a number of projects, with penicillin soon becoming first priority. It was comprised of the latter four of the above five firms, plus May and Baker - a firm active in the production of various sulphonamides.

ICI had produced a crude extract of penicillin by October 1942, and established a pilot plant. It was the first commercial enterprise in the UK to produce penicillin, and one of the first four in the world (Hobby, 1985, p127). By December 1942, Glaxo had one production unit operating, and a second by February 1943. Glaxo's penicillin production for the year 1943 was 2,570 million units, out of a total UK production of 3,500 million units. Glaxo was to remain the dominant UK supplier for the remainder of the war (Hobby, 1985, p131). By November 1945, large scale production units had been or were being completed in nine different locations under the control of seven different organizations. UK production of penicillin increased from 25-30 million units per week in March of 1943 to 25-30 billion units per week in 1945-46 (Hobby, 1985, pp 139-140). Until 1946 all penicillin distribution in the UK was controlled by the government (Hobby, 1985, p131).

During the period 1940-1945 penicillin production had been attempted in a number of other countries. In Germany, Hoechst had begun research on penicillin in 1942, and by 1944 was producing sufficient quantity for use in a limited number of cases. The production expansion planned at the beginning of 1945 was temporarily disrupted several months later when the plant was occupied by US forces. The plant was reopened the following month, and by the end of the year was producing 30 million units per month (Hobby, 1985, p208). In Austria, Biochemie GmbH commenced penicillin production in 1948 (Hobby, 1985, p207).

In France, the pharmaceutical firm Rhône-Poulenc and the Pasteur Institute began research on penicillin production in early 1943, and small amounts were being produced by the end of that year. The liberation of Paris facilitated production, and by July 1945 production had reached 300 million units per month (Hobby, 1985, pp 204-6). In Holland, two companies attempted penicillin production during the period 1940-45. The two eventually merged to become Gist-Brocades N.V., and commenced small scale production by August 1944. After liberation, this company was able to enhance its production technology, and by 1949 was able to commence exports of penicillin (Hobby, 1985, pp203-4). In Japan, research on penicillin production commenced in early 1944, and production by the Banyu Pharmaceutical Company commenced in January 1945 (Hobby, 1985, pp209-10). In Canada, interest in penicillin production was stimulated by Florey's visit in mid 1941. Work was commenced by Connaught Laboratories, with financial assistance from the Canadian Government. In October 1943 it was requested that this company be included in the information sharing arrangement amongst seventeen US companies, as established by the US War Production Board. By December 1945 three companies were producing 20 billion units per month, sufficient for the needs of Canada (Hobby, 1985, pp210-11). Production in Australia by a government owned firm had commenced in 1944, and was producing 10 billion units per month by the end of 1945.

Penicillin became generally available in most countries in the period 1945 to 1950. In some countries it was sold over the counter in the form of lozenges, nasal ointments and skin creams. Even where its use was restricted, it was frequently prescribed for topical use on cutaneous infections. This wide spread use contributed to the development of sensitivity to penicillin in some individuals, and to the emergence of penicillin resistant strains of bacteria (Stewart, 1965, p20).

The major challenge in the development of penicillin was that of production. Work on this was undertaken by a large number of firms, in a number of countries. Well before this work commenced, the antibiotic effects of penicillin had been observed and reported by a number of researchers. Fleming's work, which was arguably the first serious study of the antibiotic effects of penicillins, was published and therefore in the public domain. The development of penicillin occurred under unusual circumstances; those of World War II. While these circumstances increased the impetus for the clinical use of penicillin, in some countries they made the development of penicillin more difficult.

3.4.4.2 Penicillin Substitutes and Product Variety

Given that penicillin became generally available in the period 1945 to 1950, the consideration of the substitutes will, in the first instance, concentrate on the substitutes that were already available at that time. Penicillin was, and still is, used in the treatment of bacterial infections. Accordingly, any available alternative for treating bacterial infections can be considered a member of the same differentiated product group. The following discussion includes references to antibiotics which are efficacious in the treatment of some bacterial infections against which penicillin was, and is, ineffective. It might, therefore, be argued that they were not strictly substitutes, in the usually accepted meaning of the word. Nevertheless, as discussed in 3.2, they would all belong to the differentiated product group known as "antibiotics".

At the time of Fleming's initial observations in 1928, antiseptics and immunization were the two major means of combating bacterial infections. Both of these had their origins in the work of Pasteur in the 1860s. The use of antiseptics developed from tests of the use of carbolic acid as an antiseptic, reported in *Lancet* in 1867. The effectiveness of vaccines had been demonstrated by Pasteur against rabies, and by the end of the nineteenth century was being employed to combat typhoid and diphtheria (Kingston, 2000). The use of both of these measures was largely preventative. Although antiseptics were being used for the treatment of surface infections, their use against existing bacterial infections were limited by the non-specificity of antiseptic activity. Whether or not a preventative measure can be considered a substitute for a cure is a matter for judgement. It could be argued that the best way to deal with bacterial infections is to prevent them occurring but, once an infection exists, only treatments for that infection can be considered alternatives to penicillin.

The earliest acknowledged use of chemotherapy in the treatment of bacterial infection was salvarsan and, subsequently, neosalvarsan - a more soluble derivative of salvarsan. The synthesis of salvarsan was reported by Ehrlich and Bertheim in 1912, and neosalvarsan was developed by Ehrlich in the same year. Greenwood (1995, p93) describes salvarsan as "...the first really efficacious antibacterial agent, although its activity was restricted to spirochaetes, which are scarcely typical bacteria." Both of these were being used in the treatment of syphilis before the commencement of Word War I (Hobby, 1985, pp25, 30). Syphilis was one of the diseases subsequently treated with penicillin, and consequently these two drugs can be considered to be substitutes for penicillin in the treatment of this disease at, and well before, the time at which penicillin became available.

The sulphonamides were the next development in the use of chemotherapy in the treatment of bacterial infections. The contribution of this group of drugs to the treatment of bacterial infections, well before the use of penicillin, is summarized in the following lines from the preface to Long and Bliss (1939); both authors at that time being at The School of Medicine of The Johns Hopkins University.

"Six years have passed since Foerster reported upon the use of Prontosil in the treatment of a child ill with staphylococcal sepsis. In the intervening period we have witnessed the conquering of streptococcal, meningococcal, gonococcal, pneumococcal, and many other types of infections by means of chemotherapy, and we have seen the development of clinical application of numbers of new sulfonamide-containing drugs.

While the period has been brief it has been called ' epochal in the history of medicine.' The volume of reports upon the various aspects of the new bacterial chemotherapy is already enormous and it is ever increasing". .... (February 14th, 1939).

The first step in the development of the sulphonamide group of drugs is credited to Domagk, of the Bayer component of I.G. Farbenindustrie, in 1932 (Greenwood, 1995, p4). Motivated by previous observations by various workers that a number of azo dyes exhibited bacteriostatic properties, Domagk was involved in a large scale *in vivo* evaluation of the bacteriostatic properties of a number of sulphonamide containing azo dyes, and observed that 4′-sulphonamido-2,4 diamino-azobenzene prevented the development of what would normally be a fatal injected infection in mice (Hobby, 1985, p32). This compound was subsequently known as prontosil. The first clinical use of prontosil was by Foerster and reported to the Düssledorf dermatological society on 17th May 1933 (Long and Bliss, 1933, p1).

In 1935, workers at the Pasteur Institute suggested that prontosil was broken down *in vivo* to para amino benzene sulphonamide. This compound was subsequently shown to be the active component of prontosil, and subsequently became known as sulphanilamide (Long and Bliss, 1939, p5). In France, the sulphonamides having the trade names Septazine, Soluseptazine, Rubaziol I (Prontosil), II, III, and IV were being produced and marketed by 1935. In May of 1938, L.E.H. Whitby of London announced that sulphapyridine was more effective than sulphanilamide in the treatment of experimental pneumococcal infections, an observation which subsequently received clinical confirmation. There were absorption problems observed with sulphapyridine, and in response a sodium compound of sulphapyridine which could be administered intravenously was produced (Spink, 1941, p16).

Sulphathiazole was patented by Landon and Sjögren in Sweden in 1939. In 1940 a group at Johns Hopkins announced the synthesis of a new derivative of sulphanilamide, known as sulphanilylguanidine (or sulphaguanidine), which was successful in the treatment of bacillary dysentery. Poth and Knotts, from the same institution, reported similar activity for succinlysulpathiazole (sulphasuxidine). In the same year the American Cyanamid Company reported the synthesis of sulphadiazine and its sodium salt. This compound was subsequently demonstrated to have some therapeutic advantages over some other sulphonamides. In 1941 it was noted that sulphacetimide (sulamyd) had some therapeutic possibilities.

Hobby (1985, p31) notes that in 1943, ten million pounds of sulphonamides were produced in the US alone; estimated to be sufficient for the treatment of more than 100 million patients. May and Baker issued, in the early to mid 1950s, the following sulphonamide based drugs: sulpthiazole, sulphadiazine, sulphamerazine, sulphadimidine, succinylsulphathaziole, phthalylsulphathiazole, sulphasolucin and thiasolucin (May and Baker, 1955, pp7-12). These sulphonamides are differentiated from each other by one or more of the following characteristics: suitability for oral or parenteral administration; rate, uniformity and completeness of absorption from the gastro-intestinal tract; bacteriostatic power; adverse effects on normal intestinal flora; risk of crystalluria; required frequency of administration; time taken for maximum blood level to be reached after administration; distribution between plasma, corpuscles, cerebrospinal fluid, pleuro fluid and abdominal fluid; rate of diffusion; quantitatively different effects on various bacteria (May and Baker, 1955, pp13-20). It is not hard to see in this an example of the Lancaster characteristics, and that the sulphonamides, by themselves, represent a differentiated product group (although not in the one firm per unique product sense, as discussed below). It is also readily apparent that this differentiated product group became available as a result of innovation; that these varieties came about from "...the recognition of a costly problem to be solved..." (Schmookler, 1966, p199), and involved some cost. Each variety was not immediately obvious. Because patents were, at that time, rarely used for pharmaceuticals, there was no "ownership" of each variety by one firm, and consequently there may not have been a high level of intra-industry trade in sulphonamides. However, as discussed below, this has long since ceased to be the case in the pharmaceutical industry, and patents are now heavily used within this industry.

Streptomycin was another substitute for penicillin. It was first isolated in 1943 by Albert Schatz , a Ph.D. student of Selman Waksman. The isolation of this compound arose from a large scale research programme commenced by Waksman in 1939, with funding from Merck, to screen soil based micro-organisms for anti-bacterial activity. (Kingston, 2000). One of the main features of streptomycin was its activity against gram-negative bacilli and, in particular, tuberculosis; thus complementing the antibacterial spectrum of penicillin (Greenwood, 1995, p5). Intensive clinical trials were carried out in 1945, and wide-scale distribution commenced in September of 1946. Production volumes were 1000kg in 1946, 10,000kg in 1947 and 36,000kg in 1948 (Waksman, 1949, pp1-2). Streptomycin was the first of the general group of aminoglycosides to be discovered, and its use has largely, but not entirely, been replaced by other aminoglycosides, including neomycin, paromomycin, kanamycin (A and B), gentamycin, tobramycin, metilmicin, sissomicin, robostamycin, amikacin, dibekacin. As with the sulphonamides, the various aminoglycosides are differentiated, one from another, by a number of characteristics (Greenwood, 1995, pp35-36).

When considering substitutes for penicillin it is pertinent to note that penicillin is not one product, but a group of products. The common structural characteristic is the presence of the β-lactam ring fused to a five-membered thiazolidine ring, with the common phenotypical characteristic being the inhibition of bacterial cell wall synthesis.

The original penicillin preparations were found to contain a mixture of four similar compounds, named penicillin F, G, K and X. All four were biologically similar but, for reasons related to production, it was penicillin G (benzyl penicillin) that was further developed (Hobby, 1985, p220; Greenwood, 1995, p19). As part of the work on increasing the efficiency of penicillin production, it was observed that penicillin production from fermentation was enhanced by adding a precursor to the fermentation medium. Penicillin G production was enhanced by the addition of phenylacetic acid. It was also observed that by adding precursors with different side chains, the final product could be altered (Stewart, 1965, p17). The addition of phenoxyacetic acid as a precursor lead to the production of phenoxymethyl penicillin (penicillin V). Penicillin V is acid stable and suitable for oral administration, whereas penicillin G is not acid stable and therefore requires parenteral administration. This was an important development because the action of penicillin requires a minimum level of concentration over a period of some days, and therefore repeated administrations over that period. Penicillin V became available for general use in 1954 (Hobby, 1985, p228). However penicillin V has a narrower spectrum than penicillin V, and a lower level of intrinsic activity (Stewart, 1965, p19). Both forms are ineffective against most gram negative bacilli. Here again is an example of Lancaster characteristics, and of horizontal differentiation: penicillin V can be administered orally, but penicillin G has a broader spectrum. The preferred form of penicillin will depend on the circumstances. There is no preferred alternative for all circumstances.

One solution to the resistance to penicillin of penicillinase producing bacteria was to produce penicillin derivatives which were not susceptible to one or more penicillinases. The addition of a range of precursors, with various side-chains, to the fermentation medium offered the potential for a wide variety of penicillins to be produced. By 1952 several hundred penicillin derivatives had been produced in this manner, but only one (penicillin V) was of any particular value (Stewart, 1965, p22). It had for some time been considered that the best option for producing derivatives of penicillin was to do so synthetically. The first opportunity to do this came with the identification, isolation and preparation of the "nucleus" of penicillin, 6-amino penicillanic acid (6-APA). Chain, in the mid 1950s while working in Rome, had observed in the fermentation medium a substance which had chemical properties similar to that of penicillin, but less antibacterial activity. This was demonstrated to be 6-APA when, upon acetylation with phenylacetyl chloride, it yielded penicillin V. At Beecham, the potential for the use of this compound in the synthesis of further penicillin derivatives was recognized, and work on the production of 6-APA given top priority in July of 1957. Progress was limited and, with the recognition of a Japanese publication from 1953, attention was switched to the production of 6-APA from preformed penicillins. This approach was facilitated by the discovery of an exocellular amidase produced by *Streptomyces lavendulae* which was able to deacylate 6-APA to penicillin V (Stewart, 1965, pp22-24; Hobby, 1985, p230). The synthesis of 6-APA was announced independently by Sheehan at MIT in 1958 (Schwartzman, 1976, p51). This lead to a patent dispute between the two, which was not finally resolved until 1979 (Sheehan, 1982, pp177-196).

This development enabled the biosysnthesis of a range of penicillin derivatives, a number of which were developed jointly by Beecham and Bristol-Myers. Phenethicillin was jointly marketed from November 1957 (Stewart, 1965, p19). Phenethicillin is acid stable and therefore suitable for oral administration. Its absorption is superior to that of penicillin V. Methecillin, active against penicillinase producing staphylocci, was released in both the UK and US in September 1960. This was followed, in 1961, by propicillin, ampicillin, oxacillin and cloxacillin (Stewart, 1965, pp25-27; Hobby, 1985, pp230-231). Stewart (1965, p30), lists eight acid stable penicillins, and their clinical attributes. Again, these provide an example of differentiation by Lancaster type characteristics. None of these penicillins is superior to any other for all circumstances. From Stewart(1965, 30), Hobby(1985, p217) and Greenwood (1995, pp20-21), the following penicillins may be added to those mentioned above: phenbenicillin, carbenicillin, methicillin, procaine penicillin, benethamine penicillin, benzathine penicillin, pivampicillin, bacampicillin, talampicillin, amoxycillin, hetacillin, metampicillin, mecillinam, pivmecillinam, temocillin, tricarcillin, azlocillin, mexlocillin, piperacillin, apalcillin, carfecillin, carindacillin, naficillin, dicloxacillin, flucloxacillin. It is readily apparent that the penicillins, by themselves, constitute a differentiated product group.

The development of antibiotics during the 1950s was not limited to penicillins, as shown by Table 3.1, which lists US antibiotic production for 1948 and 1956.

Table 3.1. Output of Leading Antibiotics and Percentage of Total Output: 1948 and 1956

	1948		1956	
Antibiotic	Pounds Produced	Percent of Total	Pounds Produced	Percent of Total
Penicillins	155,873	64.9	1,059,704	34.4
Streptomycin	80,737	33.6	148,999	4.8
Dihydrostreptomycin	2,989	1.2	492,173	16.0
Chlortetracycline	661	0.3	560,663	18.2
Oxytetracycline			324,614	10.5
Tetracycline			220,074,	7.1
Chloramphenicol	46		85,408	2.8
Erythromycin			70,913	2.3
All others	26		118,825	3.9
Total	240,332	100.0	3,081,373	100.0

Source: Hobby (1985), Table A.1; data from the US Federal Trade Commission

This table shows that, even in 1948, the penicillins comprised only two thirds of total antibiotic output, with streptomycin accounting for the other one third. It should be noted that this table does not include the sulphonamides which, being totally synthetic rather than naturally occurring, are not classified as antibiotics. They are, nevertheless, substitutes in the treatment of bacterial infections. Taking these into account, the relative contribution of the penicillin group in 1948 would be less than two-thirds. By 1956 the production of penicillins had increased by a factor of seven, but they accounted for only one third of total output; the streptomycins and tetracyclines accounting for one-half of total output. Hobby (1985, p235) reports that "...by 1960, seven classes of antimicrobial drugs had been identified: the beta-lactam antibiotics (including the penicillins and cephalosporins), aminoglucosides (including streptomycin, among other drugs), macrolides, ansamycines, polypeptide and depsipeptide antibiotics, and a few miscellaneous agents that did not fall into any of these categories."

The development of antibacterial agents still continues; with those currently available being too many to list. For example, Greenwood (1995, pp304) mentions sixteen antibacterial agents (many of which represent generic classes) having some efficacy in the treatment of tuberculosis. Greenwood (1995, p395) lists fourteen new antibacterial agents which became available in the UK market in the period 1990-1993. It is not simply the case of new ones replacing old ones, although this does happen to some extent. The World Health Organization list of essential drugs (Greenwood, 1995, p403) (which "includes only a handful of antibacterial agents" (*ibid.*, p405)) includes both benzyl penicillin (the "original" penicillin), and sulphadimidine, the latter as a "class representative" of the sulphonamides; a class of drugs which pre-dates the penicillins.

3.4.4.3 Conditions for Trade Driven by Product Differentiation

There are two necessary conditions for trade driven by product differentiation and, hence, for intra-industry trade. These are the existence of a variety of individual goods within the product group, and the "ownership" by one firm of each individual good.

Ownership in the pharmaceutical industry relies heavily on patents. Taylor and Silbertson (1973, p231) state that "The pharmaceutical industry stands alone in the extent of its involvement with the patent system. No other major industry approaches pharmaceuticals in its degree of attachment to patent protection;...". In a study of innovations in three industries (Mansfield *et al*, 1981), none of the innovations studied in the pharmaceutical industry would have been carried out without the availability of patent protection. Taylor and Silbertson (1973, p202) show that, based on their sample, 68% of sales revenue from UK production was derived from products to which patent protection applied.

This reliance on patents has not always been evident in the pharmaceutical industry. Kingston (2000) suggests that the reason Bayer did not apply for a patent on prontosil was that they knew that it was broken down *in vivo* to the active ingredient, sulphanilamide, which had already been described in the literature and was therefore not patentable. The same author also suggests that one reason that Chain did not attempt to gain a patent on penicillamine in 1943 was the feeling amongst the medical fraternity that it was improper to gain monopoly control over anything which could be considered to be for the benefit of mankind. The agreement on information sharing amongst firms working on penicillin production prevented them taking out patents at that time. However, this information sharing seems to have been less than uninhibited (Sheehan, 1982, pp72-75, 202), with Hobby (1985, p285) reporting nine patents related to penicillin production issued in the US between 1947 and 1949.

The development of streptomycin is a different story. The work on streptomycin by Waksman at Rutgers was funded by Merck, on the understanding that Merck had the right to patent any discovery arising from the work. Such a patent was granted to Merck in September 1948, on the grounds that the work had led to a "new composition of matter" (Kingston, 2000; Schwartzman, 1976, p53).

Kingston (2000) suggests that the experience of the early development of antibiotics significantly altered the nature of the pharmaceutical drugs industry. Prior to the development of penicillin, firms in the pharmaceutical industry were primarily manufacturing firms, distributing their products through wholesalers. Once the availability of patent protection was appreciated, emphasis was switched to research, and also to marketing. Kingston (2000) estimates that pharmaceutical firms now spend up to 20% of sales revenue on research and development, and even more on marketing - largely direct marketing to medical practitioners. Schwartzman (1976, p78) cites a study showing that, on a sales weighted basis, the proportion of new drug discoveries made by industry increased from 33% in the period 1935-49 to 85% in the period 1963-70, with the proportion attributed to universities, hospitals and research institutions diminishing over the same period from 66% to 8%.

The approach to patenting by universities, and other non-profit research institutions has also changed over time. Mention has already been made of the opposition to

Chain's wish to gain a patent on penicillamine in 1943. Sheehan (1982, pp165-6) cites, as a further example, the public outcry when Drinker at Harvard obtained a patent on his invention of the iron lung in the 1950s. Again, it was widely argued that a life-saving device invented at a non-profit institution should not lead to private gain. For similar reasons (*ibid.*), MIT were reluctant to take out a patent on Sheehan's synthesis of penicillin in 1957, and did so only when Sheehan threatened that, unless they did, he would do so himself. Sheehan (2000, pp203-4) also points out that in 1981 Harvard decided against entering the field of recombinant DNA for commercial purposes, on the grounds that making profits is not the business of universities. There is little evidence today of reluctance within universities to patent, or to make profits.

While it appears that the ownership characteristic might have not been sufficiently in evidence to produce intra-industry trade at the time penicillin first became available for general use, this is no longer the case. It should be kept in mind that this thesis deals with conditions of the 1990s, not those of the 1940s. It is also apparent, from the preceding discussion, that a wide range of differentiated products exists; regardless of whether one defines the product group as being anti-bacterial agents, antimicrobial agents generally, or all pharmaceutical products. As a further example of this, Schwartzman (1976, pp168-9) lists 80 new chemical entities for which patents were granted in the period 1966-73, with the patents being distributed over 37 firms.

3.4.4.4 Conclusions

The story of penicillin is not consistent with any form of the product cycle theory. At the time penicillin became generally available (1945-1950) it was being produced by a large number of firms, spread over a number of countries. The fact that the development of penicillin occurred during World War II contributed to this to some extent, but at the same time delayed development in the occupied countries. A further consideration is that the earlier research had been carried out in public institutions, and knowledge of the effect of penicillin had been in the public domain for at least ten years.

There were a number of substitutes for penicillin, defined as alternative treatments for bacterial infections, available at this time. The most significant of these, the sulphonamide groups of drugs, constitutes, in its own right, a differentiated product group. Streptomycin was available only shortly after penicillin. As early as 1948 penicillin represented only two thirds of total antibiotic output, and by 1956 only one third. And this does not include the sulphonamides.

As previously discussed, the concept of a differentiated product group is not solely reliant on the level of substitutability between the constituent products. One example of this, form the previous discussion, is streptomycin, which was found to effective against a class of bacteria against which the penicillins were ineffective. Nevertheless, both would belong to a product group described as "antibiotics". This is consistent with Chamberlin's (1962, p81) view of a product group as that would "ordinarily be regarded as comprising one imperfectly competitive market". Within the trade classification system, and the level of disaggregation, used in this analysis (discussed in subsequent chapters) there is a trade category described as "antibiotics", to which both of these groups of products belong. At a further level of disaggregation there are, amongst others, groups described as "penicillins" and "streptomycins". The previous discussion shows that each of these would also be a differentiated product group.

There product cycle theory does not fit within this story. A more accurate portrayal would be as follows. A number of existing anti-bacterial treatments - including the salvarsans and the sulphonamides - were augmented by the development of penicillin G and, at or about the same time, streptomycin. These two were the first in their respective classes of antibiotics to be developed. As a result of product innovation, motivated by the availability of patents, the number of individual antibiotics in these and a number of other classes has greatly expanded over time. With a large number of differentiated products available, and firm ownership provided by patents, trade driven by product differentiation and, hence, intra-industry trade, would be expected.

It should be noted that this discussion on penicillin is not included as an attempt to in any way prove or substantiate any arguments being put forward in this thesis. One example proves little, either way. This discussion on penicillin has been included not at the volition of the author, but at the suggestion of others who, apparently, saw it as an example running counter to some of the arguments being developed in this thesis. This does not appear to be the case.

3.5 Innovation, Differentiation, and Import Demand

It is suggested that continuing product innovation will cause a growth in import demand for innovative goods. This proposition is based upon the following arguments. First, that because innovative goods are differentiated, and differentiated goods are tradeable, then innovative goods are tradeable. And second, expressed simply, that continuing product innovation leads to an increasing role for innovative goods in economic activity. This argument is better explained by considering consumption goods separately from intermediate goods and producer durables. Consumer goods are considered first.

3.5.1 Consumption Goods

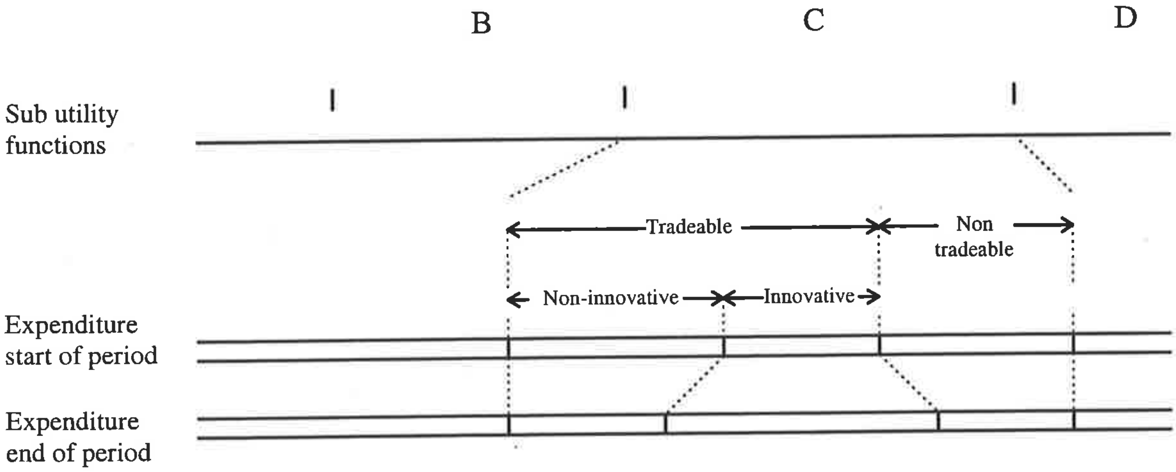
Increased demand for innovative goods can be expected if product innovation is a response to perceived economic opportunity. Firms incurring the cost of product innovation do so in the knowledge that revenue from the ensuing goods must displace expenditure on existing goods or services. If the expenditure on the new good displaces that on some pre-existing innovative good then there will be no change in aggregate expenditure on innovative goods, but, if the expenditure is displaced from a service or non-innovative good, then aggregate expenditure on innovative goods will increase. The latter can be regarded as a one way effect - it is difficult to envisage a mechanism by which it could be reversed.

As discussed in Section 3.4, innovative consumption goods can be conveniently analyzed within the framework suggested by Lancaster (1966a), wherein the utility function is defined over characteristics rather than goods, and consumers gain utility not from the consumption of goods directly, but from the consumption of characteristics embodied by any good. The Lancaster approach is apposite, given that it incorporates new goods into consumer theory, and demonstrates how new goods may replace old ones.

Innovation can be viewed as the development of a good which represents a new vehicle for acquiring one or a number of characteristics. There will be a demand for this new good if, at the prevailing price, acquiring that bundle of characteristics by the consumption of that good is utility maximizing within the current budget constraint.

Diagram 3.2 illustrates the increasing expenditure share on innovative goods over time as a result of continuing product innovation. To simplify the explanation two stage budgeting is assumed, based on utility being derived from separable sub-utility functions (..,B,C,D,...) defined over Lancaster (Lancaster 1966a) type characteristics. The first of these two stages is to allocate expenditure to each of the sub-utility functions within the overall budget constraint, the second to allocate the expenditure within the sub-utility function over the various goods and services which are a potential source of the relevant characteristics. This is a simplifying assumption only, one not necessary for increasing expenditure share on innovative goods.

Diagram 3.2. Changing Expenditure Allocation with Product Innovation.



The characteristics for each sub-utility function are sourced from a combination of goods and services. As shown in Diagram 3.2, these are categorized as either tradeable or non-tradeable, with the tradeable sector being comprised of innovative and non-innovative goods. Innovative goods are differentiated goods, which are considered to be all tradeable, and therefore innovative goods all fall within the tradeable category.

Diagram 3.2 shows the expenditure related to sub-utility function C at the beginning and end of some period, during which product innovation takes place. As a result of this innovation, the set of innovative goods relevant to sub-utility function C will change. For the reasons outlined above, utility maximization within the same expenditure constraint requires increased expenditure on the innovative good category. As shown in the diagram, this increased expenditure on innovative goods can come from expenditure on either or both non-tradeable goods and tradeable non-innovative goods. The effect of this could be observed as increased expenditure on tradeable goods as a whole but, if innovative and non-innovative goods are distinguishable, then the effect could also be observed as increased expenditure on innovative goods.

Section 3.6 develops the point that all varieties of a differentiated product group, other than those produced domestically, are imported. From this it follows that, all else being constant, an increased expenditure share on innovative goods will lead to increased expenditure on imports of innovative goods.

This argument is not inconsistent with the concept of product innovation leading to increased utility. In Diagram 3.2, the initial consumption set is still feasible at the end of the period. The selection of a new consumption set, therefore, implies increased utility resulting from product innovation.

3.5.2 Intermediate Goods

Product differentiation can also be a basis of trade in intermediate goods and producer durables. Helpman and Krugman (1985, Chapter 11) and Ethier (1979,1982) consider the case of differentiated intermediate goods and conclude that trade in such goods is similar in nature to that in differentiated final goods. Ethier (1979) shows that such trade increases with similarity between countries.

There are two relevant effects to consider here. First, one would expect innovative intermediate goods and producer durables to replace the non-innovative equivalents, for reasons similar to those proposed for final consumption goods. Second, the greater the use of tradeable intermediate goods and producer durables, the greater the value of goods which can potentially be traded, as a proportion of total income. In a hypothetical economy which produces only differentiated final goods, solely from labour inputs, the value of tradeable goods equals the value of final goods, which is the value of total income. In contrast, where there are multi-step production functions which utilize differentiated producer durables and intermediate goods, the value of tradeable goods exceeds that of final goods. Thus, the increased use of differentiated inputs and producer durables increases the value of tradeable goods as a proportion of total income.

Helpman and Krugman (1985) and Ethier (1979,1982) attribute the use of differentiated intermediates and producer durables to international economics of scale, which arise from the fixed cost of innovation. Innovation in intermediate goods and producer durables can simultaneously increase the value of tradeable goods as a proportion of total income, and increase the proportion of tradeable intermediate goods and producer durables comprised of innovative goods. The distinction between final goods, intermediate goods and producer durables is not as clear as might first appear to be the case. Within the Lancaster view of consumption, that utility is derived from consumption of characteristics rather than goods, then the distinction between non-final and final goods largely disappears - they are all intermediates by which characteristics are conveyed to the consumer. Final goods are simply the last link in a chain of intermediate goods by which characteristics are made available to households.

In some cases the distinction between a producer and consumer durable depends only on who uses it. A lawn mower used by a lawn mowing service or a vacuum cleaner by a cleaning service would be regarded as a producer durable, but in the hands of a household as a consumer durable. Either way they are really producer durables. It is the output which contains the characteristics from which utility is derived, in this case a mown lawn or clean carpet.

This view is consistent with the point made by Lancaster (1~~966b)~~, discussing a consumption technology which is similar to a production technology. Consumption efficiency is achieved by attaining, for a given budget constraint, the utility maximizing bundle of characteristics. Product innovation will change the bundle of goods by which this is achieved, potentially leading to a greater expenditure share on innovative goods. The same may be said of production efficiency with regard to intermediate goods and producer durables.

3.6 Model of Trade in Differentiated Goods

The objective of this section is to develop a model of trade in differentiated goods. The purpose of this model is to explain some expected characteristics of trade driven by product differentiation, under idealized conditions. The word model is used here in keeping with its meaning as a word within the English language. For example, "A simplified or idealized description or conception of a particular system, situation or process (often in mathematical terms: *so mathematical model*) that is put forward as a basis for calculation, predictions, or further investigation" (*OED*). It does not purport to be an economic theory.

The model of trade in differentiated goods to be developed here is based on that of Krugman (1979a), of trade in differentiated final consumption goods. This is a two country model, with utility given by a CES utility function defined over a single differentiated product group, such that utility is maximized by consuming equal quantities of each variety at equal prices and non-zero quantities of each variety if the equal price assumption is relaxed.

This model is developed into an operational one encompassing multiple countries and product groups, and independent of any specific form of utility function. The essential point of the model is that each country will import those varieties produced in other countries, and export those varieties produced within its own borders. In the Krugman (1979a) model, increasing returns to scale in the production of any one variety ensures that each variety is produced by only one firm. For the sake of simplicity, the one firm per variety relationship will be assumed in this discussion.

The following symbols are used:

Subscripts

i	denotes the differentiated product group
j,k	denotes country

Superscripts

$*$	denotes "foreign" in a two country (home and foreign) context
$\wedge$	growth rate of the indicated variable. $\hat{x} = \frac{1}{x}\frac{dx}{dt}$ (t=time)

Variables

M	the value of imports
X	the value of exports
I	per capita income
p	unit price
N	the number of varieties
n_k	the proportion of all varieties produced in country k
L	population (country size)
l_k	ratio of population of country k to total population of all countries
E_i	per capita expenditure on product group i
η_i	income elasticity of demand for product group i
g_i	share of income expended on product group i at unit income
s_{ij}	proportion of expenditure on product group i devoted to those varieties produced in country j

Start by assuming that utility is defined by a CES utility function incorporating one single differentiated product group. There are two countries, home and foreign, with foreign denoted by *. Both populations have identical per capita incomes, I, and identical tastes. Each variety has the same price, p, which, with a CES utility function, leads to equal consumption of all varieties. Total per capita consumption of the differentiated good is therefore $\frac{I}{p}$, in both countries. If N and N^* denote the number of varieties produced in home and foreign respectively, then the total number of varieties is $(N+N^*)$ and the per capita consumption of each variety is $\frac{I}{p}\left(\frac{1}{N+N^*}\right)$.

The per capita consumption of all varieties produced in the home country is $\frac{I}{p}\left(\frac{N}{N+N^*}\right)$ and of all varieties produced in the foreign country $\frac{I}{p}\left(\frac{N^*}{N+N^*}\right)$.

Let n and n^* denote the share of total varieties produced in home and foreign respectively. That is, let $n=\frac{N}{N+N^*}$ and $n^*=\frac{N^*}{N+N^*}$. It follows that $n+n^*=1$.

Per capita consumption of home and foreign varieties can now be expressed as

$n(\frac{I}{p})$ and $n^*(\frac{I}{p})$ respectively.

If the sizes of home and foreign in terms of population are given by L and L^* respectively, then the home consumption of varieties produced in foreign is $n^*(\frac{I}{p})L$ and the foreign consumption of home produced varieties is $n(\frac{I}{p})L^*$. These two terms represent respectively the volume of imports into and exports from the home country.

Multiplying both of these by the price (p) gives the value of imports (M) into the home country as

$M=n^*LI$

and exports (X) from the home country as

$X=nL^*I$.

Balanced trade requires that $\frac{n}{n^*}=\frac{L}{L^*}$

To allow for more than 2 countries, let subscripts j and k refer to countries.

Let n_k be the fraction of total varieties produced in country k. It follows that $\sum_k n_k = 1$.

Then imports into country j from country k are given by

$M_{jk}=n_kL_jI$

and exports from country j to country k by

$$X_{jk}=n_jL_kI$$

Total imports into country j are given by

$$M_j = (\sum_{k\neq j} n_k)IL_j = (1-n_j)IL_j$$

and total exports from country j by

$$X_j = n_jI(\sum_{k\neq j} L_k)$$

If $l_j = \frac{L_j}{\sum_j L_j}$, the share of country j in total population,

then multilateral trade balance requires that

$$\frac{n_j}{(1-n_j)} = \frac{l_j}{(1-l_j)}$$

or $n_j=l_j$

That is, the requirement for balanced trade is that the share of varieties produced by any country must equal its share of total population.

To incorporate multiple product groups, let E_i represent the per capita expenditure on product group i. The value of imports and exports of product group i into and from country j is now given by

$$M_{ij} = (1-n_{ij})E_iL_j$$

and

$$X_{ij} = n_{ij}E_i(\sum_{k\neq j} L_k)$$

Let g_i represent that portion of income which is expenditure on product group i at unit income, and η_i be income elasticity of demand for product group i.

Then $E_i = g_i I^{\eta_i}$

and the expressions for M_{ij} and X_{ij} become

$$M_{ij} = g_i(1 - n_{ij}) I^{\eta_i} L_j$$

and

$$X_{ij} = g_i n_{ij} I^{\eta_i} (\textstyle\sum_{k \neq j} L_k)$$

Allowing per capita income to vary across countries, and denoting the per capita income of country j by I_j, M_{ij} and X_{ij} are now given by

$$M_{ij} = g_i(1 - n_{ij}) I_j^{\eta_i} L_j$$

and

$$X_{ij} = g_i n_{ij} (\textstyle\sum_{k \neq j} I_k^{\eta_i} L_k)$$

To this point, an identical price for each variety within a product group has been assumed. Maintaining this assumption, the proportion of total expenditure on product group i which is expended on those varieties of that product group produced in country j (s_{ij}) is the same as the share of total varieties of product group i produced in country j (n_{ij}), that is $s_{ij} = n_{ij}$.

M_{ij} and X_{ij} can now be expressed as

$$M_{ij} = g_i(1 - s_{ij}) I_j^{\eta_i} L_j \qquad 3.6.1$$

and

$$X_{ij} = g_i s_{ij} (\textstyle\sum_{k \neq j} I_k^{\eta_i} L_k) \qquad 3.6.2$$

Replacing the variable n_{ij} with s_{ij} changes the meaning of a country share in a differentiated product group from that of the share of total varieties within the product group, to that of the share of total expenditure on that product group. With the assumptions of a CES sub-utility function, and equal prices for all varieties within the product group, the two variables (s_{ij} and n_{ij}) will have the same value, but replacing n_{ij}

with s_{ij} enables these two assumptions to be relaxed. Relaxing these two assumptions removes the conditions which lead to the equal consumption of all varieties within a product group. If incomes and tastes are the same for all countries, then for each country there will be the same level of expenditure for any given differentiated product group and, within that, the same level of expenditure on the set of individual goods produced in any one country. The essential element of trade driven by product differentiation is thereby retained and, without the need for a CES sub-utility function and equal prices for each variety, the model may now be considered an operational one.

The affect of variations in per capita income between countries on the share of expenditure on any differentiated product group (i) is allowed for by the income elasticity of demand, η_i. Given that this is a constant elasticity, this requires some assumptions as to the income elasticities of demand of the individual goods within the differentiated product group - for example, that each of them have a constant income elasticity of demand equal to the corresponding η_i.

The price variable is not explicitly specified in this model. There are three reasons for which, *prima facie*, it might be thought that price should be included. These are:

(a) the expenditure on each product group
(b) the consumption of each variety within a product group
(c) the effect of price variation across countries

Before dealing with each of these in turn, it is worth noting that, in the case of innovative goods, price and quantity are both endogenous. The objective of innovation is to create a demand curve for a good by building characteristics into it, in the terminology of Lancaster (1966a). Taking tastes as given, the demand curve for any variety is a function of the characteristics embodied within that variety, the characteristics of all other varieties in the same group and the expenditure on that group. The profit maximizing price and the quantity demanded at this price are a function of this demand curve. These two variables, in combination, give the revenue obtained at profit maximizing price, and it is revenue which is of primary interest here.

The level of expenditure on the product group is a function, *inter alia*, of the characteristics of all varieties within that product group. Innovation within that group will potentially change both profit maximizing prices and quantity demanded for all goods within that group, and possibly the expenditure share on that group, but the change in quantity demanded does not result just from the change in price.

The variable g_i denotes the expenditure share on product group i at a given income and level of innovation. Any effect on expenditure share of variations in per capita income are accounted for with the income elasticity of demand variable η_i. Assuming that new products become available in all countries at the same time then, at any given time, the value of g_i is identical for all countries. It is, however, free to change over time with product innovation, and it is expected that, for innovative product groups, the value of g_i will increase over time. Innovation within product group i may cause prices to change within that product group as well as changing the value of g_i, but the change in the value of g_i cannot be attributed to those price changes.

Similarly, assuming the price of each variety is set at its profit maximizing level, consumption of each variety cannot be considered a function of price. The demand curve for any variety is a function of the characteristics of that (and all other) varieties, and it is that demand curve which determines both the profit maximizing price and corresponding quantity. The "equal weighting" of each variety as in the CES utility function cannot be assumed. As Chamberlin (1962, p82) puts it "..the differentiation of the product is not, so to speak, 'uniformly spaced'; it is not distributed homogeneously among all of the products which are grouped together. Each has its own individuality, and the size of its market depends on the strength of the preference for it over other varieties".

The significance of the variable s_{ij} (the share of expenditure on product group i accounted for by varieties produced in country j) is that it correlates exports and imports of a differentiated product group for any given country, and enables some predictions as to the pattern of trade in differentiated goods. This will be used to explain the use of, and to demonstrate support for, the proxies used for innovative goods. Implicit in the use of this variable is the assumption that the distribution of expenditure share over all varieties within a group will be identical for all countries. Assuming identical tastes across countries, this will be satisfied if each variety has the same price in all countries. This can be expected if prices are set at profit maximizing levels.

The questionable assumption is that of identical tastes, but this cannot be remedied by the inclusion of prices, because non-identical tastes will result in different demand curves. To minimize the effect of different tastes, only developed economies have been included. Within a product group, taste variations should only be an issue if the individual demand curves are affected differently. Another possible source of variation between countries is the price of non-tradeables. This could influence the expenditure on a product group, all else being constant. Where applicable, this is addressed by using a measure of per capita income based on purchasing power parity[4].

Given that the GDP of country j, Y_j can be expressed as $Y_j=I_jL_j$, where I_j is the average per capita income of country j and L_j the population, then from (3.6.1), M_{ij} can be expressed as

$$M_{ij} = g_i(1-s_{ij})Y_jI_j^{\eta_i-1} \qquad 3.6.3$$

and

$$\frac{M_{ij}}{Y_j} = g_i(1-s_{ij})I_j^{\eta_i-1} \qquad 3.6.4$$

And from (3.6.2),

$$X_{ij}= g_is_{ij}I_{wj}^{\eta_i-1}\Sigma_{k\neq j}Y_k$$

$$= g_is_{ij}I_{wj}^{\eta_i-1}(Y_T-Y_j) \qquad 3.6.5$$

where $I_{wj}^{\eta_i-1}$ is the weighted (by Y_k) average of $I_k^{\eta_i-1}$ for all countries in the group other than j and $Y_T=\sum_j Y_j \ \forall j$.

The total value of exports of product group i for all countries under consideration, X_i, is given by

---

[4] The variable RGDPTT from the Penn World Table.

$X_i = \sum_j X_{ij}$

$= g_i \Sigma_j [s_{ij} \Sigma_{k \neq j}(I_k^{\eta_i} L_k)]$

$= g_i \Sigma_j [s_{ij} I_{wj}^{\eta_i - 1} (Y_T - Y_j)]$

$= g_i I_w^{\eta_i - 1} \Sigma_j [s_{ij}(Y_T - Y_j)]$

$= g_i I_w^{\eta_i - 1} Y_T (1 - \Sigma_j s_{ij} y_j)$ 3.6.6

where $y_j = Y_j / Y_T$ and $I_w^{\eta_i - 1}$ is the average of $I_{wj}^{\eta_i - 1}$ weighted by $s_{ij}(1-y_j)$.

Helpman (1987) derives a similar expression to (3.6.6), but has $g_i=1$, uses $s_{ij}=y_j$, and does not consider income elasticity of demand. Setting $s_{ij}=y_j$ makes the last term in (3.5.6) $(1-\sum_j (y_j^2))$. The expression $\sum_j (y_j^2)$ is referred as the "dispersion index", capturing the effect on trade of the number and size of countries over which the "economic world" is spread.

Growth in the total value of exports of product group i for all countries is given by

$\hat{X}_i = \hat{g}_i + (\eta_i - 1)\hat{I}_w + \hat{Y}_T + [1 - \widehat{\Sigma s_{ij} y_j}]$ 3.6.7

The last term on the right hand side can be expressed as $\frac{\sum_j s_{ij} y_j}{(1-\sum_j s_{ij} y_j)} (\widehat{\sum_j s_{ij} y_j})$. Given that, using y_j as a proxy for s_{ij}, then for all OECD countries $\sum_j s_{ij} y_j = 0.17$, and that the expected value of $(\widehat{\sum_j s_{ij} y_j})$ is zero (for a constant set of countries), then this term can be ignored for most purposes.

The growth in the import to GDP ratio can be derived from (3.6.4), and is given by

$\left(\frac{\hat{M}_{ij}}{Y_j}\right) = \hat{g}_i - \left(\frac{s_{ij}}{1 - s_{ij}}\right) \hat{s}_{ij} + (\eta_i - 1)\hat{I}_j$ 3.6.8

Given that $\sum_j s_{ij} = 1$, the expected value of the second term is zero, and systematic growth in the import to GDP ratio must be based on either an increase in the expenditure share devoted to product group i (g_i), or income growth combined with an income elasticity of demand greater than one.

3.7 Trade and Growth

3.7.1 Background

The relationship between growth rate and income elasticities of imports and exports (Kennedy and Thirlwall 1979, Bairam and Dempster 1991) can be expressed in the following way.

If total imports M=M(Y), where Y is total income, then the growth rate of M is given by $\hat{M} = \hat{Y}\eta_M$ where η_M is income elasticity of import demand with respect to Y.

If Y^* denotes total foreign income, or total income of all trading partners, and the value of exports is given by X=X(Y^*), then $\hat{X} = \hat{Y}^*\eta_X$, where η_X is income elasticity of demand for exports with respect to Y^*.

If balanced trade is to be maintained, then $\hat{X} = \hat{M}$ and

$$\hat{Y} = \frac{\eta_X}{\eta_M}\hat{Y}^* \qquad 3.7.1$$

or alternatively

$$\hat{Y} = \frac{\hat{X}}{\eta_M} \qquad 3.7.2$$

Empirical support for the second of these two relationships has been demonstrated by Bairam (1988,1990) and Bairam and Dempster (1991).

3.7.2 The Role of Product Innovation

The expression (3.7.1) is discussed by Krugman (1989), who presents data derived by Houthakker and Magee (1969) as empirical support for this relationship. Krugman *(op. cit.)* argues that this effect is not one of true income elasticities, as this assumes that the composition of imports and exports is constant over time. Rather, he argues that it is the changing composition of exports which makes the demand curve for such exports appear to shift outwards.

This issue is taken up by Muscatelli *et al* (1992), in reference to comments by Riedel (1984,1988), suggesting that income elasticities of demand for some newly industrialized economies (NIEs) in particular are implausibly high, and reflect no more than relative growth rates. Muscatelli *et al*(1992), on the basis of empirical evidence, reject the argument that price elasticities are significant, arguing, rather, that the apparent high income elasticities are the result of a shift factor, independent of prices and income, and that the true income elasticity of export demand is probably close to one.

This argument is consistent with that of Krugman (1989). Muscatelli *et al* (*op cit.*) proffer a number of explanations for this shift factor, product innovation being one of them. Muscatelli *et al* (1995) further develop this theme in an empirical analysis of export growth of a number of NIEs, where they attempt to use cumulative investment as a proxy for product innovation in estimating the export demand function. This variable is significant for five of the six countries analyzed. The inclusion of this variable reduces the estimates for both price and income elasticities of demand.

The use of cumulative investment as a proxy for product innovation could be questioned, nevertheless the authors argue that "the results are broadly supportive of a link between accumulated capital stock and export demand and hence new theories of trade which emphasise the role played by product innovation...". This "shift factor" can be incorporated into expressions (3.7.1) and (3.7.2) by defining imports and exports as being functions of income and time. That is,

$$X = X(Y^*, t) \text{ and } Y^* = Y^*(t)$$

$$M = M(Y, t) \text{ and } Y = Y(t)$$

Then

$$\frac{dX}{dt} = \frac{dX}{dt}\Big|_{Y^*} + \frac{dY^*}{dt}\frac{dX}{dY^*}\Big|_t$$

and $\hat{X} = \hat{X}|_{Y^*} + \eta_X \hat{Y}^*$ 3.7.3

Here η_X represents the true income elasticity of demand for exports with the composition of exports remaining constant. The first term, $\hat{X}|_{Y^*}$, is the growth in exports at constant foreign income, arising from the change in composition of exports - including the effects of product innovation.

Similarly, $\hat{M} = \hat{M}|_Y + \eta_M \hat{Y}$ 3.7.4

From a starting point of trade balance, continuing trade balance requires that $\hat{X} = \hat{M}$. Equating (3.7.3) and (3.7.4) gives

$$\hat{M}|_Y + \eta_M \hat{Y} = \hat{X}|_{Y^*} + \eta_X \hat{Y}^*$$, so that

$$\hat{Y} = \frac{\hat{X}|_{Y^*} - \hat{M}|_Y + \eta_X \hat{Y}^*}{\eta_M} \qquad 3.7.5$$

is the balance of trade constrained economic growth rate.

It is expected that most of the variation in the LHS variable over countries will be explained by $\hat{X}|_{Y^*}$ and η_X. For differentiated goods, Y^* represents the aggregate GDP of all but the exporting country, and consequently minimum variation is expected in $\hat{Y}^*$ for the various countries.

It is also expected that the variations in the innovative goods content of exports will be greater than for imports. Leaving aside for the time undifferentiated goods, then from the expressions

$M_{ij} = g_i(1 - s_{ij})Y_j I_j^{\eta_i - 1}$ (from 3.6.3) and

$$X_{ij}=g_i s_{ij} I_{wj}^{\eta_i -1} (Y_T - Y_j) \qquad \text{(from 3.6.5)}$$

it can be seen that if the value of s_{ij} is constant over all product groups for each country (for example $s_{ij}=y_j$,$\forall$ i,j) then, assuming unit income elasticity of demand ($\eta_i=1$, $\forall$ i), the composition of exports and imports for all countries will be identical. If the expected value of s_{ij} is y_j, then variations in import and export composition can be seen as the result of variations in the value of s_{ij} around y_j. While the elasticity of exports with respect to s_{ij} is one, that for imports is $-\frac{s_{ij}}{(1-s_{ij})}$. Using, in this instance, y_j as an estimator for s_{ij}, the value of this term, for the smallest 23 of the 25 countries, is 0.1 or less. Consequently, a lower variation in the composition of imports than of exports is expected.

A simpler way of putting this is that the 23 smaller countries are expected to import over 90% of their expenditure on each product group and variations in s_{ij} will make relatively little change to this proportion. Assuming an identical expenditure share on each product group across countries, this will lead to a high degree of uniformity of import composition across countries.

While variations in undifferentiated imports and exports will also contribute to variations in the innovative goods content of both, there is no apparent reason why this source of variation should systematically vary between imports and exports, and hence the expectation that the innovative goods content of imports will be less than that for exports remains. In Chapters 5 and 7 some empirical support will be demonstrated for this argument.

Both η_M and $\hat{M}|_Y$ are functions of import composition, and η_X and $\hat{X}|_{Y^*}$ of export composition. If export composition is more variable across countries than import composition, and $\hat{Y}^*$ is similar for all countries, then most of the variation in $\hat{Y}$ will result from variations in η_X and $\hat{X}|_{Y^*}$.

3.7.3 Innovative Products and Export Growth

There is a counterpart to the relationship $\hat{X} = \hat{X}|_{Y^*} + \eta_X \hat{Y}^*$ (3.7.3), which can be derived from (3.6.5) in the previously developed model of trade in differentiated goods.

From (3.6.5),

$$X_{ij} = g_i s_{ij} I_{wj}^{\eta_i - 1} (Y_T - Y_j),$$

Then

$$\hat{X}_{ij} = \hat{g}_i + \hat{s}_{ij} + (\eta_i - 1)\hat{I}_{wj} + \widehat{(Y_T - Y_j)} \qquad 3.7.6$$

If it is assumed that exports are comprised solely of differentiated goods, then growth in total exports from country j is given by

$$\hat{X}_j = \sum_i (x_{ij} \hat{X}_{ij}) \qquad \text{where } x_{ij} = \frac{X_{ij}}{\sum_i X_{ij}}$$

$$= \sum_i (x_{ij}[\hat{g}_i + \hat{s}_{ij}]) + \hat{I}_{wj} \sum_i (x_{ij}[\eta_i - 1]) + \widehat{(Y_T - Y_j)}$$

$$= \sum_i (x_{ij}[\hat{g}_i + \hat{s}_{ij}]) + \eta_x \hat{I}^* + \hat{L}^* \qquad 3.7.7$$

where η_X is income elasticity of demand for the exports of country j as a whole, I^* is weighted average income of export countries and L^* is the total population of those countries.

If elasticity of aggregate demand with respect to L (population) is one, then η_X is income elasticity of demand with respect to per capita income (I), and (3.7.7) can be expressed as

$\hat{X}_j = \sum_i (x_{ij}[\hat{g}_i + \hat{s}_{ij}]) + \eta_X \hat{Y}^*$. Comparing this with (3.7.3),

$$\hat{X}_j = \hat{X}_j|_{Y^*} + \eta_X \hat{Y}^*$$

it can be seen that

$$\hat{X}_j|_{Y^*} = \sum_i (x_{ij}[\hat{g}_i + \hat{s}_{ij}])$$

This can also be derived from (3.7.7) by setting $\hat{I}^*$ and $\hat{L}^*$ equal to zero.

From (3.7.6),

$$\hat{X}_{ij}|_{Y^*} = \hat{g}_i + \hat{s}_i \ .$$

Given that, at all times, $\sum_j s_{ij} = 1$, then the expected value of $\hat{s}_{ij}$ for any i,j is zero, and the expected value of $\hat{X}_{ij}|_{Y^*}$ is $\hat{g}_i$. With $\hat{g}_i$ expected to be positive for innovative goods, then the expectation is that $\hat{X}_{ij}|_{Y^*}$ will be positive for innovative goods.

With a country's export growth rate at constant foreign GDP being given by $\hat{X}_j|_{Y^*} = \sum_i (x_{ij}\,\hat{X}_{ij}|_{Y^*})$, then it is expected that the higher the innovative goods content of a country's exports, the higher the expected export growth rate at constant foreign GDP.

A similar result is obtained when considering the mean growth rate in the import to GDP ratio. Using m_{ij} to represent $\frac{M_{ij}}{Y_j}$, the mean growth rate of m_{ij} for product group i across all countries is given by (from 3.6.7)

$$\bar{\hat{m}}_{ij} = \hat{g}_i + (1 - \bar{\hat{s}}_{ij}) + (\eta_i - 1)\bar{\hat{I}}_j \quad \text{(where } ^{-} \text{ denotes mean value).}$$

Again, with the expected value of $\hat{s}_{ij}$ being zero, the expected growth rate in the import to GDP ratio at constant income is $\hat{g}_i$. As argued in Section 3.5, $\hat{g}_i$ is expected to be positive where i represents an innovative product group.

3.7.4 Export Growth and Economic Growth

The direction of causality between export growth and economic growth is debatable. The hypothesis, that export growth leads to GDP growth, has existed for some time now, and has been neither universally accepted nor rejected, but at the very least it can be claimed that the highest growth rate which can be sustained without incurring a deficit trade balance is that given by

$$\hat{Y} = \frac{\hat{X}|_{Y^*} - \hat{M}|_{Y} + \eta_X \hat{Y}^*}{\eta_M}$$

Any growth rate higher than this, from a starting point of trade balance, will induce a trade deficit, and so it can be claimed that, even if export growth does not cause economic growth, a higher export growth will accommodate a higher economic growth rate.

Short run or periodic trade deficits need not necessarily be a constraint on growth, but a long term growth rate above that shown above will result in a long term condition of $\hat{M} > \hat{X}$. The result of this will depend, to some extent, on the initial trade balance. If it is a deficit the result will be an increasing deficit, and there must be some limit on the period of time for which that is sustainable.

3.8 Identification of Innovative Goods

The examination, by way of econometric estimation, of the argument that innovative goods represent a growing proportion of total trade requires some method of identifying innovative goods. The most direct method would be to measure the innovative content, but this would require imposing some potentially restrictive definition as to what constitutes innovation. Specific measures such as R&D expenditure measure only one particular form of innovation. The use of intellectual property rights seems attractive, but again, while these are applicable to some areas of product innovation, there is no reason to believe that they are applicable to all.

In order to keep the concept of innovation as broad as possible, it is proposed to identify innovative goods on the basis of whether they behave as innovative goods. As it has been argued that innovative goods have the characteristics of differentiated goods, then the expectation is that the pattern of trade in innovative goods will correspond to that predicted for trade driven by product differentiation.

The model developed above enables a number of predictions to be made for trade driven by product differentiation. One of these is intra-industry trade. There is a considerable literature on this topic, including some discussion on what it means, the significance it might have, and how it might best be measured. This is reviewed in the next chapter, prior to further discussion on the manner in which it is proposed to use various measures of intra-industry trade to identify innovative goods.

4. Intra-Industry Trade: A Literature Review

4.1 Introduction

As foreshadowed in the preceding chapter, measured intra-industry trade will be used as a proxy for identifying differentiated product groups and, hence, innovative goods. This chapter is an analysis of the arguments concerning the underlying causes, significance, and relevance of measured intra-industry trade. The major objective is to show that observed intra-industry trade can be used, in combination with other variables, as an indication of product differentiation.

The term "intra-industry trade" referred, originally at least, to simultaneous export and import within the one industry by the one country. This, in turn, raised the question of the degree to which the various categories in which trade is recorded, and intra-industry trade measured, correspond to an industry. Those sceptical of the significance of measured intra-industry trade have been able to provide examples of goods, within the one category, which would not normally be considered to belong to the one industry (Lipsey 1976, Pomfret 1979, 1985, 1986). Some of the quoted examples highlight the uncertainty on whether the definition of an industry should be supply or demand based.

The arguments against the significance of observed intra-industry trade appear to be motivated, in part at least, by a desire to preserve the factor proportions theory as the explanation of all international trade. Such arguments claim that the categories within which intra-industry trade is measured do not truly represent industries - meaning that goods are not categorized on the basis of similarity in the use of factors of production, and that observed intra-industry trade is largely a result of this "incorrect" aggregation into categories (Finger 1975, Pomfret 1979,1985,1986). This argument is sometimes referred as "the aggregation problem", and observed intra-industry trade dismissed as a "statistical artefact" (Pomfret 1986). The difficulty in interpreting measured intra-industry trade is that, as Lipsey (1976) points out, "intra-industry trade is not one but many phenomena". Any instance of intra-industry trade can represent the cumulative effect of a number of causes, and be interpreted in a number of ways. The challenge in using intra-industry trade as a proxy for product differentiation is to distinguish intra-industry trade arising from product differentiation from that due to other causes. Measured intra-industry trade is being used in this thesis as an indication of those trade categories for which trade is consistent with that category being a differentiated product group; not to debate the omnipotence or otherwise of the factor proportions theory of trade. It is not of paramount importance whether or not categories represent industries. The degree to which the trade categories used can be expected to conform to the concept of a product group is discussed in Chapter 5 (5.2.3).

Section 4.2 analyzes the "aggregation problem" arguments, with particular reference to the theory of trade driven by factor proportions where there are multiple, rather than two, factors of production. Under these conditions the commodity content of trade is indeterminate. Consequently, no method of aggregating goods into categories would eliminate intra-industry trade, even if all trade was driven by factor proportions. Significantly, for the use of measured intra-industry trade in this thesis, such intra-industry trade, being indeterminate, would be random in nature, and not expected to be observed consistently for the one product group over a large number of countries. The significance of this, in the context of the measures of intra-industry trade to be used in this thesis, is discussed in Chapter 5, particularly (5.2.3).

The next three sections are devoted to examining the econometric evidence in support of product differentiation and economies of scale being causes of intra-industry trade. The argument put forward by Pomfret (1986), that negative results from a number of such studies cast doubts upon the contribution of these two factors to intra-industry trade, is scrutinized. Section 4.3 examines the theoretical arguments for product differentiation and scale economies as causes of intra-industry trade. Section 4.4 reviews the various measures of intra-industry trade in use, and the arguments for and against each. Section 4.5 reviews the various empirical studies on the determinants of intra-industry trade, with specific attention to the various trade classification systems used, the various measures of intra-industry trade employed, types of countries included, the various model specifications, the various proxies used, and treatment of trade imbalance. The results of estimates of both country specific and product specific determinants of intra-industry trade are examined in the light of the theoretical contributions surveyed in Section 4.3. The conclusion is that there is stronger empirical support for product differentiation as a determinant of intra-industry trade than that suggested by Pomfret (1986). There are some negative results but, given the wide ranging conditions under which these various estimations were carried out and, in particular, the different proxies used for product differentiation, this is scarcely surprising, and cannot reasonably be interpreted as evidence that product differentiation is not a contributor to intra-industry trade.

Section 4.6 discusses the concept of vertical (as opposed to horizontal) intra-industry trade, and particularly the arguments that most intra-industry trade fits within this category. There is an argument that vertical intra-industry trade is motivated by differences in quality, rather than product differentiation, and can therefore be explained by the factor proportions theory. The theoretical basis for this argument, and the empirical analyses, are examined. The conclusion is that these arguments are less than compelling.

4.2 The Aggregation Problem

A frequent criticism of measured intra-industry trade is that it is entirely, or largely, a result of an "aggregation problem" - an aggregation, within the one category of goods, of goods sufficiently dissimilar to explain the measure of intra-industry trade; the criteria for similarity (or dissimilarity) depending on the theory of trade being offered in explanation.

Such a criticism is made by Finger (1975), who argues that observed intra-industry trade could be consistent with the Heckscher-Ohlin factor proportions theory if the factor ratios used in production at any set of factor prices varied more within industry than across industries. The argument is based on a two factor two country model with many goods. If all goods can be ordered by factor ratio, then there will be specialization. All those above a certain factor ratio will be produced and exported by one country, and all others by the second country. It is argued that "overlapped trade is consistent with the factor proportions theory so long as factor inputs vary more within product groups than between."[1]. This conclusion, however, would seem to require some uniformity of distribution of factor proportions across the range of goods, an issue which is not discussed.

On the results of an analysis based on the US 4-digit SIC[2] concorded into the SITC at the 3-digit level (SITCs 5 to 8), it is claimed that "40% to 70% of the variation in factor input requirements among products is within 3 digit product groups". The two factors considered are physical and human capital. The measures[3] used for these two variables are open to interpretation but that aside, the variation within industry for these two factors was 38.8% and 39.3% respectively. The figure of 70% comes from 68.3% of the variation in scale economy being within industry. Without questioning the measure of scale economies[4], it is surprising to find scale economies regarded as a factor ratio. Apart from scale economies, the result is that factor proportions vary more across than within the SITC 3-digit manufacturing categories, a result which runs counter to Finger's opening argument.

Pomfret (1979) cites Finger (1975) in arguing that measured IIT is largely an artefact of aggregation, relying on the 70% figure to claim that it showed that "factor proportions varied more within 3-digit classes than between them". This argument (Pomfret, 1979) is based, in part, on an analysis of the effect of disaggregation on the intra-industry trade measure for Israel for 1972, measuring IIT both at the chapter (2-digit) and 7-digit level of the Brussels Tariff Nomenclature (BTN). This disaggregation increases the number of categories by a factor of 21, and decreases the measured IIT index by a factor of between five and six. At the disaggregated level, the value of the IIT index is 8% or 11%, depending on the measure used[5]. The point is made that at this level 20 "nes"[6] categories account for one quarter of the remaining IIT. However, some of these categories are quite specific, as for example: heterocyclic

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[1] Based on the argument that if by arranging all sub industry categories in factor proportions it happened that all such sub industry categories were grouped within their respective industries then factor proportions could explain "overlapped trade" for only the "marginal" industry.

[2] The US Standard Industrial Classification

[3] Physical capital intensity has been "approximated" by non-wage value added per employee, and human capital by average wage. The validity of these measures would seem to be based on the assumptions of the perfectly competitive market. A doubtful assumption when analyzing manufacturing industries, and particularly so in this case where many explanations for intra-industry trade are based on imperfect competition.

[4] Scale economies are measured as "value added per establishment".

[5] The larger of the two comes from a calculation which adjusts for overall trade imbalance.

compounds, electric telephone and telegraph apparatus, and thermionic valves. It does not necessarily follow that each category thus specified encompasses a particularly diverse range of products.

The author (Pomfret, 1979) argues that the level of intra-industry trade remaining after disaggregation is not worth worrying about. This is a matter for judgement. It is earlier argued (*ibid.*, p118), with regard to the Australian level of intra-industry trade, that "we have no criterion for deciding whether 6% is a significant share of total trade"

It is not immediately apparent how applicable the results of disaggregation obtained in Pomfret (1979) are to intra-industry trade generally, as regards both the specific country and the specific classification system used (BTN). Concerning the latter, any aggregation problem will arise from the way in which a particular classification system is constructed. The demonstration of an aggregation problem within, for example, the BTN, does not necessarily tell us anything about the magnitude of the problem within, for example, the SITC at any particular revision level.

The use of trade data for Israel is justified on the grounds that "her IIT is high at the 2- or 3- digit levels." The uncorrected value is 46%. One cannot make strict comparisons across classification systems but it is of interest to note, for example, that six of the ten countries analyzed by Grubel and Lloyd (1975) had a greater value for the IIT index in 1969. And in an analysis by Havrylyshyn and Civan (1983) the IIT index for Israel is close to the median value for 18 OECD countries. Wolter (1979) expresses some reservations about the suitability of Israel for such a study, his concerns including the size of Israel, its degree of industrialization, and the proportion of its trade with countries having very different factor endowments.

4.2.1 The Factor Proportions Theory of Trade

The theory of trade based upon factor proportions is of some relevance here. The simple version is based on a two good, two country, two factor model, within which it can be shown that each country will export the good whose production uses more intensively that factor of which that country has a relatively greater endowment. Jones (1956) extended this to the many goods case, arguing that all goods exported by a

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[6] nes - "not elsewhere specified". In some cases can effectively mean "miscellaneous".

country would use more intensively that factor with which that country was relatively well endowed than all imports.

Melvin (1968), however, demonstrates that for the two country, two factor, three good case, this proposition does not hold in the presence of factor price equalization, demonstrating that one country would export both the capital intensive and the labour intensive good, while importing the "intermediate" good. In a reply to Stewart (1971), Melvin (1971) concedes this is not a general result but maintains, nevertheless, that it is a possible one. You (1979) shows that in the three country, four commodity, two factor model, in the absence of factor price equalization, the commodity content form of the Heckscher-Ohlin theorem holds in the bilateral but not in the multi-lateral case. The case with more than two factors is not discussed, but ranking by factor intensity with more than two factors is problematic.

Melvin (1968) did, however, demonstrate that the aggregate factor content of net trade was predictable. Vanek (1968) generalizes this to the many products, many factors case, enforcing factor price equalization by imposing the restriction that specialization should occur for no more than (m-n) goods, where m is the number of goods and n is the number of factors. Brecher and Choudri (1982) extend the factor content conclusion to the two factor case in the absence of factor price equalization. The conclusion based on the factor content of net trade has been extended to the many goods many factors case in the presence of factor price equalization (Horiba (1974), Leamer (1980)), and is generally known as the Heckscher-Ohlin-Vanek theorem. Deardorff (1982) produces a weaker relationship between factor intensity and the factor content of trade; one which holds in the absence of factor price equalization, non-identical technologies and factor intensity reversals.

The limited ability of the factor proportions theory to predict the commodity content of trade is of some relevance when considering the "aggregation problem". Finger (1975) bases his theory on the proposition of Jones (1956), a proposition which has been shown by Bhagwati (1972) to hold only when factor prices are not equalized, and by You (1979) only in the bilateral case. Finger (*op. cit.*) uses multi-lateral rather than bilateral trade data, and while the theory is based on two factors of production, the analysis employs both physical and human capital intensity as independent variables, implying the existence of a third factor, presumably labour. This makes the task of "ranking" products by factor intensity problematic, but the underlying theory presented assumes that this can be done.

Rodgers (1988) considers the product content of trade in a two country, three factor, four product model by simulation. The concept of "ranking" by factor intensity is replaced by that of an inter-product "distance" based on factor use[7]. The four goods are allocated to two "industries" on the basis of minimizing the distance between goods in an industry. The simulation gives intra-industry trade within each industry and no factor price equalization. Under a certain set of conditions, it is demonstrated that the more similar the production functions in each industry, then the greater is the percentage of intra-industry trade as a percentage of total trade in that industry.

The conclusion is that, for all practical purposes, the Heckscher-Ohlin theory cannot predict the commodity content of trade, and that it is possible to have intra-industry trade within an industry even where all products use identical factor proportions and all trade is driven by factor proportions. Intra-industry trade driven by factor proportions is possible without an aggregation problem. However, such intra-industry trade would arise not as a consequence of the characteristics of an industry but, rather, of a specific country or country pair, and in such a case one would not expect to find a consistent measure of intra-industry trade for that category across a range of countries or country pairs. In contrast, it would be expected that intra-industry trade would be consistently observed within any category for which intra-industry trade was based on product differentiation.

There has been some significance attached to the observation that measured intra-industry trade reduces with disaggregation (Pomfret 1979,1985) - that this supports the argument that measured intra-industry trade is largely a result of the “aggregation problem”. This argument, seemingly, implies that, with disaggregation, the range of factor proportions per category falls and, with it, the volume of intra-industry trade arising from goods of different factor proportions having been included in the one category. The former does not necessarily follow, and the latter assumes the commodity content form of the factor proportions theory as a general result, when it has been shown to hold only for bilateral trade in the absence of factor price equalization, and then with only two factors of production.

The reduction in measured intra-industry trade with disaggregation, of itself, has no significance. If all trade were consolidated into one category, all countries would have a measured intra-industry trade of one (assuming balanced merchandise trade) and if, at the other extreme, trade data were to be exhaustively disaggregated such that all categories contained only one identifiable product, there would be zero measured intra-industry trade. Consequently, one would always expect a reduction in measured intra-industry trade with disaggregation. If the direction of trade in all goods was random, then one would still expect measured intra-industry trade to fall with disaggregation, simply because the fewer goods in a category the lower the probability of two way trade, and of balanced two way trade. This will be discussed later.

4.3 Determinants of Intra-Industry Trade

4.3.1 Product Differentiation

There are a number of models which employ product differentiation to demonstrate concurrent export and import within any one product group or industry and, hence, intra-industry trade. The common feature of these models is that any one specific product is produced in only one country, and consequently any other country in which there is demand for this specific product must import it. The unique location of production is achieved in one of several ways; increasing returns to scale at the plant level[8], or innovation which produces either country specific knowledge[9] or firm specific knowledge[10]. The two way trade in such products, necessary for the phenomenon of intra-industry trade, can come either from a symmetrical trading relationship between any two countries[11] or an asymmetric one (of the North/South style) involving "technology diffusion"[12] or multi-national corporations[13].

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[7] The square root of the sum of squares of the difference between elasticities for all 3 factors of production.

[8] Krugman (1979a, 1980, 1989), Lancaster (1980), Helpman (1981, 1987)

[9] Krugman (1979b)

[10] Posner (1961), Vernon (1966), Helpman (1984), Grossman and Helpman (1989,1991c)

[11] Posner (1961), Krugman (1979a,1980), Lancaster (1980), Helpman (1981,1987), Grossman and Helpman (1989,1991c)

[12] Krugman (1979b)

[13] Vernon (1966), Helpman (1984)

The more recent, and formal, of these models have been referred to collectively as the "new theories of trade" yet, as the following brief history shows, the idea of trade based on product differentiation goes back further than these "new theories". Posner (1961) proposed that trade could arise as a result of either product or process development. Any other country wherein there was demand for a new product would import it until such time that the product was produced domestically. With new products being continuously developed this provides a basis for continuing trade, and if there is development in more than one country, two way trade. Vernon (1966) develops the concept of the product cycle, showing that a product originally exported as a new product could ultimately be imported as a "standardized" product, but with product “ownership” retained by the original firm. Relevant aspects of innovation, uncertainty, and availability of information are discussed.

Krugman (1979b) specifies more formally a similar concept. In a two country model (North and South) innovation is confined to North, as is production until there is "technology transfer" to South. This leads to a higher wage in North which therefore exports "new" products and imports "old" products. The production function is constant returns to scale. The unique location of production (at any one time) is maintained by limiting innovation to one country and a lower production cost in the other. In contrast, in Krugman (1979a) it is the increasing returns to scale production function which both limits the variety of products produced in any one country and ensures that any one variety is produced in only one country. There is no innovation and no wage difference. With two countries of equal size this model is symmetrical. Lancaster (1980) also uses economies of scale to demonstrate intra-industry trade based on product differentiation.

All of the above are based on the concept of trade driven by product differentiation. This includes the product cycle theory which, for some reason, seems to have a level of acceptance not enjoyed by other members of the product differentiation family. For example, Pomfret (1979, p119) includes the product cycle theory in "existing theories", and as such is prepared to use it to explain observed intra-industry trade, but later (Pomfret, 1986, p60)[14] appears reluctant to entertain product differentiation as an explanation of intra-industry trade.

The form of differentiation may be unspecified, horizontal or vertical. Horizontal differentiation depicts variety reflecting either taste diversity over consumers, or an individual taste for variety (for example, variety in colour). Vertical differentiation refers either to trade based on variety in quality, for example Grossman and Helpman (1991a,b,c,d), or to trade in intermediate and final goods within the one industry. The models of trade based on product differentiation discussed above have used either unspecified or horizontal differentiation. Vertical product differentiation will be discussed in some detail later in this chapter (4.6).

4.3.2 Scale Economies

While economies of scale are frequently proposed as a cause of intra-industry trade, there is no underlying theory comparable to that for product differentiation. Product differentiation cannot be considered in isolation from scale economies, because product differentiation implies some economies of scale. As discussed above, models of trade in differentiated goods rely on scale economies to maintain one firm per variety in the presence of perfect information - "...in the absence of scale economies, all product varieties would be produced domestically and no intra-industry trade would take place" (Balassa, 1986b, p225), while Caves (1981) contemplates an extreme where, in the total absence of scale economies, each consumer would request a variety tailored to his own specific tastes. All of which assumes no informational barriers to the production of any variety, nor ownership of any variety.

In those cases where each variety is effectively owned by a firm through, for example, intellectual property rights or firm specific knowledge, and varieties are created by innovation, then the one firm per variety relationship is still maintained by implicit scale economies. The difference being that these are dynamic, rather than static, economies of scale; in the sense that here the fixed costs (of innovation) are incurred in one period, and the variable costs (manufacture) in subsequent periods.

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[14] "There is a belief that IIT is explained by product differentiation and scale economies, which requires rejection of any suspicion that observed IIT is primarily a definitional or taxonomic phenomenon."

Intra-industry trade driven by scale economies requires some form of product differentiation - scale economies cannot explain the concurrent import and export of an identical good. Whether this diversity is described as product differentiation or an aggregation problem is a matter for judgement. The fixed costs giving rise to scale economies may be the traditional production fixed costs, fixed costs incurred by innovation, and/or the fixed costs associated with marketing (including advertising) and distribution[15]. The last two can be associated with product differentiation and firm ownership of a variety. The first is not necessarily associated with product variety, some arguing (see later) that it is a measure of product standardization, the antithesis of product variety.

Grubel and Lloyd (1971) discuss the high level of Australian intra-industry trade at the 5 digit level of SITCs 673 and 674 (basic iron and steel goods)[16]. They point out that Australia is well endowed with all the relevant inputs for these two categories and argue that the basis of intra-industry trade is scale economies "specific to individual, narrow product lines" - narrower even than the 5-digit category specifications. Whether this should be seen as intra-industry trade based on product differentiation or on economies of scale would depend largely on the definition of product differentiation. Intra-industry trade on this basis differs from that based on firm ownership of a variety in two significant ways.

If, as might be expected, exports of such products were limited to those countries relatively well endowed with the relevant inputs, then intra-industry trade in these categories would be limited to those countries, and intra-industry trade would not be observed consistently over a number of countries. And if the relevant information and technology are freely available, then the number of countries within that group exporting any one variety would be determined by the minimum efficient size and global demand - there could conceivably be the one variety exported from a number of countries. This form of apparent differentiation does not correspond to the meaning normally associated with the expression.

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[15] Some of these may be better represented as indivisibilities rather than fixed costs. Economies of scope as well as economies of scale may apply here.

[16] SITC 673:Iron & steel bars, rods, angles, shapes and sections. SITC 674: Universals, plates & sheets of iron & steel.

4.4 *The Measurement of Intra-Industry Trade*

4.4.1 The Grubel and Lloyd Index

Alternatively known as the Balassa index, the Grubel and Lloyd index is the most commonly used measure of intra-industry trade. It was used by Balassa (1966) in an analysis of the effects of the formation of the European Economic Community on the trade patterns of its foundation members and, specifically, to test the hypothesis that the reduction in tariffs would increase the share of "dominant suppliers" in intra-EEC trade. A finding to the contrary motivated a further test of the general theory that a reduction in tariffs would cause a relocation of resources from import replacing to export sectors, and a consequent contraction of activity in the former and expansion in the latter. Thus increased trade would be inter-industry in form - increased exports in the exporting sector and increased imports in the importing, or previously import replacing, sector. That which was not inter-industry was intra-industry, and to measure the latter the index

$$\frac{1}{n}\sum_{i=1}^{n}\frac{|X_i - M_i|}{X_i + M_i}$$

was devised. That is, intra-industry trade in any category (industry) was defined as being the value of exports matched by that of imports, normalized by the value of total trade (X_i+M_i). This normalization enables cross-section and longitudinal comparison, and aggregation.

In a more detailed treatment of the topic, Grubel and Lloyd (1971) note that this is really a measure of inter-industry trade, and criticize its being an unweighted rather than weighted average. Grubel and Lloyd also define intra-industry trade as being the value of exports matched by that of imports for any industry, and are not concerned as to the definition of an industry, using any level of aggregation that is of interest. Intra-industry trade is then defined for country i and industry (category) j as

$$R_{ij}=(X_{ij}+M_{ij})-|X_{ij}-M_{ij}|$$

and inter-industry trade as

$$S_{ij}=|X_{ij}-M_{ij}|$$

To permit comparisons, these can be normalised to give inter-industry trade

$$A_{ij} = \frac{|X_{ij} - M_{ij}|}{X_{ij} + M_{ij}}$$

and intra-industry trade

$$B_{ij} = 1 - \frac{|X_{ij} - M_{ij}|}{X_{ij} + M_{ij}} = 1 - A_{ij}$$

An aggregate measure of B_i, the level of intra-industry trade for country i, is a weighted average of the components, given by

$$B_i = \frac{\sum_{j=1}^{n}[(X_{ij} + M_{ij}) - |X_{ij} - M_{ij}|]}{\sum_{j=1}^{n}(X_{ij} + M_{ij})} = 1 - \frac{\sum_{j=1}^{n}|X_{ij} - M_{ij}|}{\sum_{j=1}^{n}(X_{ij} + M_{ij})}$$

$$= 1 - \frac{\sum_{j=1}^{n}|X_{ij} - M_{ij}|}{X_i + M_i}$$

4.4.2 Adjustment for Trade Imbalance

Grubel and Lloyd (*op. cit.*) point out that, if there is an imbalance in merchandise trade, this measure of intra-industry trade will be biased downwards, arguing that C_i has a maximum value of less than 1 whenever $X_i \neq M_i$, and propose the following adjusted measure of intra-industry trade:

$$C_i = \frac{\sum_{j=1}^{n}[(X_{ij} + M_{ij}) - |X_{ij} - M_{ij}|]}{\sum_{j=1}^{n}(X_{ij} + M_{ij}) - |\sum_{j=1}^{n}X_{ij} - \sum_{j=1}^{n}M_{ij}|}$$

C_i has a minimum value of zero and a maximum of one, regardless of trade balance, and its use could be justified by the fact that it permits comparison of trade structure between countries which is not influenced by trade balance.

Aquino (1978) argues that B_i is an average, and that the correction should be not to the average, but to the individual components, and proposes the measure

$$Q_i = \frac{\sum_{j=1}^{n}(X_{ij} + M_{ij}) - \sum_{j=1}^{n}|X_{ij}^{e} - M_{ij}^{e}|}{\sum_{j=1}^{n}(X_{ij} + M_{ij})} = 1 - \frac{\sum_{j=1}^{n}|X_{ij}^{e} - M_{ij}^{e}|}{\sum_{j=1}^{n}(X_{ij} + M_{ij})}$$

where

$$X_{ij}^{e} = X_{ij}\frac{\frac{1}{2}\sum_{j=1}^{n}(X_{ij} + M_{ij})}{\sum_{j=1}^{n}X_{ij}} \quad \text{and} \quad M_{ij}^{e} = M_{ij}\frac{\frac{1}{2}\sum_{j=1}^{n}(X_{ij} + M_{ij})}{\sum_{j=1}^{n}M_{ij}}$$

While it is apparent that for $X_i \neq M_i$, $C_i > B_i$, there is no predictable relationship between C_i and Q_i. Aquino (1978) calculates all three measures for a number of countries for 1972 and shows that while, as expected, $C_i > B_i \ \forall \ i$, there were some countries for which $Q_i < B_i$ although, for the most part, $Q_i > Bi$. Also, $C_i > Q_i \ \forall \ i$ ($C_i \geq Q_i \ \forall \ i$ would be expected).

Greenaway and Milner (1981) offer a number of arguments against the concept of adjusting the measure of intra-industry trade to correct for trade imbalance. One of these is that any trade imbalance may be a transitory disequilibrium condition[17] which should not influence the measure of intra-industry trade, this being regarded as a more stable structural entity. In response, Aquino (1981) cites Japan as an example, arguing that this country has a stable trade deficit in natural resources and an accommodating surplus in manufactured goods; this being an equilibrium condition, and one which should be taken into account when determining the measure of intra-industry trade for this country.

Both arguments are credible; for a given country any imbalance on merchandise trade may be stable or it may be transitory. Greenaway and Milner (1981) propose avoiding periods of disequilibrium or, where such periods are extended, taking an average of the index during this period. This latter proposal presumes that any merchandise trade

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[17] The example given is the initial deterioration in the UK's current account deficit following the 1972 oil shock followed by deflation and exchange rate adjustment which in turn lead to an increased trade surplus in manufactured goods.

imbalance is transitory in nature. One approach might be to use an average of the trade balance over a period of time, thereby accommodating both transitory and stable trade imbalances.

Greenaway and Milner (1981) perceive the adjustment for trade imbalance as being a way to free the measurement of intra-industry trade from the influence of extraneous forces - to determine its value in the absence of such forces. This implies that such imbalance is accommodating rather than autonomous. The authors draw attention to the difficulty in determining those imbalances which are autonomous and those which are accommodating. This question can be summarized as follows. Does the current account accommodate the capital account, or *vice versa*. Within the current account, are the balances on services, income and merchandise independent or is there some co-dependency? And within merchandise trade is the balance on manufactured goods influenced at all by the balance on non-manufactured goods?

Aquino (1978) and Loertscher and Wolter (1980) use trade balance in manufactured goods as the basis of adjustment. Greenaway and Milner (1981) criticize this approach, claiming that there is no *a priori* justification for so doing, but without suggesting an alternative. Aquino (1978) argues that the approach is valid because the objective is to compare, across countries, the intra-industry specialization within trade in manufactured goods. Balassa (1986) uses the same method of adjustment, but adjusts for the imbalance in total trade.

Greenaway and Milner (1981) further criticize the use of the Q measure on the grounds that the correction for trade imbalance is proportionately the same for all categories. Aquino (1981) does not defend this on logical grounds, but simply that it is the best which can be done with the information available. Vona (1991) is also critical of the "need for correction argument", claiming that he cannot understand why a country's trade imbalance should not be included in its intra-industry trade measure. He is particularly critical of the Aquino correction, arguing that it was originally designed[18] as a measure of dissimilarity between the structure of a country's imports and exports, and finds it "hard to understand" how this is linked to the concept of intra-industry trade. However, it is readily apparent that, the greater the level of intra-industry trade, the greater the similarity in structure of imports and exports, measured at the same level of aggregation. The converse is also true, at any given level of trade imbalance.

Lee and Lee (1993), in their analysis of the determinants of intra-industry trade, are persuaded by the arguments of Greenaway and Milner (1981) and Vona (1991) against correcting their measure of intra-industry trade for trade imbalance, but in their estimation include a measure of bilateral trade imbalance[19]. The coefficient is significant with the expected sign. Rajan (1996) sets out to compare the intra-industry content of bilateral trade both for Singapore/US and Singapore/Japan, but acknowledges that the different levels of trade imbalance (24% with Japan, 9% with the US) may influence the results. Rather than use any of the existing adjustment procedures, he devises a new index (discussed below) which, he argues, will at least "mitigate" the effects of trade imbalance. Glejser (1983) and Glejser *et al* (1979,1982) also use a measure (discussed below) which is not sensitive to trade imbalance.

The majority of work on intra-industry trade uses the unadjusted Grubel-Lloyd (GL) index. This does not necessarily mean that the majority opinion is that trade imbalance is not an issue but, rather, that if adjusting for it introduces other problems, then it is better to keep it simple. It seems that there is no one right answer to this question and whether or not one adjusts for trade imbalance, and if so how, depends on the use to which the measure of intra-industry trade is to be put.

4.4.3 The Glejser Measure

Glejser (1983) and Glejser *et al* (1979,1982) take a different approach to the measurement of the degree to which a country's trade is intra-industry. While these authors support the correction for trade imbalance, and agree that the Aquino (1978)

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[18] Michaely (1962) pp 87-92 used the index $D_j = \sum_{i=1}^{n} \left| \frac{X_{ij}}{Xj} - \frac{M_{ij}}{M_j} \right|$ as an "index of dissimilarity" between the imports and exports of country j. Only a low level of disaggregation was used, n having the value of 5.

correction is an improvement on the Grubel and Lloyd (1971) attempt, they argue that there are still problems, and that the only solution is to break the connection between exports and imports.

The connection is severed by having two separate measures, one for imports and one for exports. These measures were originally calculated (Glejser *et al*, 1979) for the members of four groups of countries drawn from 21 predominantly OECD countries, using "intra-group" imports and exports. The reasoning behind the measure used is that, if a country's trade is predominantly intra-industry, then the composition of its imports and exports should be similar to that of the aggregate imports and exports of the group as a whole.

The Glejser export index is calculated as follows. For each country i and commodity j

$\xi_{ij} = \log(\frac{X_{ij} / X_{.j}}{X_{i.} / X_{..}})$ where X_{ij} is the total intra-group export of commodity i from country j, $X_{.j}$ is the total intra group export of country j, $X_{i.}$ is the total intra-group export of commodity i and $X_{..}$ is the total intra-group export.

The Glejser export index for any country is s_ξ^2, the variance of the ξ_{ij}, calculated as

$$s_\xi^2 = \frac{1}{n}\sum_{i=1}^{n}(\xi_{ij} - \xi_j)^2$$

where ξ_j is the mean value of ξ_{ij} for country j. $\xi_j = \frac{1}{n}\sum_{i=1}^{n}\xi_{ij}$

The Glejser import index, s_μ^2, is calculated in the same way using the corresponding import values.

The s_ξ^2 and s_μ^2 are calculated for each of the 21 countries, together with the Grubel - Lloyd and Aquino coefficients. The values of the correlation coefficients between s_ξ^2 and s_μ^2 and the Grubel-Lloyd coefficient are 0.63 and 0.82, and between s_ξ^2 and s_μ^2 and the Aquino coefficient 0.68 and 0.81.

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[19] Trade imbalance is measured as $|X-M|/(X+M)$.

Glejser (1983) suggests that $X_{i.}$ and $X_{..}$ should exclude X_{ij} and $X_{.j}$ respectively for the country under consideration, the argument being that there will otherwise be, particularly in the case of large exporters, an upward bias in the measure of intra-industry trade. It is not explicitly covered, but the same argument could apply to the import measure.

4.4.4 The Vona Measure

Vona (1991) suggests that, at some disaggregated level of bilateral trade (4 or 5 digit SITC are suggested), trade should be considered intra-industry or not, depending on the existence or otherwise of two-way trade regardless of, as it is described, whether or not there is an imbalance. At any higher level of aggregation, the value of the intra-industry trade index for category j for bilateral trade between countries A and B is given by

$$IIT_{A,B,j} = \frac{\sum_i I_{A,B,i}}{X_{A,B,j} + M_{A,B,j}} \quad \forall\, i \in j$$

where $I_{A,B,i} = \mid X_{A,B,i} + X_{B,A,i}$ if ($X_{A,B,i}$ and $X_{B,A,i}$) $\neq 0$

$\mid 0$ otherwise

The value of this index for bilateral trade in manufactures between twelve countries is, as expected, greater than that for the Grubel-Lloyd index (uncorrected). The correlation coefficient is 0.73. The skewness was -1.32 for the former and 0.32 for the latter.

The values of the index for a number of 3 digit SITC categories were spread over the full range. This, together with the fact that adjustment for trade imbalance is not necessary, is regarded as an advantage.

4.4.5 The Rajan Measure

To reduce the effect of bilateral trade imbalance, Rajan (1996) employs the measure,

for industry i, $$R_i = \frac{\min(X_i, M_i)}{2M_i} + \frac{\min(X_i, M_i)}{2X_i},$$

and the aggregate $R = \sum_i \frac{X_i + M_i}{X + M} R_i$

The overall intra-industry trade measure is higher using this index than with the traditional Grubel-Lloyd index, with the increase being greater for Singapore/US trade[20], such that the difference between the measured intra-industry trade for the two pairs of trading partners is no longer significant. For Singapore/US trade, the top ten product groups (3 digit SITC), in terms of measured intra-industry trade, are identical for both measures; while for Singapore/Japan trade there are only two product groups in common between the two measures. Using the Grubel-Lloyd index, there are only two product groups in common in the top ten between the two sets of trading data, while with the Rajan measure there are eight.

The range of possible values for this index ($0.5 \leq R_i \leq 1$) is less than that for the Grubel-Lloyd index ($0 \leq B_i \leq 1$). Rajan (*op. cit.*) points out that the index proposed here meets the requirement for linearity described by Greenaway and Milner (1986, p63).

4.4.6 Other Measures of Intra-Industry Trade

Grubel and Lloyd (1971) cite a number of earlier measures of intra-industry trade. These include Verdoorn (1960), who used the measure (X_i/M_i), Kojima (1964) used $\min(X_i/M_i, M_i/X_i)$, and Grubel (1967) used $\max(X_i/M_i, M_i/X_i)$. The connection between these and the G-L index is as follows. If $u_i = \min(X_i/M_i, M_i/X_i)$ then $B_i = 2u_i/(1+u_i)$, where B_i is the Grubel-Lloyd index.

4.4.7 Marginal Intra-Industry Trade

The objective of the measure of marginal intra-industry trade is to measure the intra-industry content of a change, usually an increase, in trade.

In an analysis of the effect of the Closer Economic Relationships (CER) Agreement on Australian/New Zealand trade, Hamilton and Kneist (1991) attempt to measure, for specific sectors, the proportion of increased trade which is intra-industry. They argue that, because any increase in inter-industry trade which reduces the trade imbalance in any category will show up as increased intra-industry trade, the difference in the

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[20] Bilateral trade imbalance Singapore-Japan is 24%, while that for Singapore-US is 9%.

"before and after" values of the unadjusted Grubel and Lloyd index is potentially misleading as a measure of increased intra-industry trade.

As a solution the following measure of marginal IIT is proposed:

$$
\mathrm{MIIT} = \begin{cases} \dfrac{X_t - X_{t-n}}{M_t - M_{t-n}} & \text{for } M_t - M_{t-n} > X_t - X_{t-n} > 0 \\[2ex] \dfrac{M_t - M_{t-n}}{X_t - X_{t-n}} & \text{for } X_t - X_{t-n} > M_t - M_{t-n} > 0 \\[2ex] \text{undefined} & \text{for } X_t < X_{t-n} \text{ or } M_t < M_{t-n} \end{cases}
$$

Greenaway et al (1994b) point out that a serious bias is introduced because this index is undefined whenever exports or imports decrease. Their solution is to use an unscaled measure, $\Delta IIT_j = \Delta[(X_j+M_j)-|X_j-M_j|]$, which in turn needs to be adjusted for inflation. The authors claim some advantage in this measure being unscaled, arguing that it can now be normalized against total trade.

Shelburne (1993) argues that the analysis of Globerman (1992), showing an increase in intra-industry trade for bilateral US/Mexico trade during the 1980s, suffers the same problem as that outlined by Hamilton and Kneist (1991). In this analysis, Globerman (*op. cit.*) shows Mexico and Canada having approximately the same value of intra-industry trade for bilateral trade with the US at the end of the decade, but Mexico with a lower starting value. Shelburne (*op. cit.*), using the measure $MIIT_i = A_i = 1 - \dfrac{|\Delta X_i - \Delta M_i|}{|\Delta X_i| + |\Delta M_i|}$ for marginal intra-industry trade, finds that the intra-industry trade content of the increased bilateral trade between Canada and the US is substantially larger than that for Mexico.

Brulhart (1994) points out that the Greenaway *et al* (1994b) measure still has the problem that an increase in inter-industry trade, which decreases the imbalance in the category being considered, will show up as an increase in intra-industry trade in that category, and endorses the measure used by Shelburne (*op. cit.*), with the qualification that ΔX and ΔM should refer to real changes noting, as do Greenaway et al (1994b), that the use of nominal values will inflate the measure of marginal intra-industry trade.

It is further suggested by Brulhart (1994) that the measure of marginal IIT provided by

$B_i=1-\frac{\Delta X_i - \Delta M_i}{|\Delta X_i|+|\Delta M_i|}$ may be more informative as it gives the direction of change. Being signed, this measure cannot be meaningfully aggregated.

4.5 Empirical Support

4.5.1 Empirical Methods

There have been a number of empirical analyses of the determinants of intra-industry trade, the results of which have not been in total agreement. When account is taken of the varying domains represented by the samples used, the range of measures of intra-industry trade and the variety of models estimated, this is not surprising. The objectives of the various analyses differ, some estimating industry specific determinants[21], others country specific determinants[22], and some both.[23] Within this categorization, intra-industry trade may be considered on either a bilateral[24] or multilateral[25] basis.

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[21] Caves (1981), Clark (1993), Gavelin and Lundberg (1983), Greenaway (1983), Greenaway and Milner (1984), Hughes (1993), Lundberg (1982,1988), Marvel and Ray (1987), Pagoulatos and Sorensen (1975), Tharakan (1984), Toh (1982).

[22] Balassa (1986a), Bergrstrand (1990), Havrylyshyn and Civan (1983), Hummels and Levinsohn (1995), Lee and Lee (1993), Stone and Lee (1995).

[23] Balassa (1986b), Balassa and Bauwens (1987), Loertscher and Wolter (1980), Culem and Lundberg (1986), Somma (1994).

[24] Balassa (1986a) and Balassa and Bauwens (1987) using a sample of 38 countries (18 developed, 20 developing) for 1979. Bergstrand (1990) uses 1976 data for "fourteen major industrialised countries". Hummels and Levinsohn (1995) use trade data 1962-1983 for the OECD. Lee and Lee (1993) bilateral trade between Korea and 81 trading partners for 1986.Loertscher and Wolter (1980) use intra OECD (exc Australia and New Zealand) trade for 1972 and 1972. Somma (1994) uses 1989 data from a sample of eight OECD countries.

[25] Balassa (1986b) using the same data set as Balassa (1986a). Caves (1981) 1970 data from 13 OECD countries. Clarke (1993) US multilateral trade for 1980,4,6 with RoW. Culem and Lundberg (1986) 1980 trade of 11 OECD countries with 5 country groups. Gavelin and Lundberg(1983) use Swedish trade with a group of LDCs for 1970,74,77,79. Greenaway (1983) and Greenaway and Milner (1984) use 1977 UK trade with RoW. Havrylyshyn and Civan (1983) 1978 trade for a group comprising 44 developing and 18 industrialized countries. Hughes (1993) the trade from 1980-7 of 6 OECD countries with the RoW. Lundberg (1982) Swedish total trade (RoW) 1979 & 1977. Lundberg (1988) Swedish trade with a group of LDCs and CPEs. Marvel and Ray (1987) 1972 US trade with the RoW. Pagoulatos and Sorensen (1975) 1965 and 1967 trade for the US with RoW. Stone and Lee (1995) multilateral trade with RoW for 1970 and 1987 for 36 manufacturing countries (inc 20 OECD) and 32 non-manufacturing countries. Tharakan (1984) multilateral trade between 5 individual DCs and a group of LDCs for1972-4. Toh (1982) 1970 and 1971 US trade with RoW.

4.5.1.1 Trade classifications

The classification and categorization of trade data varies across analyses, as follows.

4.5.1.1.1 SITC Standard International Trade Classification

All of the following use only the manufacturing SITC sections (5-8). Caves (1981) employs 94 3-digit SITC categories, Greenaway (1983) and Greenaway and Milner (1984) concord a number of 3-digit SITC categories with the UK SIC to produce up to 68 categories, Loertscher and Wolter (1980) use 59 3-digit categories, Pagoulatos and Sorensen (1975) and Tharakan (1984) use 102 3-digit categories, Lee and Lee (1993) and Stone and Lee (1995) use 144 3-digit categories.

4.5.1.1.2 US SIC United States Standard Industrial Classification

Balassa (1986a, 1986b) and Balassa and Bauwens (1987) merge "economically similar" categories of the 4-digit level of the US SIC to come up with 167, 167 and 152 categories. Toh (1982) uses 112 4-digit categories, and Marvel and Ray (1987) 314 4-digit categories.

4.5.1.1.3 ISIC International Standard Industrial Classification

Culem and Lundberg (1986), Gavelin and Lundberg (1983) and Lundberg (1982) use 4-digit manufacturing categories, the last of these specifying 77 categories, while Hughes (1993) uses 68 categories from the 4-digit ISIC.

4.5.1.1.4 Others

Somma (1994) aggregates data from 16 8-digit European Community External Database (NIMEXE) categories in an analysis of the European computing industry. Lundberg (1988) uses the lowest level of the SNI (Swedish) - claimed to be virtually identical to the ISIC - excluding agriculture, food and mineral extracting industries; leaving 139 categories.

4.5.1.2 Intra-Industry Trade Measures

The most commonly used measure of intra-industry trade is the unadjusted Grubel and Lloyd index.[26] Balassa (1986a,b), Balassa and Bauwens (1987) and Loertscher and Wolter (1980) use the Aquino (Aquino, 1981) measure, the adjustment being made on the basis of total merchandise trade imbalance. Bergstrand (1990) uses the trade imbalance adjusted Grubel-Lloyd (Grubel and Lloyd, 1971) index. Caves (1981) employs the method of Hesse(1974), to give an aggregate measure by industry across the countries being considered. Loertscher and Wolter (1980), in addition to the Aquino measure, use $(-\ln|X_{ijk}/M_{ijk}|)$.

4.5.1.3 Model Specifications

Ordinary least squares estimation using a linear model is the one method most commonly employed. In addition to, or instead of, the linear model, Greenaway (1983) and Greenaway and Milner (1984) use log linear, as does Hughes (1993); while Pagoulatos and Sorensen (1975), Culem and Lundberg (1986) and Lundberg (1988) employ a double log model.

Balassa (1986a,b) and Balassa and Bauwens (1987) use non-linear least squares to estimate a logistic model[27], as do Lee and Lee (1993) and Stone and Lee (1995). Bergstrand (1990), Caves (1981), Loertscher and Wolter (1980), and Tharakan (1984) estimate a logit model[28] using weighted least squares, while Culem and Lundberg (1986), Lee and Lee (1993), Lundberg (1988), Hummels and Levinsohn (1995)and Stone and Lee (1995) estimate a logit model with ordinary least squares.

Loertscher and Wolter (1980) do not discuss their reason for using the logit model. Caves (1981) justifies the use of the logit transformation on the grounds that, while the measure of IIT used is bounded by zero and one, there is always the possibility that a regression will predict values outside of this range. Those who do not use the logit or logistic forms are apparently unconcerned with this possibility.

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[26] Bergstrand (1990), Culem and Lundberg (1986), Gavelin and Lundberg (1983), Lundberg (1987), Greenaway (1983), Greenaway and Milner (1984), Hughes (1993), Lee and Lee (1993), Marvel and Ray (1987), Pagoulatos and Sorensen (1975), Somma (1994), Tharakan (1984), Stone and Lee (1995), Toh (1982)

[27] $IIT_i=1/(1+\exp^{(-\beta' z)})+u_i$

[28] The dependent variable is transformed to ln[IIT/(1-IIT)].

However the logit form brings its own problems, since it does not permit the use of values of zero or one for the measure of intra-industry trade (zero is quite probable, one highly improbable), and this is the reason given by those who use the logistic form. The rate of incidence of zero intra-industry trade is likely to be highest in the case of, for example, Balassa and Bauwens (1987), who analyze bilateral intra-industry trade at the level of 152 different categories, in a sample which includes developing countries. In this particular example, the incidence of observed zero intra-industry trade is 22% in the case of trade between developed countries, 51% in the case of trade between all countries, 64% between developed and developing and 74% between developing countries.

Balassa (1986b), in a similar study at the individual trade category level but considering only bilateral trade with the US, estimates a logit model with weighted least squares (excluding zero observations), and a logistic model with non-linear least squares, both with and without zero observations, thereby enabling comparisons. The logistic form including zero observations produced the higher number of significant estimates. Balassa (1986a) estimates the determinants of intra-industry trade on a country basis, for bilateral trade between the US and 38 countries - where one would expect no instances of zero intra-industry trade- using both logit with OLS and logistic with non-linear least squares, and obtains very similar results. Caves (1981) uses a cross-country aggregate measure of industry specific industry trade and obtains a range of intra-industry trade values of 25 to 82, with only 7 of the 94 observations below 40.

Balassa (1986b) is critical of the use of WLS to estimate the logit model, pointing out that the rationale for heteroscedasticity does not apply here. Lee and Lee (1993) explicitly test their logit model for heteroscedasticity, rejecting the null hypothesis of heteroscedasticity, and accordingly use OLS to estimate their logit model. It is also pointed out (Balassa, *op cit*) that Loertscher and Wolter (1980) weighted the explanatory variables but not the dependent variable, and that Caves (1981) divided rather than multiplied the variables by the weighting factor - a technique which, when replicated by Balassa, resulted in the number of significant variables being reduced from fourteen to two and R^2 from 0.87 to 0.1.

4.5.1.4 Trade Imbalance

Another source of variation is the treatment, if any, of trade imbalance. Culem and Lundberg (1986), Lee and Lee (1993) and Stone and Lee (1995) all use the unadjusted Grubel and Lloyd index, but include as an explanatory variable a measure of trade imbalance[29] which, in all three cases, is significant and negative. Given that the measure of intra-industry trade is at the country pair/industry level in Culem and Lundberg (1986), at the country pair level in Lee and Lee (1993), and at the country level in Stone and Lee (1995), this result has broad application. In Stone and Lee (1995), trade imbalance is also significant in a model where all variables represent change in value over time.

The conclusion is that, under some circumstances, not allowing for trade imbalance could lead to a specification error.

4.5.2 Determinants of Intra-Industry Trade

Measured intra-industry trade is determined both by the attributes of the countries involved, and by the attributes of the individual trade categories.

4.5.2.1 Country Attributes

Models of trade which include trade driven by product differentiation, and trade in an undifferentiated good, show that measured intra-industry trade (and the volume of trade in differentiated goods) increases with the degree of similarity in factor endowments between trading partners[30]. Empirically, similarity between trading partners is often proxied by difference in per capita GDP. Balassa (1986b), Balassa and Bauwens (1987), Bergstrand (1990), Culem and Lundberg (1986), Hummels and Levinsohn (1995), Lee and Lee (1993), Loertscher and Wolter(1980) and Somma (1994) all show that difference in per capita GDP is negatively correlated with measured bilateral intra-industry trade. The result of Balassa and Bauwens (1987) is qualified to the extent that a significant negative estimate was obtained only for trade between all the sampled countries, and between developed and developing countries.

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[29] Culem and Lundberg (1986) use X_{ij}/M_{ij} or reciprocal, which ever is greater, where X_{ij} and M_{ij} are bilateral manufactured exports and imports between countries i and j. Lee and Lee (1993) and Stone and Lee (1995) $|X_i+M_i|/(X_i+M_i)$ where X_i and M_i are total exports and imports for, in the case of the former country pair i, and in the case of the latter country i with the rest of the world.

In the cases of trade solely between developed countries, and between developing countries, the estimate was not significant.

Attempts to measure directly the effects of differences in factor endowments have been less successful. Bergstrand (1990) finds the difference in the capital to labour ratio insignificant in bilateral trade between 14 OECD countries for 1976, for a narrow range of industries[31]. Hummels and Levinsohn (1995) also estimate the effect of the difference in the capital to labour for intra OECD trade for each year of the period 1962 to 1983. The coefficient is significantly negative for the years 1962 to 1968, not significant for the years 1969 to 1980, and significantly positive thereafter (there is an overall trend throughout the period).

The difference in the labour to land ratio is significantly negative throughout the entire period. However, with the addition of a distance variable, it becomes insignificant for the last 5 years (but still negative). Difference in the capital to land ratio, which has some significance (negative) in the absence of the distance variable, becomes consistently insignificant in its presence. It appears that the only factor ratio with any robustness is that of land to labour - the only factor ratio estimated which is comprised solely of exogenous factors.

Both Krugman (1979a) and Lancaster (1980) rely on economies of scale to determine the level of product differentiation. Stone and Lee (1995), Somma (1994) and Balassa and Bauwens (1987) argue that country size contributes to the development of scale economies. The implicit assumption here is that the domestic market size has significance even for traded goods, and is consistent with Krugman (1980) and Weder (1995). Balassa (1986b), Balassa and Bauwens (1987), Bergstrand (1990), Loertscher and Wolter (1980) and Somma (1994) find the coefficient of the average GDP of the two countries to be positive in the case of bilateral trade, while Balassa (1986a) and Stone and Lee (1995) find the coefficient of GDP to be positive in the case of multilateral trade.

The model of Helpman (1981) demonstrates that, all else being equal, intra-industry trade is maximized when two countries are of equal size. This argument is an

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[30] Lancaster (1980), Helpman (1980,1984), Grossman and Helpman (1989,1991c)

[31] SITCs 71: non-electrical machinery, 72:electrical machinery, 73: transportation equipment.

extension of the concept of "false comparative advantage" propounded by Lancaster (1979), whereby the larger country will have a relatively lower price in the increasing returns to scale manufacturing industry relative to that of the constant returns to scale agricultural industry, leading to inter-industry trade even with equal factor endowments. Balassa (1986b), Bergstrand (1990), Lee and Lee (1993) and Loertscher (1980) use difference in GDP as an explanatory variable for bilateral intra-industry trade, and find the coefficient to be significantly negative. Balassa and Bauwens (1987) find the coefficient positive in the case of bilateral trade between developing countries, but negative in each of the other three cases.[32] Somma (1994) estimates a quadratic function of GDP difference and finds the coefficient for GDP difference to be positive but the coefficient for its square to be negative, suggesting that small differences in GDP increase intra-industry trade, but large differences reduce it. This is a relatively narrow study, however, being based on bilateral trade in computers amongst eight European countries, so that this result is not necessarily applicable to the general case.

Geography also seems to play a part in intra-industry trade. Balassa and Bauwens (1987), Balassa (1986a,1986b), Culem and Lundberg (1986), Hummels and Levinsohn (1995), Loertscher and Wolter (1980) and Stone and Lee (1995) obtain negative estimates for the distance variable, be it bilateral distance or weighted average distance in the case of multilateral trade. In the case of Stone and Lee (1995) distance was negative in the case of trade between manufacturing countries, but positive in the case of trade between non-manufacturing countries.[33] Balassa (1986a), Balassa and Bauwens (1987), Bergstrand (1990) and Loertscher and Wolter (1980) test for the effect of a common border, which they find to be positive, although in the Loertscher and Wolter (1980) analysis this is so only in the case of the estimation using the unadjusted Grubel-Lloyd index, and not with the logit transformation of the Aquino measure.

Both of these results are open to interpretation. At a minimal level, the negative coefficient for distance could be interpreted as reflecting the effect of transport costs,

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[32] The other three cases being: bilateral between all countries, bilateral between developed countries, bilateral between developed and developing countries.

[33] Manufacturing countries are those for whom manufactured exports accounted for at least 25% of total exports in both 1970 and 1987.

and the significance of adjacency as a measure of "cross-border trade". An interpretation more specific to differentiated goods is that the distance variable reflects the cost of providing information. The significance of the common border may reflect a measure of proximity not included in the distance variable, similarity in tastes, or simply not being separated by ocean. One might, for example, expect a common US/Canada border to have some impact on bilateral trade between these two countries beyond that of "cross-border trade".

4.5.2.2 Product Attributes

Scale economies and product differentiation are commonly proposed determinants of intra-industry trade are. The difficulty in estimating the contribution of these two is that, as earlier discussed, neither is independent of the other. Trade based on differentiated products requires the interaction of both attributes. Neither is directly measurable, thereby requiring the use of proxies - the validity of which cannot be independently verified. This can lead to the one variable being used as a proxy for both attributes. For example, the proxy used by Somma (1994) for product differentiation is very similar to that used by Balassa (1986) and Belassa and Bauwens (1987) for scale economies. While in this case all three obtained the same sign, Hughes (1993) obtained a negative estimate for the concentration ratio as a proxy for scale economies, but when it was used as a proxy for product differentiation, the estimate obtained by Marvel and Ray (1987) was positive and by Balassa (1986b) negative.

4.5.2.2.1 Scale Economies

The more frequently used proxies for scale economies are the ratio of output or value added for larger firms to that of smaller firms, and the concentration ratio[34]. For the most part such estimates are negative, although Somma (1994) finds evidence of an inverted U effect. Loertscher and Wolter (1980) employ value added per establishment[35], for which they obtain a negative estimate. Tharakan (1982) employs the same measure but, following the argument of Bergstrand (1983) that the degree of increasing returns is a positive function of product differentiation, argues that one

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[34] Balassa (1986), Balassa and Bauwens (1987), Caves (1981), Gavelin and Lundberg (1983),Greenaway (1983), Greenaway and Milner (1984), Hughes (1993).

[35] US data for 1972, in $US M.

cannot include both variables, and as an alternative divides the observations into two groups around the median value of this measure, and estimates each separately.

Marvel and Ray (1987) use the capital to labour ratio as a proxy, and obtain a negative estimate. Toh (1982) uses as a proxy the ratio of degree of mechanisation to the level of human capital[36], and obtains a positive estimate. These two variables gave positive and negative estimates respectively when estimated separately.

These apparently contradictory results are not surprising, given the range of proxies employed, and are not inconsistent with theory. In those models which rely on scale economies to define product differentiation, the absence of scale economies could lead to each variety being produced in each country, while sufficiently high scale economies could lead to very few varieties, or only one variety, being produced globally. In fact Balassa and Bauwens (1987) argue that scale economies are an indication of product standardization, and expect the coefficient for scale economies to be negative, which they find to be the case.

It has been suggested that the lack of clear evidence for scale economies as a determinant of intra-industry trade should be interpreted as indicating that scale economies are not a determinant (Pomfret, 1986)[37]. However such comments overlook the fact that, as outlined above, the theoretical contribution of scale economies to intra-industry trade is not a simple one, and therefore it is not inconsistent with theory that results for this variable should be mixed.

4.5.2.2.2 Product Differentiation

The range of proxies employed for product differentiation is no less diverse than that for scale economies. Some of the more commonly used proxies, and the results, are as follows.

4.5.2.2.2.1 The Hufbauer Index

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[36] The degree of mechanization is calculated as the expenditure on new equipment per worker, and the level of human capital as the difference between average wage by industry and average wage for males with eight years of education.

[37] Commenting on Tharakan (1983).

This index was developed by Hufbauer (1970). Based on US export data for 1965 it is the coefficient of variation in unit values across countries of destination[38]. Originally calculated at the 7-digit level of the SITC revision 1 for those categories for which quantity data are available, it is presented and summarised at the 3-digit level (SITCs 5-8) using a simple mean, ignoring those categories for which quantity data are not available.

Gray and Martin (1980) criticize the use of this index as an indicator for product differentiation on two grounds. It is argued that unit values are not prices or price indices, citing Kravis and Lipsey (1971)[39], that the 7-digit level of the SITC is too high a level of aggregation for such a purpose, and that variations in unit value are more likely to reflect variations in composition than in price. It is noted that Hufbauer and O'Neill (1972), in a regression of a sample of relative unit values against country specific determinants, obtained an R^2 value of only 0.16, concluding that the Kravis and Lipsey (1971) were correct and that much of the variation arises from variation in content.

Kravis and Lipsey (1972) may have been critical of the use of unit value as an index but not of the concept that prices may vary across countries. In a cross-country regression of the price index of tradeables against per capita GDP, Kravis and Lipsey (1978) obtain an R^2 of 0.45 to 0.78[40]. These authors argue that price discrimination can occur between countries where, coupled with market separation, oligopolistic firms face different elasticities in different markets, and that this is more likely to occur in the case of differentiated products.

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[38] The distinction by country of destination is not a design point of this index, but is dictated by the availability of data. The original intent seems to have been to use simply variation in UV by export shipments (Hufbaeur 1970 p190).

[39] Kravis and Lipsey (1971) are critical generally of the use of unit value (UV) as price indices, but do not specifically mention the Hufbaeur index or the use to which it is put. K&L (1971) are specifically interested in measuring export "price competitiveness" across countries and changes over time. Consequently they are sensitive to differences in composition over time and between countries, which would tend to invalidate their analysis. In support of the argument that change in composition is a real problem with the use of UV indices, the divergence of wholesale price indices (domestic) and export unit values indices is given as an example (K&L 1971 pp6-7). However in a later work (Kravis and Lipsey 1978) examples of divergence between wholesale (domestic) price indices and export price indices over time (pp228-32), even at the 4 and 5 digit level of the SITC (pp237-40). This is attributed, in part at least, to different prices being set in domestic and overseas markets.

[40] Kravis and Lipsey (1978) p222. Price levels calculated across all tradeable commodities. They obtain an elasticity coefficient of 0.095 for per capita GDP, compared with an estimate of 0.08 for per capita GDP by Hufbaeur and O.Neill (1972).

This argument seems to have been missed by Greenaway (1984) who asserts that, while the index may be a useful proxy for vertical differentiation, it cannot be used for horizontal differentiation. This is, perhaps, based on an implicit assumption that cross country variation in prices can arise only from variation in quality. Several lines earlier it is argued that, with market power, "pricing policy may be geared to local market conditions"(*ibid.* p234), but the connection between product differentiation and market power seems to have been missed.

Gray and Martin (1980) list a number of 3-digit SITC categories which they describe as "clearly monopolistically-competitive", but which have low values of the index. They do not, however, mention any categories with high values of the index which they consider should not qualify. This is not inconsistent with the argument that, even if product differentiation provides market power, which in turn enables price discrimination across countries, it does not follow necessarily that all cases of product differentiation will give rise to significant price variation across countries. To this extent, the Hufbaeur index is a less than perfect proxy for product differentiation.

A number of studies[41] have found this index to be positive at the 1% significance level, but this result is not unanimous. Pagoulatos and Sorensen (1975) use this index in the form of a dummy variable, which has a value of one where the Hufbauer index exceeds the mean, zero otherwise. No reason is given for this approach. The estimate, while positive, is not statistically significant. Lundberg (1988) finds the Hufbauer index significant when a dummy signifying natural resource intensity is omitted. The correlation between the two is -0.36.

Tharakan (1982) divides his observations into two groups, those with scale economies above the median value and those below, and estimates each separately. For that group characterized as low economies of scale, the estimate was negative at the 1% level, while for the other group it was not significant. The measure used here for scale economies was found to be significant and negative in another study[42], but this does not readily explain these results. As the trade being studied by Tharakan (1982) was

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[41] Toh (1982), Gavelin and Lundberg (1983), Balassa (1986), Balassa and Bauwens (1987), Lundberg (1988) at 5%.

[42] The measure is value added per establishment, estimated by Loertscher and Wolter (1980) to be negative at the 1% level.

between developed and developing countries, this result is not inconsistent with that of Balassa and Bauwens (1987), who found the Hufbauer index to be significant for bilateral trade between all countries in their sample, between developed countries only, between developing countries only, but not between developed and developing countries. Culem and Lundberg (1986) obtain positive estimates for trade between developing countries only with the double log and logit models, and for trade between developed and developing countries only with the linear and double log models.

Caves (1981) does not obtain a significant estimate for the Hufbaeur index. However the comments by Balassa (1986b) on the use of WLS for the logit model employed by Caves (1981) should be kept in mind when interpreting this result.

4.5.2.2.2.2 Marketing Effort

Caves (1981) uses two variables here, one being all costs related to marketing, other than purchased advertising, as a percentage of total costs; and the other being purchased advertising as a percentage of sales. Both are based on US data. Neither Caves (*op. cit.*) nor Balassa (1986b) obtain significant estimates for the advertising variable, and Balassa and Bauwens (1987) do not estimate it.

Caves (*op. cit.*) argues that advertising can be high in situations where product differentiation is at the trivial level, and may be limited to image or packaging (for example soap powder or cigarettes), and that such differentiation is unlikely to be a basis of trade. Within the theory of trade in differentiated goods some fixed cost (and therefore scale economy) is necessary to achieve the one country per variety condition which underlies trade based on product differentiation. It might be of interest to estimate the interaction of scale economies and product differentiation. The difficulty is that this would need to be scale economies at the product variety level, and most, if not all, proxies which have been used for scale economies apply at the firm or plant level. The type of industry described by Caves (*op. cit.*) is that traditionally associated with brand proliferation.

Clarke (1993), Greenaway (1983) and Greenaway and Milner (1984) obtain positive estimates for the advertising to sales ratio. The only explanation to hand as to why this result should differ from that obtained by Caves (1981) and Balassa (1986b), is that the variable is not the same in both cases. In the case of the marketing variable Caves (1981) estimates a negative coefficient, while Balassa (1986b) and Balassa and Bauwens (1987) estimate a positive coefficient. Balassa (1986b) and Balassa and Bauwens (1987) employ non-linear least squares with a logistic model and include observations with zero intra-industry trade. Balassa (1986b) carries out three estimations: linear with logit transformation, non-linear logistic both with and without observations of zero intra-industry trade. The significant estimate was obtained only with the inclusion of the zero intra-industry trade observations. Caves (1981) uses bilateral data, but the method of calculating intra-industry trade leads to there being no observations with zero intra-industry trade (the minimum is 0.25), so that the condition required for a significant estimate in the analysis of Balassa (1986b) is not met.

4.5.2.2.2.3 Research and Development

Hughes (1993) obtains positive (mostly significant) estimates for research and development, Gavelin and Lundberg (1983) only for 1979, and Lundberg (1982) not at all. Lundberg (1982) does not include an estimate for 1979. It should be noted that while Hughes (1993) uses the ratio of R&D expenditure to value added from UK data for 1980 to 1987, Gavelin and Lundberg (1983) and Lundberg (1982) use the ratio R&D expenditure to sales value, apparently from Swedish data, pre 1975. Toh (1982) estimates a composite variable, the product of the date first traded and the number of patents issued 1970-72, which is found to be positive.

One difficulty in using R&D as a proxy for differentiation is the need to distinguish process R&D from product R&D; only the latter being considered relevant for differentiation. There is no evidence of this distinction being made in the cited studies. Another is obtaining consistent measures of R&D. There is an OECD standard, but it is not immediately apparent whether any of these studies conformed to it.

4.5.2.2.2.4 Other Measures

Caves (1981) uses the standard deviation of profit rates on equity capital, from 1969 US data, as do Balassa (1986b) and Balassa and Bauwens (1987). All obtain positive estimates, but that of Caves (1981) is not significant. Balassa (1986b) obtains a significant estimate only with a logistic model, not logit. Balassa and Bauwens (1987) obtain significant estimates only when both developed and developing countries are included. Given that Caves (1981) employs a logit model and considers only trade between developed countries, the lack of a significant estimate is consistent with the results of Balassa (1986b) and Balassa and Bauwens (1987).

Clark (1993), Culem and Lundberg (1986), and Gavelin and Lundberg(1983), include the unit value of exports, the theory being that, the higher the value relative to freight costs, the higher the probability of intra-industry trade. Clarke (1993) obtains a positive estimate for this variable in an analysis of US multilateral trade with the rest of the world, Culem and Lundberg (1986) obtain a positive estimate for trade between developed countries and a negative estimate when developing countries are included, and Gavelin and Lundberg (1983) a negative estimate for trade between Sweden and a group of developing countries.

Pagoulatos and Sorensen (1975) include the "mean distance shipped" variable, developed by Weiss (1972), as the mean distance shipped to market by industry in the US, and obtain the expected positive coefficient using US multilateral trade for 1965 and 1967. Toh (1982), using similar data for 1970 and 1971, does not obtain a significant estimate. Toh (1982) includes a number of industry specific independent variables not used by Pagoulatos and Sorensen (1975), a number of which are significant, which might explain this apparently contradictory result. In their respective studies of intra OECD trade, Caves (1981) does not obtain a significant estimate, while Loertscher and Wolter (1980) obtain a negative estimate. The latter result appears to be contrary to expectations, but is not discussed[43].

4.5.3 Conclusions

The evidence for intra-industry trade being a substantive phenomenon, as opposed to being a statistical artefact, may not be conclusive, but neither can it be easily dismissed.

The estimates of determinants which are country specific are more consistent than those which are industry specific. One reason for this might be that, in the case of country specific determinants, the variables used - GDP, per capita GDP, size, distance

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[43] Preliminary discussion describes this variable as a proxy for industry transaction costs and expresses an expectation that the sign will be positive.

- are readily available, on an annual basis if not better, so that various estimates are likely to use the same values for the same variables, and the values of variables used in any estimation can come from the same time period. Moreover, they are directly measurable, and do not rely on the use of proxies.

In contrast, the proposed industry specific determinants - scale economies and particularly product differentiation - are less precisely defined, and in both cases the relationship with intra-industry trade need not be monotonic. Increasing scale economies can ultimately reduce the number of varieties to one, eliminating intra-industry trade, while, at the other extreme, minimal scale economies can lead to unconstrained differentiation, thus eliminating the basis of trade in differentiated goods. Such problems are compounded by the fact that neither variable is directly measurable, the only option being proxies, some perhaps questionable. In most cases such industry specific proxies are derived from data for one country, yet applied cross-country; from one specific time period, yet applied to a time period up to 20 years later.

The level of intra-industry trade differs significantly amongst groups of countries. For example, from Stone and Lee (1995), a group of 34 non-manufacturing countries has an average intra-industry trade value of 0.17, while that for a group of 36 manufacturing countries an average of 0.52, and within that group the 20 OECD countries have an average intra-industry trade value of 0.61, with an average of 0.42 for the remaining 16. Yet, with few exceptions, the significance of the various country specific determinants remains consistent across different samples of countries, regardless of whether bilateral or multilateral trade data are used. As discussed in (4.2.1), any intra-industry trade arising from trade driven by factor proportions and an inappropriate categorization of goods would be random in nature. The consistency of results obtained on a country basis does not accord with such an explanation.

Another consideration which could contribute to estimates of intra-industry trade determinants being more consistent on a country than industry basis is that, while the definition of any country is likely to be consistent from one estimation to another, in many cases the level of aggregation of an "industry" is determined by the level at which industry specific data are available. The number of categories covering manufacturing goods varies from 314 to 59. Even within the one classification, the 3-digit SITC, the number of categories used ranges from 59 to 144. The analysis using only 59 of the 3-digit SITC manufacturing categories is that of Loertscher and Wolter (1980), who point out that "about half" of the categories had to be omitted because of "a lack of sufficiently reliable exogenous data". Taking into account all of the variations and difficulties in the estimates of industry specific determinants of intra-industry trade, some lack of consistency in the results is not surprising. Nevertheless, it is probably safe to say that there is considerable evidence in support of the argument that product differentiation is a determinant of intra-industry trade rather than, as suggested by Pomfret (1986), as evidence that product differentiation explains little intra-industry trade.

4.6 Horizontal and Vertical Intra-Industry Trade

4.6.1 Vertical Intra-Industry Trade from Quality Variation

Abd-el-Rahman (1991) distinguishes two categories of intra-industry trade on the basis of the ratio of import to export unit values in any category. Where this ratio falls outside of the range 1±0.15, trade is referred to as intra-range trade, and within the range as two way trade. These two categories are now commonly referred to respectively as vertical and horizontal intra-industry trade. On this basis it was estimated that some 50% of all French trade was horizontal intra-industry trade, 30% vertical intra-industry trade, and the remainder inter-industry trade.

On a similar basis, Greenaway, Hine and Milner (1994a) find that, for the UK, 70% of bilateral intra-industry trade is vertical and 30% horizontal, measured on a bilateral basis. This is markedly different from the break-down obtained by Abd-el-Rahman (1991) (60% horizontal, 40% vertical), for French trade with the rest of the world. In the latter case, the figures are based on multilateral trade, rather than bilateral, and it is of interest that some two thirds of horizontal IIT was on a triangular[44] rather than bilateral basis. This may, in part, explain the quantitative difference between the two results, although it is not immediately apparent why the so called vertical intra-industry trade should be more prevalent in bilateral than in multilateral trade.

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[44] Exports to and imports from different countries.

Greenaway, Hine and Milner (*op. cit.)* argue that a higher unit value is an indication of higher quality. It is suggested that the production of higher quality goods would be more capital intensive than that of the lower quality varieties and, accordingly, such trade could be explained by factor proportions. Difference in capital intensity, proxied by difference in per capita GDP, as a determinant of vertical, horizontal and total intra-industry trade, was estimated. In all three cases it was significant and negative. If vertical intra-industry trade is motivated by quality differences arising from differences in capital intensity, it would be expected that for vertical intra-industry trade the estimated coefficient would be positive.

Torstensson (1991,1996) uses quality of imports in an analysis of country specific determinants of vertical intra-industry trade, where import quality is measured by the ratio of import to export unit values. Using per capita GDP as a proxy for capital intensity of the source country, the expected sign is obtained in both cases. In the second study (Torstensson, 1996), other measures of physical capital intensity are not significant[45]; whereas a proxy for human capital is significant, with the expected sign[46]. In Torstensson (1991) the analysis is limited to those 4-digit categories of the SITC for which quantity was available in units of items (as distinct from weight or volume). This turns out to be only 23 categories, 13 of which are clothing products. Using per capita income as a proxy for capital to labour intensity the coefficient for this variable is found to be significant and positive for 17 of these products for both 1985 and 1986. Of these 17 products, 13 are clothing[47].

Ballance, Forstner and Sawyer (1992) estimate the significance of import/export unit value ratios as a determinant of North/South bilateral intra-industry trade between 20 developed counties and 25 LDCs. In an estimation including all manufactured goods, this variable is significant at the 10% level, with the expected sign. Replacing this ratio with a dummy variable, indicating whether the unit value of exports exceeds the imports for the developed country, gives a positive estimate for the dummy variable significant at the 1% level. The estimated coefficient for this dummy variable, from a

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[45] Cumulative gross investment (Summers and Heston, 1991), and energy consumption per capita.

[46] Mean years of schooling in 1980.

[47] Men's overcoats, suits, trousers and jackets. Women's coats and jackets, suits and costumes, dresses, skirts, and blouses. Men's shirts; pull-overs, twin-sets, cardigans, jumpers and the like; dresses, skirts suits and costumes; other knitted or crocheted outer garments.

number of estimations for specific 3-digit SITC groups, was not always significant, and several estimates had the wrong sign. Tharakan and Kerstens (1995) analyze bilateral intra-industry trade in toys between eight high income European countries and a number of lesser developed countries, and conclude that the intra-industry trade is predominantly horizontal in nature.

Greenaway, Hine and Milner (1995), in a cross-industry analysis of multi-lateral UK trade, test the hypothesis that industry specific determinants of intra-industry trade would vary between horizontal and vertical intra-industry trade. Three measures of scale economy were employed:

(a) average size of establishment
(b) the number of enterprises represented at the 3-digit SITC level
(c) the five firm concentration ratio.

In an analysis of total intra-industry trade, the coefficients were significantly (a) negative, (b) positive and (c) negative - suggesting on all three counts that scale economies make a negative contribution to intra-industry trade. When horizontal and vertical intra-industry trade were analyzed separately[48], (a) was again negative for both while (b) was positive for vertical intra-industry trade but negative for horizontal intra-industry trade. The five firm concentration ration was not analyzed at this level. The importance of Multi-National Enterprises (MNEs) to each industry was significant and positive both for overall and horizontal intra-industry trade, but significant and negative for vertical IIT. The results for vertical intra-industry trade were obtained only when a unit value difference of ±25% was used to distinguish horizontal from vertical intra-industry trade.

These results provide some support for the argument that there are some differences between horizontal and vertical intra-industry trade, but provide little information on the basis of these differences. There is little evidence that vertical intra-industry trade is based on variations in capital intensities between trading partners. The proposition

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[48] The dependent variable is the vertical or horizontal IIT within each of 77 manufacturing UK 3-digit SIC classifications. The distinction between the two types of IIT is made at the component 5-digit SITC categories.

that vertical intra-industry trade is motivated by different capital intensities between the two trading partners is based on the following premises:

(i) That higher quality varieties of goods are produced using relatively capital intensive techniques.

(ii) That capital abundant countries have a comparative advantage in the production of high quality varieties.

(iii) That unit price (or unit value) within a category is a proxy for quality. Specifically, that the ratio of an index of export prices to that of import prices in any category is a measure of the relative quality of exports and imports within that category.

All of the empirical analyses described above justify proposition (i) by citing Falvey (1981). This author explicitly sets out to create a model which is capable of explaining intra-industry trade in terms of the Heckscher-Ohlin model[49], and makes any assumption necessary to meet that end. This includes the assumption that the production of higher quality varieties is relatively capital intensive, and further assumes, *inter alia,* that capital is both sector specific and immobile between countries.

The second proposition also has its basis in Falvey (1981), where it is assumed that each country has a different wage. If the lower wage country is not to have an absolute advantage, in which case there would be no intra-industry trade, it is necessary to further assume that the higher wage country has the lower cost of capital and therefore a comparative advantage in high quality varieties. The model is based on these assumptions, rather than factor proportions, to ensure the absence of factor price equalization, the presence of which would make the direction of trade indeterminate. In Falvey and Kierzkowski (1987), non factor price equalization, with one country having a higher wage and the other a higher price of capital, is achieved in a less direct fashion[50].

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[49] p 496 "We attempt to minimize the departure from traditional theory by modifying the standard framework in only two essential respects."

[50] This model introduces a homogenous good with labour as the sole factor of production. Home is assumed to have a Ricardian technological advantage in the production of this good. Non specialization in production of this good requires home to have a higher wage. Non specialization in the quality differentiated good requires foreign to have a higher capital rental rate.

The third proposition, that price is a proxy for quality, is suggested by Abd-el-Rahman (1991) and further argued by Greenaway, Hine and Milner (1994a). The argument appeals to the logic that if an individual is willing to pay a higher price for one variety then it must be of higher quality, assuming perfect information. One difficulty with this argument is that there is no independent definition of quality. Quality all too easily becomes that not always tangible something (anything) which motivates a consumer to purchase a variety at one price when there is an otherwise ostensibly identical variety available at a lower price.

Greenaway *et al* (1994a) draw attention to several other difficulties in using price as a proxy for quality when dealing with aggregated trade data, and particularly in using unit value as a measure of price. One is that the exports and imports, in any one category, need not necessarily represent an identical - apart from quality - bundle of goods. That is, price difference could represent a difference in composition rather than in quality.

The other difficulty to which attention is drawn is that, in many instances, quantity data are not available in items but only in weight, so that price is per unit weight. Torstensson (1991, p186) argues that under these conditions " Unit prices will not then reflect quality very well", and consequently limits his analysis to those categories where quantity is available in units[51]. Greenaway *et al* (1994a) cite three references as precedents for price being used as a measure of quality, but these are specific industry analyses, the industries being motor vehicles, foot-wear, and clothing and textiles. These are industries for which the unit of measure is likely to be items, and the concept of quality easily grasped.

But even for motor vehicles, the relationship between price and quality, particularly in an international context, cannot be assumed. Mertens and Ginsburgh (1985) calculate price indices for motor vehicles for five European countries, controlling for variations in motor vehicle specifications. Ignoring country of origin, values of the index ranged from 100 to 144[52]. Taking into account country of origin, the range was 79 to 158[53]. In

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[51] In subsequent analyses, for example Torstensson (1996), this restriction is not maintained.

[52] This range of values reflects the price discrimination between countries for an identically specified vehicle.

[53] This index gives six values for each country, one for each country of manufacture. Variation in specification has been controlled for.

both cases one third of the values lie outside of the range of mean ±15%, and would qualify as vertical intra-industry trade under one of the criteria of Greenaway et al (1994), even though variations in specifications have already been allowed for.

This is one example of the literature on "pricing to market", dealing with cross country price variations. Monopoly power provides the ability to price discriminate between segmented markets (for example, between countries), and product differentiation is a source of monopoly power. It could well be that the price variations - seen by some as indicative of vertical intra-industry trade - are no more than an expression of the ability to price discriminate which comes with product differentiation.

In Greenaway *et al* (1994a), the single digit category for which vertical intra-industry trade represents the highest proportion of total intra-industry trade is SITC 5 (chemicals). Assuming that quantity in this category is measured in weight, it is not readily apparent that price per tonne represents quality. In fact, it is not apparent what the concept of quality means in this category, other than possibly different levels of concentration for the one chemical substance, and this would require an extremely detailed level of disaggregation to detect.

Some empirical support for price as a proxy for quality comes from Caves and Greene (1996), who analyze the correlation between product and quality for some 200 product categories. The median value of the rank correlation coefficient is between 0.3 and 0.4, depending on the form of price used, but for some 30% of the individual categories the correlation is negative. Wills and Mueller (1989), from an analysis of 133 food products, demonstrate that advertising is a significant determinant of price, holding, *inter alia*, quality constant. Marketing expenditure has been used as a proxy for product differentiation (Belassa and Bauwens, 1987, Francois and Kaplan, 1996).

Empirical support for the proposition that higher capital to labour ratio countries have a comparative advantage in the production of higher quality varieties is not overwhelming. Greenaway *et al* (1994a) obtain no support at all. Torstensson (1996) obtains the expected result only when using per capita GDP as a proxy. Torstensson (1991) obtains some support, but it is informative to consider this analysis in some detail. The scope of the analysis was limited to 23 products at the 4-digit SITC level, being those for which quantity data were obtainable in items. Of the seventeen for which per capita income had a significant positive coefficient for both years of the analysis, thirteen were clothing. While a positive correlation between quality and price of clothing products might be expected, the relationship between quality and capital intensity is less apparent.

It could be argued that, for these products, higher quality is more likely to be associated with "hand made" and small volumes rather than "machine made" and large volumes. It is likely that demand in a higher income country will be for higher price clothes, be it for reasons of quality, fashionable design, or the “image” associated with successfully marketed brand names. Domestic demand could be expected to have some influence on the decisions of producers, and the relative prices of imports and exports might be no more than a reflection of a “home market” effect.

Per capita income is likely to be correlated with wages, particularly in a group including both developed and lesser developed countries. The result that higher priced imports come from countries with a higher capital to labour ratio (proxied by per capita income) could equally be interpreted as nothing more than that higher priced imports come from countries with higher wages. Mean years of schooling, employed by Torstensson (1996) as a proxy for human capital, is also likely to be correlated with wages. Unequal wages between two trading partners requires non factor price equalization, but this is not unexpected in the case of bilateral trade between a developed country and a lesser developed country. And the model of Falvey (1981) explicitly requires non factor price equalization. The argument that wages are a determinant of price is not inconsistent with the theoretical literature. Models based on the product cycle with horizontal differentiation give different prices where there are different wages (Krugman, 1979b, Grossman and Helpman, 1993), while Krugman (1980) shows horizontal intra-industry trade with price differences arising from country specific demand conditions. Models incorporating quality levels and trade in differentiated goods may or may not have equal prices, depending on whether or not there is factor price equalization. Models within the product cycle framework tend to have price variations (Grossman and Helpman, 1991b, 1991d), whereas those based on similar countries have equal prices where there is factor price equalization (Grossman and Helpman, 1991a,1991c).

The possibility of concurrent imports and exports within the one category being driven by quality differences cannot be denied. But for differentiated products, there are explanations for price differences other than difference in quality. Neither is there any reason to expect quality to be systematically correlated with capital intensity. Any argument that intra-industry trade is largely vertical in nature and explicable by factor proportions is less than compelling, particularly for intra-industry trade between countries at similar stages of economic development.

4.6.2 Vertical Intra-Industry Trade in Intermediate Goods

The term "vertical intra-industry trade" has also been used to describe trade in intermediate good where such goods are contained within the one trade classification (for example, Pomfret 1986).

Such trade is given a theoretical foundation in Ethier (1979,1982), and Helpman and Krugman (1985, Chapter 11 "Intermediate Inputs".). A model based on Krugman (1985) was estimated by Harrigan (1995) using bilateral data from 21 OECD countries at the 2 digit ISIC level. The results show no support for the model and the author concludes (p286) that it is a "poor description of reality". The results were not improved by disaggregation into 3 digit ISIC categories, nor was the addition of factor endowments to the model supported by results.

4.7 Summary

To regard observed intra-industry trade as a substantive phenomenon is not to dispute the factor proportions theory of trade but rather to accept that not all trade need be explained by factor proportions. Both the theory of trade driven by product differentiation and the Product Cycle theory are based on such a premise.

Leamer (1993) argues that "the Heckscher-Ohlin factor-proportions theory is both factually correct and factually incorrect..... factor supplies can explain a substantial amount of *net* trade...in raw materials, agricultural products, and labour-intensive manufactures. The net trade in more complex or more disaggregated manufacturing categories is not so well explained.". Lipsey (1976), discussing the significance of measured intra-industry trade, argues "It does suggest that there are large portions of international trade not explained by conventional trade theory....puts a strong emphasis on the need to take account of both economies of scale in production and product differentiation". Vernon (1966) introduces the product cycle theory as one which "...puts less emphasis upon comparative cost doctrine and more upon the timing of innovation, the effects of scale economies, and the roles of ignorance and uncertainty in influencing trade patterns.".

While it is argued that trade based on product differentiation will lead to observed intra-industry trade, it is not suggested this is the only cause. There is therefore the problem of distinguishing intra-industry trade caused by product differentiation from that from other causes.

Hufbauer and Chilas (1974) categorize traded goods as being either Ricardo goods, Heckscher-Ohlin goods or Product Cycle goods. Ricardo goods are those whose production requires significant amounts of natural resources, and are predominantly SITCs 0-4. Heckscher-Ohlin goods are those produced with standardized constant returns to scale techniques utilizing freely available production technology, predominantly SITC 6. Product Cycle goods are those for which there are large rents for information, or knowledge, and generally conform to the description of differentiated goods - predominantly SITCs 5 and 7. Each of these is capable, at some level of aggregation, of exhibiting intra-industry trade, but because there are different underlying reasons for this apparent intra-industry trade, different characteristics of this intra-industry trade are expected.

Aggregation of Ricardo goods into trade categories could give rise to an aggregation of superficially similar but distinct resource requirements[54] and consequently lead to some measure of intra-industry trade, at least at higher levels of aggregation. Such intra-industry trade would be dependent on aggregation and expected to diminish rapidly with disaggregation. [55] The commodity content of trade in Heckscher-Ohlin goods is indeterminate, and consequently random effects can give rise to intra-industry trade. The level of intra-industry trade from this source would not be expected to

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[54] For example SITC 057 (fruit and notes) disaggregates into a variety of fruits requiring different climatic conditions. Similarly SITC 278 (crude minerals) disaggregates into a variety of minerals.

[55] In Pomfret (1979) a number of categories showing high reductions in measured IIT with disaggregation would fit this classification. Unfortunately total trade volumes by category are not provided and it is therefore not possible to estimate the total contribution of such categories to the reduction with disaggregation in measured IIT.

decrease dramatically with disaggregation, but the random nature of such intra-industry trade in such goods makes it unlikely that it would be consistently observed for a number of similar countries. Intra-industry trade is expected from Product Cycle (differentiated) goods. With no random effects involved, it is expected that intra-industry trade based on product differentiation will be observed consistently within a group of developed economies. Because intra-industry trade based on product differentiation does not rely on the aggregation of dissimilar goods, it is expected to be prominent even at low levels of aggregation.

To summarize, it is suggested that, for Ricardo goods, intra-industry trade would be widely observed but not at a consistent level, and diminish rapidly with disaggregation; that for Heckscher-Ohlin goods, intra-industry trade would be inconsistent across countries and relatively insensitive to disaggregation, and that for differentiated goods intra-industry trade will be consistent across countries and not sensitive to disaggregation. A good indication of differentiated goods would therefore be a high level of intra-industry trade consistently observed over a number of countries even at high levels of disaggregation, and a consistent trade pattern over a number of countries. The high level of disaggregation is provided by using the 4-digit (sub-group) level of the SITC. This gives 786 categories overall, 520 of which are manufactured goods. The measure of intra-industry trade for each sub-group will be the mean value of the Grubel-Lloyd index for all 22 OECD countries, a high value of which will require a high value for most individual countries. A further measure of consistency will come from the Glejser import and export indices, discussed earlier in this chapter and in more detail in Chapter 5.

5. Intra-Industry Trade: An Empirical Analysis

5.1 Introduction

This chapter analyzes the Grubel-Lloyd, Aquino and Glejser measures of intra-industry trade, using values of these indices calculated from trade data at the SITC sub-group level for 22 OECD countries. Section 5.2 further develops the theory behind the Grubel-Lloyd, Aquino and Glejser measures of intra-industry trade, and relates this to trade driven by product differentiation. Descriptive statistics for each index are provided, summarized by SITC section. Sub-section 5.2.1 deals with the Grubel-Lloyd index. Sub-section 5.2.2 deals with the Aquino index, and compares the values of this index with those of the Grubel-Lloyd index at both the SITC sub-group and country levels. Sub-section 5.2.3 analyzes the two Glejser indices.

In Section 5.3 a number of arguments related to the "aggregation affect" on the Grubel-Lloyd measure of intra-industry trade (Pomfret 1979,1985) are analyzed. Sub-section 5.3.1 considers the effect of the level of aggregation on the value of the Grubel-Lloyd index, by analyzing the relationship between the values of the SITC groups with the weighted average, and number, of the component sub-groups. The results show that the number of component sub-groups is a statistically significant determinant of the value of this index, but that it explains very little of the variation in that variable. Most of the variation is explained by the weighted average of the component sub-groups. The value of the index at the three digit group level is, on average, 95% of the weighted average of the component sub-group index values, with an elasticity of 0.9. Sub-section 5.3.2 analyzes the contribution of the "not elsewhere specified" sub-groups to the values of the Grubel-Lloyd and Glejser indices. The conclusion is that these sub-groups do have, on average, a higher level of measured intra-industry trade than the other sub-groups. However, this effect is much more pronounced for the non-manufacturing than for the manufacturing sub-groups and, amongst the manufacturing sub-groups, is not discernible for the Glejser import index. The omission of the "nes" sub-groups from the calculation of the various intra-industry trade indices at the country level reduces measured intra-industry trade by between 4% and 7%, depending on the index. Sub-section 5.3.3 discusses the degree to which the

SITC sub-group is a suitable form of categorization for the measurement of intra-industry trade.

Section 5.4 analyzes the correlation between the four measures of intra-industry trade considered so far in this chapter. The Grubel-Lloyd and Aquino indices are so closely correlated that there is little point in using both. The Grubel-Lloyd index, being the more straight-forward of the two, will be used. The correlation between the Grubel-Lloyd and the two Glejser indices is analyzed in some detail. The conclusion is that the correlation between the three is sufficiently high as to be consistent with all three being a proxy for trade based on product differentiation, but not sufficiently high as to render the use of all three redundant. Section 5.5 discusses the use of the intra-industry trade indices as proxies for product differentiation.

5.2 The Intra-Industry Trade Indices

5.2.1 The Grubel-Lloyd Index

The Grubel-Lloyd index for trade category i country j is given by

$$B_{ij} = 1 - \frac{|X_{ij} - M_{ij}|}{X_{ij} + M_{ij}}$$

and the overall index for country j is a weighted average of B_{ij} calculated as

$$B_j = 1 - \frac{\sum_i |X_{ij} - M_{ij}|}{\sum_i (X_{ij} + M_{ij})}$$

The intra-industry trade index will be used in this thesis to measure intra-industry trade by product group (or trade category) rather than by country, and is the mean value of the B_{ij} for all 22 OECD countries within the data set used. Either the mean or median value could have been used, and both are reported in the initial summaries, but, since there was little to choose between them, the mean was selected for its greater analytical convenience.

Unlike the country specific B_j measure, the SITC sub-group measure (denoted B_i) will be an unweighted mean. The country measure is used as a summary measure of the degree to which a country's total trade is intra- or inter-industry, and this requires a weighted mean. The use of the mean value at the SITC sub-group level is to obtain a "representative" value by minimizing the contribution of random country specific effects. Using a weighted mean would mean that the result would be heavily influenced by the US and Japan, these two countries together accounting for half of the total GDP of the 22 countries.

The reasoning behind the use of this index is as follows. From Chapter 3 (3.6.3) and (3.6.5)

$$M_{ij} = g_i(1-s_{ij})Y_j I_j^{\eta_i-1}$$

and

$$X_{ij}=g_i s_{ij} I_{wj}^{\eta_i-1}(Y_T-Y_j)$$

Assuming an income elasticity of demand of one, these become

$$M_{ij} = g_i(1-s_{ij})Y_j$$

$$X_{ij}=g_i s_{ij}(Y_T-Y_j)$$

Substituting these expressions into $B_{ij} = 1-\frac{|X_{ij}-M_{ij}|}{X_{ij}+M_{ij}}$ gives

$$B_{ij}=1-\frac{|s_{ij}(Y_T-Y_j)-(1-s_{ij})Y_j|}{s_{ij}(Y_T-Y_j)+(1-s_{ij})Y_j}$$

In the absence of any other information the best estimate of s_{ij} is y_j, where $y_j=\frac{Y_j}{Y_T}$.

Y_j is the GDP of country j, and $Y_T=\sum_j Y_j$.

The above expression for B_{ij} can be rearranged to

$$B_{ij} = 1-\frac{|s_{ij}-y_j|}{s_{ij}(1-y_j)+y_j(1-s_{ij})}$$

It can be seen that when $s_{ij}=y_j$, the expression simplifies to $B_{ij}=1$. The greater the difference between s_{ij} and y_{ij}, the lower the value of B_{ij}, with B_{ij} approaching 0 as s_{ij} approaches 0 or 1.[1] While the use of y_j as the expected value of s_{ij} is not unreasonable, there will be variation of s_{ij} around that expected value, giving a value of B_{ij} less than one, even in the case of differentiated goods which behave as predicted by the model.

The condition $s_{ij}=y_j$ will give balanced trade in product group i for country j, but there is no reason to expect balanced trade at the individual product group level. If all trade is comprised of differentiated goods, then overall balanced trade requires that $s_j^w=y_j$ where s_j^w is the average value of s_{ij}, weighted by g_i. Even if this condition is satisfied, variations of s_{ij} around s_j^w will cause B_{ij} to have a value less than one.

The addition of trade in undifferentiated goods changes nothing if trade in undifferentiated goods is balanced. In this case overall trade balance still requires balanced trade in differentiated goods. A trade surplus or deficit in undifferentiated goods requires a compensating deficit or surplus in differentiated goods if trade is to be balanced, and accordingly s_j^w will be less than or greater than y_j.

Both of these factors, the variation of s_{ij} around s_j^w, and the variation of s_j^w around y_j, will cause the B_{ij} value for differentiated goods to have less than the theoretical maximum. However, for a country for which the value of $y_j<0.1$, and this includes all but 2 countries, a value of s_{ij} in the range $0.5y_j \le s_{ij} \le 2y_j$ will give a value for B_{ij} greater than 0.6.[2]

The mean value of B_{ij} for 1992 is 0.43 (median 0.41), with standard deviation 0.15, so that the range of s_{ij} values described above will still give values of B_{ij} well towards the upper end of the range. Analysis of variance shows that 20% of the variance of B_{ij} is

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[1] $B_{ij}=1-\frac{|s_{ij}-y_j|}{s_{ij}(1-y_j)+y_j(1-s_{ij})}=1-\frac{|s_{ij}-y_j|}{s_{ij}-2s_{ij}y_j+y_j}$. When $s_{ij}=0$, $B_{ij}=1-\frac{y_j}{y_j}=0$. When $s_{ij}=1$, $B_{ij}=1-\frac{|1-y_j|}{1-y_j}=0$.

due to country and 20% to SITC sub-group, indicating that the determinants of B_{ij} are both SITC sub-group and country specific.

Table 5.1 is a summary of the values of the Grubel-Lloyd index for the individual SITC sub-groups (B_i), using both the mean and median values of B_{ij} as measures of B_i.

Table 5.1. Grubel and Lloyd Index of Intra-Industry Trade for SITC Sub-Groups.

	mean	standard deviation	skewness	Q1	median	Q3	maximum
1982							
mean	0.38	0.14	-0.34	0.29	0.39	0.47	0.74
median	0.34	0.21	0.03	0.16	0.35	0.49	0.86
1992							
mean	0.43	0.15	-0.41	0.33	0.44	0.54	0.76
median	0.41	0.21	-0.21	0.26	0.42	0.58	0.87

Note: The full 786 sub groups are represented for 1982 but only 770 for 1992[3].

The increase in the mean of both measures over the 10 year period is statistically significant, using the paired difference test[4]. For the mean measure, the 1992 value exceeded the 1982 value for 587 sub-groups and, in the case of the median measure, for 571 sub-groups. There is no statistically significant change in the standard deviation. The median measure gives a wider range of values than does the mean.

Table 5.2 gives a summary of the distribution of the intra-industry trade index for the ten SITC sections.

Table 5.2.Grubel-Lloyd Index for 1992 (mean measure) by SITC Section.

SITC	0	1	2	3	4	5	6	7	8	9	all
N	93	11	103	20	18	93	183	157	86	6	770
mean	0.34	0.36	0.30	0.30	0.27	0.44	0.48	0.48	0.50	0.47	0.43
min	0.014	0.18	0.001	0.06	0.07	0.13	0	0.06	0.30	0.36	0
max	0.67	0.61	0.61	0.50	0.46	0.65	0.75	0.72	0.76	0.56	0.76
stdev	0.14	0.12	0.15	0.13	0.12	0.11	0.12	0.12	0.10	0.07	0.15

Each column contains the summary statistics of the B_i values for all the SITC sub-groups (4-digit) within that SITC section. The B_i are calculated as the mean value of the Grubel-Lloyd index for SITC sub-group i for all 22 OECD countries.

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[2] Derived from the expression $B_{ij} = 1 - \frac{|s_{ij} - y_j|}{s_{ij}(1-y_j) + y_j(1-s_{ij})}$ by substituting y_j=0.1 and successively the values of 0.05 and 0.2 for s_{ij}.

[3] The 16 not represented for 1992 are 0019, 2479, 5828, 5851, 6344, 6518, 6551, 6553, 6574, 6741, 6750, 6784, 7432, 7433, 8461, 8464. There were no trade data reported for any of these by any of the 22 countries for 1992.

[4] The following applies to both the mean and median measures. Using the Shapiro-Wilk test the null hypothesis that the differences were drawn from a normally distributed population could not be rejected at the 10% level of significance. Using the t-test described in Section 5.5.4 the null hypothesis that the mean difference in the value of the Grubel-Lloyd index between 1982 and 1992 was zero is rejected at the 0.01% level of significance. This null hypothesis is also rejected at the 0.01% level by both the sign test and the Wilcoxon signed rank test.

The mean values of SITC sections 0, 2, 3 and 4 are statistically significantly less than the mean value of all sub-groups, those of 6,7 and 8 statistically significantly greater, and those of 1, 5 and 9 not significantly different from the overall mean[5]. The mean values by SITC section conform with the expectation that intra-industry trade is greater for manufactured than for non-manufactured goods[6].

5.2.2 The Aquino Measure

The Aquino measure is a variation on the Grubel and Lloyd index which takes into account imbalance in merchandise trade. In this analysis, the compensating factor is derived from the values of total merchandise exports and imports. The Aquino measure for country i sub group j, Q_{ij} is calculated as $Q_{ij} = 1 - \frac{|X^e_{ij} - M^e_{ij}|}{X^e_{ij} + M^e_{ij}}$, where

$$X^e_{ij} = X_{ij} \frac{\frac{1}{2}\sum_{j=1}^{n}(X_{ij} + M_{ij})}{\sum_{j=1}^{n} X_{ij}} \quad \text{and} \quad M^e_{ij} = M_{ij} \frac{\frac{1}{2}\sum_{j=1}^{n}(X_{ij} + M_{ij})}{\sum_{j=1}^{n} M_{ij}}$$

Tables 5.3 and 5.4 provide summaries of the Aquino measure of intra-industry trade.

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[5] Tests of statistical significance are based on the probability of obtaining the observed value for the mean of each SITC section, or one further from the mean of all SITC sub-groups, if in fact the SITC sub-groups in each SITC section were a random sample of the same size drawn without replacement from the population of all 770 SITC sub-groups. For SITC sections 0,2,3,4,6,7,8 this probability is less than 1%. This is based on the assumption that the sample mean is normally distributed. However, given that the parent population is not normally distributed, and that the number of SITC sub-groups in some SITC sections represent small samples, this cannot be automatically assumed. However, when the Shapiro-Wilk test for normality was applied to the sample mean of a large number of random samples each drawn without replacement from the population of all SITC sub-groups, the null hypothesis that the sample mean is normally distributed could not be rejected at the 10% level for a sample size of 4 or greater. The finite population correction factor has been used in the estimation of the standard error of the sample mean.

[6] The non-manufactured SITC sections are 0-4, and the manufactured sections 5-9. Section 9 is comprised of goods "not elsewhere specified".

Table 5.3. The Aquino Measure of Intra-industry Trade at the SITC Sub Group Level.

	mean	standard deviation	skewness	Q1	median	Q3	maximum
1982							
mean	0.38	0.14	-0.36	0.29	0.40	0.48	0.73
median	0.34	0.21	-0.007	0.18	0.36	0.51	0.86
1992							
mean	0.43	0.15	-0.40	0.34	0.44	0.54	0.78
median	0.41	0.21	-0.22	0.26	0.43	0.58	0.90

The rows labelled "mean" are the summary statistics of mean values of the Q_i, calculated as the mean value of the values of the Aquino index for SITC sub-group i for all 22 OEDC countries (Q_{ij}), while the rows labelled "median" contain the corresponding statistics for Q_i calculated as the median value of the Q_{ij}.

Table 5.4. The Aquino measure for 1992 (mean measure) by SITC section.

SITC	0	1	2	3	4	5	6	7	8	9	all
N	93	11	103	20	18	93	183	157	86	6	770
mean	0.34	0.38	0.31	0.30	0.27	0.44	0.49	0.49	0.50	0.45	0.43
min	0.014	0.17	$8E^{-4}$	0.07	0.07	0.12	0	0.06	0.30	0.35	0
max	0.71	0.64	0.61	0.53	0.47	0.68	0.76	0.73	0.78	0.51	0.78
stdev	0.14	0.13	0.15	0.13	0.12	0.12	0.12	0.13	0.13	0.10	0.15

Each column contains the summary statistics of the Q_i values for all the SITC sub-groups (4-digit) within that SITC section. The Q_i are calculated as the mean value of the Aquino index for SITC sub-group i for all 22 OECD countries.

A comparison of Tables 5.1 and 5.2 with 5.3 and 5.4 suggests very little difference between the two indices. Table 5.5 gives a more detailed analysis of the difference by showing the distribution of the paired difference between the two, being the Aquino index minus the Grubel-Lloyd index.

Table 5.5. Difference Between the Aquino and Grubel-Lloyd 1992 Intra-Industry Trade Measures.

measure	mean	std dev	min	Q1	median	Q3	max
mean	0.005	0.016	-0.065	-0.005	0.005	0.015	0.052
median	0.003	0.041	-0.186	-0.020	0.0008	0.025	0.168

On the basis of the paired difference test there is an increase in the mean for both the mean and median measures[7]. The proportion of sub-groups showing an increase in the

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[7] In the case of the mean measures, the null hypothesis that the differences are normally distributed could not be rejected at the 10% level using the Shapiro Wilk test. Using the t-test described in Section 5.5.4 the null hypothesis that that the mean difference between the Grubel-Lloyd and Aquino mean measures is zero is rejected at the 0.01% significance level. It is also rejected at the 0.01% level by both the sign test and the Wilcoxon signed rank test.
In the case of the median measures the null hypothesis that the differences are normally distributed is rejected at the 5% level by the Shapiro-Wilk test but not at the 1% level (P=0.049). Using the t-test the null hypothesis that the mean difference between the two median measures is rejected at the 5% level (P=0.029), at the 10% level by the sign test (P=0.070) and at the 5% level by the Wilcoxon signed rank test (P=0.045).

mean measure was 0.63, significantly greater than 0.5[8], while for the median measure it was 0.53, not significantly greater than 0.5[9].

To further analyze the relationship between the two, a regression was carried out with the Aquino measure as the dependent variable. The results are summarised in Table 5.6.

Table 5.6. Regression of Aquino Measure of Intra-Industry Trade Against the Grubel-Lloyd Index.

	mean		median	
	linear	double log	linear	double log
R^2	0.99	0.99	0.96	0.99
intercept	$-1.4\mathrm{x}10^{-4}$	$8.7\mathrm{x}10^{-3}$ ***	$9.3\mathrm{x}10^{-3}$ ***	-0.005
	($1.8\mathrm{x}10^{-3}$)	($3.2\mathrm{x}10^{-3}$)	($3.3\mathrm{x}10^{-3}$)	(0.006)
coefficient	1.011 ***	0.9985 ***	0.985 ***	0.987 ***
	($4.0\mathrm{x}10^{-3}$)	(0.0031)	(0.0073)	(0.0041)

Figures in parentheses are standard errors. ***, significant at 1%. N=770.

For the mean measure, the intercept in the linear model is not significantly different from zero, but the estimated value for the coefficient of the Grubel-Lloyd index is significantly greater than one, with the value of the estimate leading to the conclusion that, on average, the value of the Aquino index is 1% greater than the value of the corresponding Grubel-Lloyd index. For the double log model, the estimated value of the coefficient of the log of the Grubel-Lloyd index is not significantly different from one, suggesting a linear relationship between the two indices. The estimated value of the intercept is significantly greater than zero and translates to a value of 1.009, again leading to the conclusion that, on average, the value of the Aquino index is 1% higher than the value of the corresponding Grubel-Lloyd index.

Similar results are observed for the median measure, although the relationship between the two indices appears to be slightly different. For the linear model, the estimated value of the intercept is significantly greater than zero, while the estimated value of the coefficient for the Grubel-Lloyd index is significantly less than one. On the basis of these two estimated values, the conclusion is that the median measure of the Aquino index is greater than the value of the corresponding Grubel-Lloyd index up to a value of that index of 0.62, which is above the 80th percentile. The Aquino index is, on

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[8] Significant at 0.01%. Based on the standard hypothesis test concerning proportions.

[9] The actual proportion is 0.528 which is not significantly different from 0.5 at the 5% level of significance 2-tailed but is significant at the 10% 1-tailed significance level.

average, 2% higher than the corresponding Grubel Lloyd index at the first quartile value of the Grubel-Lloyd index, and 0.1% higher at the third quartile value. For the double log model, the estimated value of the intercept is not significantly different from zero, while the estimated value of the coefficient of the log of the Grubel-Lloyd index is significantly less than one, suggesting a non-linear relationship between the two, with the value of the Aquino index exceeding that of the corresponding Grubel-Lloyd index in the range of values of zero to one of that index. The Aquino index is, on average, 2% higher than the corresponding Grubel Lloyd index at the first quartile value of the Grubel-Lloyd index, and 0.8% higher at the third quartile value.

While the difference between the two indices is statistically significant, it could scarcely be described as material. This is not to argue that the Aquino index serves no purpose - it was originally developed for use in the analysis of bilateral intra-industry trade, where trade imbalances are likely to be greater than in the case of multilateral trade.

Table 5.7 summarizes the two measures at the country level, and suggests that, while for the most part there is little difference between the two measures on a country basis, there are a few countries - Greece, Japan, Portugal and Spain - for which the Aquino index is noticeably bigger than the Grubel-Lloyd index. These are the countries with the largest trade imbalance. As expected, the difference between the two measures is significantly correlated with the trade imbalance[10].

The increase in the overall measure of intra-industry trade using the Aquino measure is statistically significant[11], with the standard deviation across countries virtually unchanged. Only 16 out of the 25 countries (64%) showed an increase with the Aquino measure. This ratio does not differ significantly from 0.5, leading to the conclusion that, on a country basis, the use of the Aquino index is just as likely to give a lower as it is higher value of intra-industry trade than the Grubel-Lloyd index.

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[10] The Pearson correlation coefficient is 0.82, significant at 0.01%, and the Spearman rank correlation coefficient is 0.65, significant at 0.04%.

[11] Using the paired difference test, significant at the 5% level.

Table 5.7. Aquino and Grubel-Lloyd Indices of Intra-industry Trade by Country - 1992.

Country	Aquino (A)	GL (B)	(A)-(B) x100	TIMB	Country	Aquino (A)	GL (B)	(A)-(B) x100	TIMB
Australia	0.272	0.274	-0.14	0.027	Japan	0.292	0.258	3.49	0.186
Austria	0.632	0.626	0.78	0.098	Korea	0.355	0.357	-0.28	0.032
Belgium	0.670	0.670	-0.01	0.007	Netherlands	0.633	0.635	-0.18	0.020
Canada	0.541	0.541	0	0.047	New Zealand	0.213	0.216	-0.35	0.034
Denmark	0.551	0.551	0.52	0.084	Norway	0.298	0.302	-0.41	0.133
Finland	0.405	0.402	0.3	0.062	Portugal	0.373	0.335	3.79	0.257
France	0.672	0.671	0.02	0.015	Singapore	0.636	0.631	5.75	0.064
Germany	0.670	0.667	0.32	0.022	Spain	0.583	0.551	3.24	0.216
Greece	0.285	0.248	3.76	0.409	Sweden	0.536	0.534	0.26	0.051
Hong Kong	0.546	0.567	-2.29	0.063	Switzerland	0.548	0.548	0	0.001
Iceland	0.043	0.043	0.06	0.048	UK	0.712	0.704	0.78	0.088
Ireland	0.483	0.472	1.11	0.112	United States	0.566	0.565	0.074	0.11
Italy	0.521	0.520	0.03	0.028					

TIMB: A measure of trade imbalance, |X-M|/(X+M)

Note: Both indices calculated as trade weighted average of measures at the 4 digit SITC level[12].

The conclusion is that the use of the Aquino measure can give a materially different measure of intra-industry in the presence of a significant trade imbalance, but of the 25 countries considered most did not have a sufficiently high trade imbalance to make any significant difference. This might explain the small difference between the two at the individual sub-group level, this value being calculated as the mean or median for 22 countries. Were bilateral trade data to be used, higher trade imbalances would be likely, and a larger variation between the two measures might be expected. In this thesis, it is the level of intra-industry trade for each individual SITC sub-group which is to be used as a proxy for product differentiation, and this will be determined using multilateral data. Consequently, there is no appreciable advantage in using the Aquino index rather than the Grubel-Lloyd index.

5.2.3 The Glejser Measure

As for the previous two measures, the Glejser measure, (Glejser 1983, Glejser *et al* 1979,1982), was designed to measure intra-industry trade on a country basis. It differs from the previous two measures both in concept and in that separate measures are

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[12] $B_i = 1 - \frac{\sum_{j=1}^{n} |X_{ij} - M_{ij}|}{\sum_{j=1}^{n} (X_{ij} + M_{ij})}$ and $Q_i = 1 - \frac{\sum_{j=1}^{n} |X_{ij}^{e} - M_{ij}^{e}|}{\sum_{j=1}^{n} (X_{ij}^{e} + M_{ij}^{e})}$, X_{ij}^{e} and M_{ij}^{e} as previously defined.

obtained for exports and imports. Separate measures for imports and exports means that trade balance is not an issue.

As designed, the country based Glejser export index for country j is the variance of ξ_{ij} over all trade categories i.

$$\xi_{ij} = \log(\frac{X_{ij} / X_{.j}}{X_{i.} / X_{..}}) \text{ where}$$

X_{ij} = export of category i by country j

$X_{.j}$ = total exports from country j ($\sum_i X_{ij}$)

$X_{i.}$ = total exports of category i from all countries in the group ($\sum_j X_{ij}$)

$X_{..}$ = total exports of all categories from all categories in the group ($\sum_i \sum_j X_{ij}$)

The value of the Glejser export index for country j is calculated then as

$$s^2_{\xi(j)} = \frac{1}{n} \sum_{i=1}^{n} (\xi_{ij} - \xi_j)^2$$

where ξ_j is the mean of ξ_{ij}, $\xi_j = \frac{1}{n} \sum_{i=1}^{n} \xi_{ij}$

This index is adapted for use at the SITC sub-group level rather than at the country level by calculating $s^2_{\xi(i)} = \frac{1}{m-1} \sum_{j=1}^{m} (\xi_{ij} - \xi_i)^2$ where $\xi_i = \frac{1}{m} \sum_{j=1}^{m} \xi_{ij}$, where m is the number of countries.

In this thesis, rather than use the value of the variance ($s^2_{\xi(i)}$) as the value of the index, the standard deviation ($s_{\xi(i)}$) will be used.

ξ_{ij} is defined as before except that now X_i is calculated as $\sum_{k=1}^{m,k\neq j} X_{i,k}$ and $X_{..} = \sum_{k=1}^{m,k\neq j} X_{.k}$. This is as suggested by Glejser(1983) to prevent a bias in the case of a large exporting country. There are a small number of cases for which X_{ij} (or M_{ij}) is zero which means that with the log formulation the corresponding ξ_{ij} would be undefined. This difficulty is avoided by ignoring such observations, and not including the country totals in the overall totals used in calculating the index for that sub-group. An example of the calculation of the Glejser indices is provided in Appendix D to this chapter.

The logic underlying the use of this index as a proxy for trade driven by product differentiation can be summarized as follows. Whereas trade in undifferentiated goods requires differences between countries, trade in differentiated goods does not, and hence trade is expected to exhibit a higher level of uniformity amongst the included countries. This can be seen more clearly in the case of imports. Using the model developed in Chapter 3 (3.6.3), it is expected that the smallest 20 of the 22 OECD countries will import more than 90% of the expenditure on any differentiated product group. With the assumption that the expenditure share on any differentiated product group is constant for all countries, this leads to a similar composition of imports with respect to each differentiated product group and a low value of the Glejser import index. This is discussed in greater detail in Appendix B to this chapter.

The values of the Glejser indices are summarized in Table 5.8.

Table 5.8. Glejser Measure of Intra-industry Trade at the SITC Sub Group Level

	N	mean	std dev	min	Q1	median	Q3	max
1982								
import	786	1.28	0.71	0.30	0.76	1.09	1.90	5.49
export	786	2.03	0.78	0.62	1.48	1.89	2.44	6.03
1992								
import	769	1.05	0.68	0.23	0.56	0.84	1.31	4.36
export	769	1.93	0.70	0.64	1.44	1.78	2.33	5.25

As expected, the mean values of the Glejser export (G_X) indices are greater than the corresponding values of the import (G_M) indices. The difference is statistically significant[13] and is consistent with Glejser's results on a country basis. Most sub-groups have export values greater than the corresponding import ones but not all (92% and 94% for 1982 and 1992 respectively). In 1992, for those 46 sub groups for which $G_M>G_X$, the mean value of G_M is more than double the overall mean, while the mean value of G_X does not differ significantly from the overall mean[14].

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[13] Test of statistical significance carried out using the paired difference t-test. The null hypothesis that the paired differences are normally distributed could not be rejected on the basis of the Shapiro Wilk test at a significance level of 10%. The null hypothesis that the mean value of the import and export indices is the same was rejected at the 0.01% level by the t-test, the sign test and the Wilcoxon signed rank test.

[14] Tests of statistical significance based on the probability of obtaining a mean value of the respective index equal to that of the relevant group or further from the mean of all SITC sub-groups from a random sample of 46 drawn from the population of all SITC sub-groups. The probability is less than 0.01% for the Glejser import index, and greater than 20% (1 tailed) for the export index.

Table 5.9. Mean Value of Glejser Intra-industry Trade Indices by SITC Section.

SITC	0	1	2	3	4	5	6	7	8	9	all
1982											
N	94	11	104	20	18	95	191	159	88	6	786
import	1.78	1.40	1.87	1.92	1.73	0.88	1.10	1.07	0.90	2.20	1.28
export	2.59	2.29	2.54	3.10	2.46	1.93	1.71	1.83	1.56	2.45	2.02
1992											
N	93	11	103	20	18	93	182	157	86	6	769
import	1.46	1.13	1.75	1.67	1.28	0.78	0.84	0.84	0.57	2.13	1.05
export	2.36	2.25	2.41	2.54	2.42	1.92	1.65	1.76	1.52	2.41	1.93

N is the number of sub-groups in the SITC section.

Table 5.9 shows that the Glejser measures, both import and export, conform with the expectation that intra-industry trade should be higher (reflected in lower G_M and G_X values) for manufacturing than for non-manufacturing goods. The analysis of statistical significance of the differences between the mean values of the indices for each SITC section and the corresponding overall mean yields much the same results as for the Grubel-Lloyd index, with some minor exceptions[15]. The values for Section 9 (not elsewhere specified) are noticeably higher than for other manufacturing sections. The previous observation, that the export index has higher values than does the import index, applies to each of the SITC sections.

When considering the country measure of intra-industry trade, the Glejser measure for any country, unlike the previous measures, cannot be determined in isolation, but must be determined as one of a group of countries, and the value obtained might be expected to vary with the composition of that group. To be consistent with the sub-group measure of intra-industry trade only the 22 OECD countries should be included, but a full comparison with the Aquino and Glejser measures of intra-industry trade at the country level the 25 countries would be preferable. On this occasion, however, the difference between the values obtained using the 22 OECD countries and the full set of 25 countries is negligible and not statistically significant[16], so there is no problem in using all 25 countries. The results are shown in Table 5.10

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[15] For the Grubel-Lloyd index, the value of the mean for SITC sections 0,2,3, and 4 were statistically significantly less, and those of 6,7 and 8 greater, than the overall mean. The variations from this, for the Glejser import index for 1992, are that the means for SITC Section 4 are not statistically significantly different, while those for Sections 5 and 9 are statistically significantly different, from that of the overall mean. All cited cases of statistical significance are at the 1% level.

[16] Using the paired difference t-test.

Table 5.10. Glejser Measure of IIT by Country From SITC Sub Group Components.

Country	G_M 1982	G_X 1982	G_M 1992	G_X 1992	Country	G_M 1982	G_X 1982	G_M 1992	G_X 1992
Australia	2.06	2.26	1.74	2.10	Japan	1.70	2.63	1.49	2.51
Austria	1.43	2.11	1.30	1.86	Korea	2.16	2.61	1.70	2.50
Belgium	1.05	1.65	1.03	1.59	Netherlands	1.08	1.76	1.13	1.64
Canada	1.58	1.91	1.24	1.75	New Zealand	1.79	2.54	1.63	2.63
Denmark	1.43	2.15	1.37	2.10	Norway	1.63	2.35	1.45	2.31
Finland	1.61	2.43	1.44	2.34	Portugal	1.79	2.53	1.38	2.22
France	0.91	1.42	0.85	1.26	Singapore	1.81	2.07	1.73	2.04
Germany	0.96	1.42	0.82	1.36	Spain	1.40	1.97	1.12	1.64
Greece	1.76	2.73	1.49	2.49	Sweden	1.49	1.97	1.26	2.01
Hong Kong	1.85	3.10	1.82	3.14	Switzerland	1.31	2.47	1.40	2.33
Iceland	1.78	3.14	1.71	3.10	UK	1.01	1.49	0.90	1.40
Ireland	1.63	2.20	1.45	2.13	United States	1.67	1.54	1.26	1.21
Italy	1.13	2.04	0.96	1.69					

From Table 5.10 it can be seen that, where the Glejser indices are calculated on a country basis, the Glejser export index is consistently greater than the import index, and the values for the 1992 indices are less than those for the 1982 indices. These observations are consistent with the indices calculated by individual SITC sub-group.

5.3 Aggregation and the Level of Intra-Industry Trade

It has been argued that rather than being a phenomenon of any significance, observed intra-industry trade is wholly or largely an artefact arising from the aggregation into the one trade category of a collection of disparate goods. This section examines the empirical support for that argument.

Several aspects of aggregation will be considered.

(i) The effect of aggregating from a lower to higher level of aggregation within the SITC classification on the measured value of intra-industry trade.

(ii) The contribution to measured intra-industry trade of those categories of the SITC whose identifying number contains a "9", that is, the "not elsewhere specified" categories.

(iii) The criteria by which individual goods are aggregated into various categories.

5.3.1 The Level of Aggregation

Greenaway and Milner (1983) compared the Grubel-Lloyd measure of intra-industry trade for the UK at the 3 digit level of the SITC calculated in two ways; one method being to calculate the intra-industry trade index of each category using aggregated trade data for that category, the other to calculate the intra-industry trade index at the 4 or 5-digit level and take the weighted average of these as the intra-industry index for the corresponding SITC groups (3-digit). To use the nomenclature of Greenaway and Milner (1983), the intra-industry trade measure for category i can be calculated as either

$$B_i = 1 - \frac{|X_i - M_i|}{X_i + M_i} \text{ or as}$$

$$C_i = 1 - \frac{\sum_{m=1}^{n} |X_{im} - M_{im}|}{\sum_{m=1}^{n} (X_{im} + M_{im})} \text{ where } X_{im} \text{ is sub-category m of category i.}$$

$$X_i = \sum_{m=1}^{n} X_{im} \text{ and } M_i = \sum_{m=1}^{n} M_{im} .$$

$0 \le C_i \le B_i \le 1$, and $C_i = B_i$ only if m=1 or the sign of $(X_{im}-M_{im})$ is the same for all m.

The B_i and C_i values for the 3-digit (group) level of the SITC for 1992 can be compared, the intra-industry trade measure for each group being calculated as an average over the 22 OECD countries as before. Subsequent analyses will be carried out at the 4-digit (sub-group) level, but it is not possible to analyse the aggregation affect on measured intra-industry trade at this level without 5-digit data, and if 5-digit data were included in the data set being used then that would be the aggregation level used for subsequent analysis. Nevertheless, it is hoped that some generalizations can be drawn from an analysis of the effect of aggregating from the 4 to the 3-digit level.

Table 5.11: Disaggregation Effects, Grubel-Lloyd IIT Index by SITC Section

SITC	Count			Intra-Industry Trade Index			Aggregation	
	N	not disagg	# nes	B_i	C_i	Δ	mean	max
0	34	11	2	0.40	0.35	0.05	2.76	2.97
1	4	1	0	0.46	0.37	0.09	2.73	3.0
2	33	10	4	0.35	0.30	0.05	3.08	3.42
3	7	2	0	0.34	0.29	0.05	2.84	3.14
4	4	0	0	0.43	0.32	0.11	4.53	5.25
5	25	1	3	0.53	0.47	0.06	3.88	4.6
6	52	9	10	0.56	0.49	0.06	3.63	3.92
7	45	2	5	0.55	0.51	0.04	3.56	4.09
8	28	6	8	0.52	0.49	0.03	3.22	3.75
9	6	6	6	0.47	0.47	0	1.0	1.0
Total	238	48	38	0.49	0.43	0.06	3.31	3.71

Data: 1992 , 22 OECD countries.
Count: N number of SITC groups, "not disagg" number of groups not disaggregating to more than one sub-group , # nes number of groups having a 9 in their identifier (nes).
Aggregation: Refers to the number of sub-groups within a group. Max is the maximum number of sub groups for any one group across all countries, while mean is the mean number. The figures shown are the mean of each for the relevant SITC section.

The aggregation counts in Table 5.11 refer only to the disaggregation from the 3-digit groups to the 4-digit sub-group, and not to any lower level of disaggregation. There are instances of no disaggregation from the 3 to 4 digit level but disaggregation from the 4 to 5 digit level, and vice versa. Of the 786 sub-groups, only 435 disaggregate to the 5 digit level. From Table 5.11 it can be seen that, while the level of aggregation for the manufacturing groups (SITCs 5-8) is greater than that for the non-manufacturing groups, the difference is not dramatic. There is no evidence to suggest that the difference between the two measures (B_i-C_i) is greater for manufacturing than non-manufacturing groups and, therefore, no reason to suppose that the higher average level of intra-industry trade for manufactured goods is as a result of a higher level of aggregation.

The correlation between the difference in the two measures (B_i-C_i) and the aggregation count was analyzed. Both the absolute difference and the difference relative to the B measure were considered. Correlation analyses were carried out separately for several sets of SITC groups. These were

(i) All SITC sections.

(ii) The SITC manufacturing and non-manufacturing sections separately.

(iii) As for (ii) further divided into two sub-sets, as follows.

One sub-set is comprised of all SITC groups that disaggregate into more than one sub-group. The reasoning is that a disaggregation count of one (no disaggregation) must be associated with a $(B_i\text{-}C_i)$ value of zero, and a disaggregation count greater than one with a value for $(B_i\text{-}C_i) \geq 0$, thereby introducing a bias. The second sub-set is formed by eliminating the "nes" groups, the rationale being that the structure of these groups is more arbitrary and the measured intra-industry trade more likely to include random effects.

Table 5.12. Correlation of $(B_i\text{-}C_i)$ with Aggregation Count.

SITC Groups Included	Correlation absolute Δ/ aggregation count						Correlation relative Δ/aggregation count		
	All		SITCs 0-4		SITCs 5-9		All	SITCs 0-4	SITCs 5-9
All	0.68	*238*	0.77	*82*	0.63	*156*	0.59	0.77	0.56
Agg count>1	0.53	*191*	0.62	*58*	0.49	*133*	0.39	0.58	0.38
and no "nes"	0.51	*164*	0.61	*55*	0.47	*109*	0.39	0.59	0.36

Data: 1992 22 OECD countries. The correlation figures are the Pearson correlation coefficients. All figures shown are significant at the 0.01% level. Figures in italics are the number of SITC groups in each sub-set.

The aggregation count used here is the mean aggregation count. It could be argued that while the max aggregation count reflects the "structure" of the SITC group, the mean represents the data which are represented in these particular values. In practice there is little difference in the correlation between one or the other, the correlation with the mean in the main being several percentage points higher.

Table 5.12 shows that the difference between the two measures is significantly correlated with the aggregation count, for all sub-sets. The separate analysis of that sub-set having an aggregation count greater than one is justified by the lower correlation coefficients which are, nevertheless, still significant. In all cases the correlation coefficients for SITCs 5-9 is less than that for SITCs 0-4. While these results suggest that the difference between the C and B measures is influenced by the degree of aggregation, the main point of interest is the extent to which the actual intra-industry trade index values are a function of the degree of aggregation. The correlation between the two is summarized in Table 5.13.

Table 5.13. Correlation of B and C Values with Aggregation Count.

IIT measure	SITCs 0-9		SITCs 0-4		SITCs 5-9	
	all	excl " nes"	all	excl "nes"	all	excl "nes'
B_i	0.32 ***	0.36 ***	0.16	0.22 *	0.39 ***	0.43 ***
C_i	0.10	0.15 **	-0.17	-0.11	0.18 **	0.25 ***

Data: 1922 from 22 OECD countries. Pearson correlation coefficients.
***, **, *: significant at 1%, 5% and 10% levels. The aggregation count is the mean aggregation count.

There are two points of interest from Table 5.13. One is that the correlation of the measured value of intra-industry trade with the aggregation level is, for the most part, confined to the manufacturing SITCs. The other is that, amongst the manufacturing

SITCs, the C measure of intra-industry trade - the weighted average of the intra-industry trade index of each of the 4-digit components - is also significantly correlated with the degree of aggregation. While the "aggregation argument" predicts the positive correlation of the B measure with the degree of aggregation from 4 to 3-digit SITC, it cannot explain the correlation with the C measure, which is a weighted average of the values at the 4-digit level. The existence of this correlation raises the question of the direction of causality.

The correlation of the C measure with the disaggregation level from 3 to 4-digit could be explained if this level of disaggregation was positively correlated with the level of disaggregation from 4 to 5-digit within any SITC group. However the correlation between these two levels of disaggregation[17] is -0.02 (not significant), so there is no support for that argument.

Table 5.14 summarizes the results of a number of regressions which further analyze the relationship between measured intra-industry trade and the level of aggregation.

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[17] Disaggregation for 3 to 4-digit measured the number of sub-group within the group. The disaggregation of the sub-groups within a group is the ratio of the number of lowest levels (4 or 5 digit) within a group of each sub-group.

Table 5.14. Estimated Effects of Aggregation on the GL IIT Index. SITCs 5-9.

Model linear	Dep var	adj R^2	intercept	aggregation	C_i	"nes" dummy	dv*aggreg	dv*C_i
A	(B_i-C_i)	0.36	-0.010 (0.011)	0.017 *** (0.003)		0.018 (0.013)	-0.005 (0.003)	
B	(B_i-C_i)	0.36	0.004 (0.005)	0.013 *** (0.001)				
C	C_i	0.03	0.460 *** (0.016)	0.009 ** (0.004)				
D	B_i	0.15	0.464 *** (0.017)	0.022 *** (0.004)				
E	B_i	0.91	0.020 (0.035)	0.017 *** (0.003)	0.942 *** (0.062)	-0.002 (0.038)	-0.005 (0.003)	0.033 (0.070)
F	B_i	0.91	0.019 (0.014)	0.013 *** (0.001)	0.966 *** (0.027)			
log								
C	C_i	0.03	-0.81 *** (0.068)	0.068 ** (0.029)				
D	B_i	0.15	-0.79 *** (0.034)	0.145 *** (0.027)				
E	B_i	0.91	-0.113 ** (0.046)	0.095 *** (0.017)	0.838 *** (0.063)	0.048 (0.053)	-0.015 (0.020)	0.065 (0.068)
F	B_i	0.92	-0.073*** (0.022)	0.084 *** (0.009)	0.895 *** (0.024)			

N=156. Data: 1992, 22 OECD countries. Figures in parentheses are standard errors. ***, ** : significant at 1% and 5% respectively. "dv*aggreg" is the product of the "nes"dummy and the aggregation count, and "dv*C_i" with the C_i variable

Only the manufacturing SITC groups were included, as the non-manufacturing groups demonstrate little or no correlation with the aggregation level.

To investigate the contribution of "nes" categories to any aggregation effect, each model was estimated three ways:

(i) With the full set of manufacturing SITC groups.

(ii) As for (i) but with a dummy variable for "nes" categories.

(iii) Excluding the "nes" categories.

The dummy variables were not significant for any of the models, and the estimates from (iii) were not significantly different from those obtained when the "nes" categories were included.

Considering the linear models first, Models A and E are included to demonstrate the non-significance of the "nes" dummy, both individually and in combination with the aggregation count and the C value; while model B demonstrates the relationship between the aggregation count and the difference between the B_i and C_i.

With B_i as the dependent variable, the estimate for the aggregation coefficient in model D is 0.022, suggesting that, for each increment in degree of aggregation, the B_i measure on average increases by 0.022. However, some of this is due to the correlation of C_i with aggregation, the coefficient being estimated in model C as 0.009. When this is taken into account by including the C_i variable, as in Model F, the estimated coefficient for the aggregation coefficient is 0.013. The estimated coefficient for C_i in Model F does not differ significantly from one. The conclusion is that, on average, an increase of one in the degree of aggregation, holding the value of C_i constant, increases B_i by 0.013. Expressed another way, an increase in the degree of aggregation from one (no aggregation) to five, holding C_i constant, will on average, increase B_i by 0.05. Given that the mean level of aggregation is 3.5, and the standard deviation 2, there are no grounds for claiming that the measured level of intra-industry trade for any category is largely determined by the level of aggregation.

The models in log form give similar results. Model F gives an estimate of the elasticity of the B measure with respect to aggregation of 8.4%. The elasticity from the equivalent linear model, evaluated at mean values[18], is 8.3%, which is consistent.

The conclusion can be drawn that the degree of aggregation is a statistically significant factor in the value of the Grubel-Lloyd index, but the contribution is insufficient to support any argument that observed intra-industry trade is largely an artefact of aggregation. The degree of aggregation appears to contribute in two ways. One is the expected increase over the level of intra-industry trade calculated at a lower level of aggregation (B_i-C_i). The other, not so easily explained, is the higher value of intra-industry trade calculated at the lower level (C_i). One possible explanation is that both the degree of aggregation and the measured level of intra-industry trade are increasing functions of the level of product differentiation.

5.3.2 Aggregation and the "nes" Categories

Any "aggregation effect" might be expected to be more pronounced for the "nes" categories, representing as they do a group of goods categorized together on the basis of not having been classified elsewhere. It should be noted, however, that, particularly at lower levels of aggregation, some such groups are precisely defined. Summary data is presented in Table 5.15.

Table 5.15.Contribution of "nes" Categories to Measures of Intra-Industry Trade

	N			GL IIT Index			Glejser Import Index			Glejser Export Index		
SITCs	0-4	5-9	all	0-4	5-9	all	0-4	5-9	all	0-4	5-9	all
"nes"	29	147	176	0.410	0.505	0.489	1.157	0.820	0.876	1.941	1.618	1.672
others	216	378	594	0.304	0.465	0.407	1.630	0.793	1.098	2.455	1.758	2.012
all	245	525	770	0.317	0.476	0.425	1.574	0.801	1.047	2.395	1.719	1.934

Data: 1992, 22 OECD countries. All figures shown are the mean values for the indicated groupings, calculated at the 4 digit level of the SITC.

The mean level of intra-industry trade, as measured by the three indices, is statistically significantly[19] greater for the "nes" sub-groups than for all sub-groups. This effect is more pronounced for the non-manufacturing than for the manufacturing SITC sub-groups. For the manufacturing sub-groups, there is a statistically significant increase in the measured level of intra-industry amongst the "nes" sub-groups as measured by both the Grubel-Lloyd and Glejser export indices[20], although this increase is only approximately 30% and 10% respectively of that for the non-manufacturing sub-groups. The difference in the mean level of intra-industry trade, as measured by the Glejser import index, between the "nes" manufacturing sub-groups and all manufacturing sub-groups is not statistically significant, and is in the opposite direction to that which might have been expected.

For the manufacturing SITC sub-groups, the mean level of intra-industry trade for "nes" sub-groups, as measured by both the Grubel-Lloyd index and Glejser export index, is approximately 6% higher than for all manufacturing sub-groups. This difference is less than 25% of one standard deviation of the measured intra-industry trade for all manufacturing sub-groups. While this difference is statistically significant, it does not constitute grounds for arguing that measured intra-industry trade is largely a result of aggregation within the "nes" sub-groups, at least for the manufacturing

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[18] Mean value of B (SITCs5-9) is 0.54, σ=0.11. Mean C is 0.49, σ=0.10. Mean aggregation count is 3.5, σ=2.0.

[19] The null hypothesis being evaluated is that the sub-set of "nes" sub-groups is a random sample drawn from the corresponding set of all SITC sub-groups. Statistical significance is based on the probability of obtaining a value of the mean, or one further from that of the corresponding set containing both "nes" and non-"nes" sub-groups, from a random sample of the same size drawn from that set. The assumption of the normal distribution of the sample mean is justified by the size of the relevant sub-sets. The difference in the mean level of intra-industry trade between all SITC sub-groups and all "nes" sub-groups was significant at the 1% level, 1 tailed, as was the case for the non-manufacturing sub-groups.

[20] Significant at the 1% level (1 tailed) for the Grubel-Lloyd index, and at the 5% level (1 tailed) for the Glejser export index.

SITC sub-groups. It is also worth noting that the level of intra-industry trade, as measured by the Glejser import index, does not differ significantly between the "nes" manufacturing sub-groups and all manufacturing sub-groups.

Table 5.16 shows the contribution of the "nes" categories to the level of intra-industry trade calculated at the country level.

Table 5.16. The Effect on Country Intra-Industry Trade Indices of Excluding "nes" Sub-Groups

Country	Grubel Lloyd Index			Glejser Import Index			Glejser Export Index		
	original	no "nes"	Δ	original	no "nes"	Δ	original	no "nes"	Δ
Australia	0.274	0.228	0.045	1.74	1.85	0.11	2.10	2.22	0.12
Austria	0.626	0.591	0.034	1.30	1.31	0.01	1.86	1.89	0.03
Belgium	0.670	0.649	0.022	1.03	1.04	0.01	1.59	1.60	0.01
Canada	0.541	0.493	0.048	1.24	1.27	0.04	1.75	1.86	0.11
Denmark	0.551	0.504	0.043	1.39	1.43	0.04	2.10	2.18	0.09
Finland	0.402	0..361	0.041	1.44	1.51	0.07	2.34	2.43	0.09
France	0.671	0.654	0.017	0.85	0.84	-0.01	1.26	1.33	0.08
Germany	0.667	0.640	0.027	0.82	0.83	0.01	1.36	1.46	0.10
Greece	0.248	0.240	0.008	1.49	1.56	0.07	2.49	2.62	0.13
Hong Kong	0.567	0.564	0.003	1.82	1.85	0.03	3.14	3.19	0.05
Iceland	0.043	0.031	0.012	1.71	1.77	0.06	3.10	3.33	0.23
Ireland	0.472	0.398	0.074	1.45	1.48	0.02	2.13	2.18	0.05
Italy	0.520	0.494	0.027	0.96	1.00	0.04	1.69	1.79	0.10
Japan	0.258	0.228	0.029	1.49	1.57	0.08	2.51	2.68	0.17
Korea	0.357	0.336	0.021	1.70	1.80	0.11	2.50	2.62	0.13
Netherlands	0.635	0.608	0.026	1.13	1.20	0.07	1.64	1.70	0.06
New Zealand	0.216	0.192	0.025	1.63	1.70	0.08	2.63	2.77	0.13
Norway	0.302	0.241	0.060	1.45	1.53	0.08	2.31	2.38	0.08
Portugal	0.335	0.308	0.027	1.38	1.42	0.04	2.22	2.32	0.09
Singapore	0.631	0.595	0.036	1.73	1.82	0.09	2.04	2.18	0.13
Spain	0.551	0.528	0.023	1.12	1.19	0.07	1.64	1.73	0.09
Sweden	0.534	0.484	0.050	1.26	1.32	0.06	2.01	2.08	0.07
Switzerland	0.548	0.504	0.044	1.40	1.47	0.07	2.33	2.43	0.10
UK	0.704	0.677	0.028	0.90	0.91	0.01	1.40	1.44	0.05
United States	0.565	0.527	0.037	1.26	1.32	0.06	1.21	1.24	0.03
Overall Mean	*0.476*	*0.443*	*0.032*	*1.35*	*1.40*	*0.05*	*2.05*	*2.15*	*0.09*

Data: 1992 from the UN COMTRADE data base, calculated at the sub-group level. The Glejser indices with the "nes" categories excluded is calculated using the same country and overall totals as for the original (all inclusive) indices.

As anticipated, excluding the "nes" categories reduces the measured intra-industry trade at the country level but the effect is relatively minor, being on average approximately a 7% change for the Grubel-Lloyd index and 4% for the Glejser indices. The significance of the "nes" categories to the country level of intra-industry trade is therefore quite small. This result does not support the implication of Pomfret (1979, p119) that the "nes" categories are signifcant contributors to intra-industry trade, when measured at the country level.

5.3.3 The Criteria for Aggregation

The preceding analysis suggests that measured intra-industry trade is not strongly influenced by the degree of aggregation, but there are still to be considered the criteria by which individual goods are aggregated into categories within the data set to be used here. Given that intra-industry trade is to be used in this analysis as a proxy for trade driven by product differentiation, the ideal form of aggregation would be one within which intra-industry trade occurred for that reason alone.

The term intra-industry trade implies that the categories being examined are based on industries. Davis (1995) makes the point that the interpretation placed on the phenomenon of intra-industry trade, by some authors, implies that industries are considered to be defined by goods representing identical or similar factor proportions; but that within any one trade classification examples of aggregation both on the basis of similarity in production and on the basis of similarity in consumption can be found. This is also discussed by Grubel and Lloyd (1975, p86) concerning the aggregation of 4 and 5-digit SITC categories into 3-digit categories, arguing that some 3-digit groups seem to represent similarity of input requirements, some substitutability in consumption, and others both.

Where the existence of intra-industry trade is used to argue that not all trade can be explained by factor proportions, it could be expected that the industries within which intra-industry trade is measured should be defined in such a way that any intra-industry trade cannot be explained by factor proportions. This is the basis of the argument of Finger (1975) and criticisms by Pomfret (1986) of the use of the 3-digit SITC as definition of an industry. However, this analysis is concerned not with intra-industry trade related to factor proportions, but with that related to product differentiation. The distinction between intra-industry trade based on factor proportions and that based on product differentiation will be discussed below. The important issue is whether the SITC categories are consistent with the concept of a product group.

Lancaster (1980) envisages a product group as being a collection of goods encompassing the same characteristics. Chamberlin (1962, p81) suggests a collection of goods "ordinarily" thought of as comprising one imperfectly competitive market, but also considers cross-price elasticity of demand (*ibid.* pp102-3). Davis (1995) uses the phrase "substitution possibilities in consumption", and Grubel and Lloyd (1975) use a similar expression.

Dixit and Stiglitz (1977) describe a product group as a group of goods which are "good substitutes among themselves, but poor substitutes for the other commodities in the economy". The Lancaster characteristics are conceptually appealing, but not operationally useful. To define groups in terms of elasticity of substitution would be an objective approach, but not feasible given the number of individual goods involved. All that remains is the Chamberlin (1962, p81) definition of a product group as that "... which has *ordinarily* been regarded as composing one imperfectly competitive market:..." (author's italics).

It can be assumed that the grouping of goods within the various SITC categories is on the basis of some common element, related either to production or consumption. If consumption based, it is likely to conform to the Chamberlin definition of a product group. The consumption attributes of manufactured goods are, for the most part, more readily observable than the production attributes, and so it is not unreasonable to assume that categorization on the basis of similarity in consumption will be the prevailing approach. Even for SITC 6 ("classified chiefly by material"), classification at the 4-digit level is frequently consumption based[21].

In the summary of Chapter 4, it was concluded that intra-industry trade for any SITC sub-group for which trade is driven by factor proportions will not be consistently observed for a range of similar countries, whereas that based on product differentiation will be, and that this could be used to distinguish the two. This difference between the two types of intra-industry trade will be reflected in the values of the Glejser indices for the various SITC sub-groups, and in the values of the Grubel-Lloyd index calculated as the mean value for the 22 OECD countries. With the value of this index being bounded by zero and one, a high value of the mean requires a consistently high value for at least most of the countries. In the extreme case, a mean value of zero or one requires zero variance. This point is developed further in Appendix C to this chapter, which describes an analysis of the relationship between the mean value (B_i)

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[21] For example, rubber tyres (separate sub-categories for vehicle type - 625.1, 625.2, 625.3, 625.4), manufactures of wood for decorative or domestic use (exc furniture) - 635.4, hand polishing stones - 663.1.

for a sub-group and the standard deviation of the value of the index for each individual country (B_{ij}).

5.4 Correlation Between the Various Measures of Intra-Industry Trade

The Grubel-Lloyd and Glejser indices are to be used as proxies for trade based on product differentiation, and as they are being used to measure the same thing the correlation between them is of some importance. The Aquino index is included because it is a version of the Grubel-Lloyd index adjusted for trade imbalance, and, since the Glejser indices are insensitive to trade imbalance, a comparison of the degree of correlation between them of the Glejser indices is of interest. The correlation coefficients are summarized in Table 5.17.

5.4.1 Correlation at the SITC Sub-group Level

Table 5.17. Correlation of Intra-Industry Trade Measures at the SITC Sub-Group Level.

	Pearson correlation				Spearman Correlation			
	Grubel Lloyd	Aquino	Glejser Import	Glejser Export	Grubel Lloyd	Aquino	Glejser Import	Glejser Export
Grubel Lloyd		0.99	-0.62	-0.75		0.99	-0.62	-0.75
Aquino	0.99		-0.64	-0.75	0.99		-0.64	-0.75
Glejser Import	-0.62	-0.63		0.65	-0.59	-0.61		0.57
Glejser Export	-0.71	-0.71	0.65		-0.71	-0.72	0.60	

1982 values are above the diagonal, 1992 values below.

The correlations shown in Table 5.17 are all significant at the 0.01% level, and are stable over the 10 year period. There is no difference between the correlation of the Grubel-Lloyd and Aquino indices with the Glesjer indices. The correlation between the Grubel-Lloyd and Glejser export index (-0.71) is greater than that between the Glejser import index and both the Grubel-Lloyd and Glejser export indices (-0.62 and 0.65). There is no ready explanation for this apparently higher correlation between the Grubel-Lloyd and Glejser export indices.

To examine the possibility of these correlations being dependent on the manufacturing/non-manufacturing divide, Table 5.18 shows the same correlations for manufacturing and non-manufacturing SITC sections separately.

Table 5.18. Correlation of Intra-Industry Trade Measures at SITC Sub Group Level: Manufacturing and Non Manufacturing.

	SITCs 0-4				SITCs 5-8			
	Grubel Lloyd	Aquino	Glejser Import	Glejser Export	Grubel Lloyd	Aquino	Glejser Import	Glejser Export
Grubel Lloyd		0.99	-0.47	-0.60		0.99	-0.53	-0.72
Aquino	0.99		-0.48	-0.60	0.99		-0.56	-0.72
Glejser Import	-0.53	-0.53		0.55	-0.47	-0.49		0.51
Glejser Export	-0.62	-0.62	0.51		-0.64	-0.65	0.55	

1982 values are above the diagonal, 1992 values below. Pearson correlation coefficients.

Although the correlation coefficients are lower, they are all still significant at the 0.01% level. Again, the highest correlation is between the Glejser export and Grubel-Lloyd indices.

5.4.2 Correlation at the Country Level

Table 5.19. Correlation of Country Measures of Intra-Industry Trade - 25 Countries.

	Pearson Correlation				Spearman Rank Correlation			
	Grubel Lloyd	Aquino	Glejser Import	Glejser Export	Grubel Lloyd	Aquino	Glejser Import	Glejser Export
Grubel Lloyd		0.99	-0.78	-0.76		0.99	-0.61	-0.77
Aquino	0.99		-0.78	-0.76	0.99		-0.63	-0.77
Glejser Import	-0.64	-0.69		0.72	-0.64	-0.69		0.57
Glejser Export	-0.75	-0.78	0.84		-0.75	-0.78	0.84	

1982 values are above the diagonal, 1992 values below.

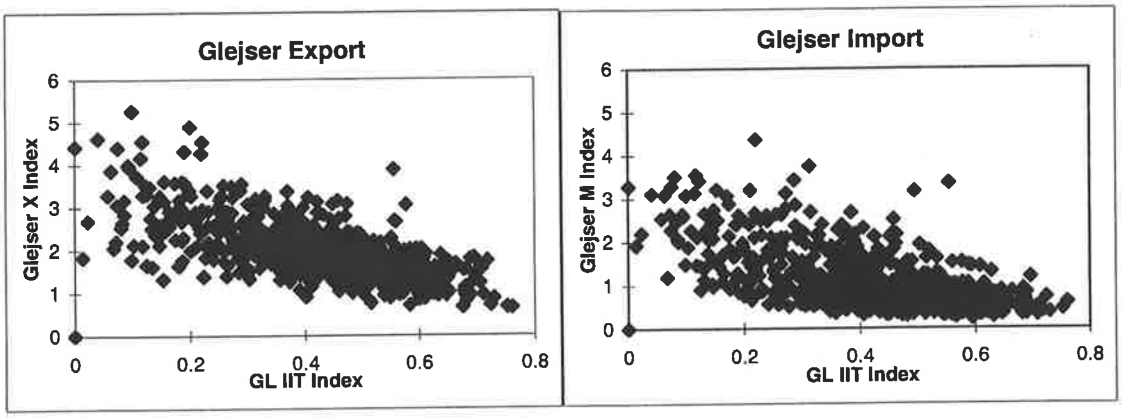
Table 5.19 shows that the correlations amongst the various measures calculated at the country level are much the same as those at the calculated at the SITC sub-group level.

The Aquino index is designed to compensate for the effects of trade imbalance and, with the Glejser indices being independent of trade imbalance, one might have expected the Glejser indices to be more highly correlated with the Aquino than with the Grubel-Lloyd index. While this appears to be the case for 1992, there is little evidence of it for 1982, and so no conclusions can be drawn. The Grubel-Lloyd and Glejser indices are based on different theoretical foundations, but the correlation between them is sufficiently high to suggest that they are measuring the same thing, although not sufficiently high as would render their joint use redundant. For example, from Table 5.2, the value of the Grubel-Lloyd index for SITC Section 9 (the "nes " section) would not distinguish this from any other manufacturing section yet, from Table 5.9, the value of the Glejser indices for Section 9, and particularly the import index, are substantially higher than the other manufacturing sections and the overall average. On the other hand the Grubel-Lloyd and Aquino indices are so highly correlated that the use of both would provide no additional information. Accordingly, the Aquino index will not be used.

5.4.3 Correlation Between the Grubel-Lloyd and Glejser Indices

In this section the relationship between the Grubel-Lloyd and Glejser indices is examined more closely.

Figure 5.1. Scatter Plot of the Glejser and Grubel-Lloyd Indices



Indices calculated from 1992 trade data for 22 OECD countries for all SITC sub groups.

Figure 5.1 illustrates the relationship between the Grubel-Lloyd and each of the Glejser indices. The correlation is evident over the range of the Grubel-Lloyd index, although the dispersion of the Glejser indices is lower at the higher values of the Grubel-Lloyd index.

Estimations with the Grubel-Lloyd index as the dependent variable and the Glejser indices, both individually and jointly, as the explanatory variable(s) were significant with R^2 values ranging from 0.35 to 0.6, depending on the functional form and whether the original form or logit transformation of the Grubel-Lloyd index was used. The explanatory power was increased by a small but significant amount with the use of both rather than one of the Glejser indices. Even with the use of WLS as a remedy for heteroscedasticity, no functional form was found that would yield estimates that were stable over various ranges of values for the Grubel-Lloyd index. This is not surprising, considering that trade for the various sub-groups is motivated by a variety of factors, which are unlikely to be distributed independently of the value of the Grubel-Lloyd index.

A non-parametric approach was used in the form of a contingency table to further analyze the joint distribution of the two indices. This is illustrated in Table 5.20.

Table 5.20. Joint Distribution of the Grubel-Lloyd and Glejser Indices.

GL iit	Glejser Import Index Upper Bound						Glejser Export Index Upper Bound					row
upper	0.5	1.0	1.5	2.0	2.5	4.5	1	1.5	2	2.5	5.5	Σ
0.2	0 -11.8 ***	4 -24.3 ***	14 2.3	12 6.1 ***	15 10.9 ***	20 16.8 ***	0 -2.9 ***	1 -14.9 ***	6 -15.1 ***	13 0.4	45 32 ***	65
0.3	0 -15.1 ***	24 -12.2 **	18 3.1	16 8.4 ***	13 7.8 **	12 7.9 ***	0 -3.7 ***	3 -17.3 ***	13 -14.0 **	19 2.9	48 32 ***	83
0.4	9 -18.7 ***	65 -1.2	42 14.7 ***	19 5.2 *	14 4.5 *	3 -4.5 **	0 -6.7 ***	9 -28.2 ***	52 2.6	56 26.5 ***	35 5.7	152
0.5	40 0.68	111 16.9 **	40 1.2	17 -2.7	6 -7.4 ***	2 -8.7 ***	2 -7.5 ***	55 2.2	93 22.8 ***	50 8.1	16 -26 ***	216
0.6	57 27.9 ***	77 7.3	19 -9.7 **	6 -8.6 ***	0 -10.0 ***	1 -6.9 ***	13 5.9 ***	72 32.9 ***	61 9.0	10 -21 ***	4 -27 ***	160
0.8	34 17.1 ***	54 13.5 **	5 -11.7 ***	0 -8.5 ***	0 -5.9 ***	0 -4.6 **	19 14.9 ***	48 25.3 ***	25 -5.2	1 -17 ***	0 -18 ***	93
col Σ	140	335	138	70	48	38	34	188	250	149	148	769

$\chi^2 = 356$ df=25 $\chi^2 = 475$ df=20

χ^2 value for each individual row and column statistically significant. Cell contents (from the top): frequency, deviation from the expected frequency based on independent distribution of the two indices, and significance indication : ***, **, * significant at 1%, 5% and 10%, based on normal distribution of sample proportion around the null hypothesis value calculated assuming independent distribution. Outlined cells are those for which the deviation from expected is significantly positive, while shaded cells are those for which the deviation is significantly negative.

Table 5.20 is a quantitative representation of Figure 5.1. The expected correlation is evident in the concentration of observations around the right to left (upward sloping) diagonals. While interpretation is hampered by the arbitrary definition of the categories, the correlation between high values of the Grubel-Lloyd index and low values of the Glejser indices is evident. This is consistent with the expectation that trade in differentiated products will lead to high values of the Grubel-Lloyd index, and a consistent pattern of trade for the countries included.

Although the two types of indices are strongly correlated not all observations lie on the right to left diagonal, and there is some advantage in using both indices jointly. As an example, SITC Section 9, by reason of it being the "not elsewhere specified" section, could be expected to experience intra-industry trade for reasons other than product differentiation. The mean value of the Grubel-Lloyd index for this section is indistinguishable from that for the other manufacturing sections, yet the mean Glejser import index is double that, and so distinguishes Section 9 from the other manufacturing sections.

5.5 Empirical Use of the Intra-Industry Trade Indices

It remains to be considered how the intra-industry trade indices will be used to measure product differentiation. It would be convenient to consider each sub-group of the SITC as being either differentiated or not, but this would be an over simplification. In any event the intra-industry trade indices are continuous variables, and there is no basis for defining threshold values. It would not be unexpected to find, within the one sub-group, both differentiated and non-differentiated goods - possibly the range and expenditure share of the differentiated goods increasing with innovation, and possibly a number of the differentiated goods losing their differentiation, perhaps from the expiration of intellectual property rights. Even if trade within any one sub-group were based entirely on product differentiation, the values of the intra-industry trade indices would depend on a number of other factors, such as the distribution of the s_{ij}.

The worst case distribution of s_{ij} would be if, for some differentiated product group i, all varieties were produced in some country k; giving $s_{ik}=1$, and $s_{ij}=0$ for all countries $j \neq k$. This might happen at the initial stage of a new innovative product group, but there is no reason to believe that it would be other than a transitory phenomenon. In any case, such an occurrence would lead to all other countries ($j \neq k$) importing all varieties of that product group, and only one country (k) having non-zero exports of that product group, so that, while the value of the Grubel-Lloyd index would be zero, the values of the Glejser indices, and particularly that of the Glejser import index, could be expected to be low, consistent with it being a differentiated product group.

While it is not being argued that the intra-industry trade indices are perfect measures of product differentiation, it is argued that, all else being equal, the higher the value of the Grubel-Lloyd index (or the lower the value of either Glejser index) the greater the expected contribution of product differentiation to trade in that sub-group or, alternatively, the greater the probability that that sub-group represents a differentiated product group. Although the value of the intra-industry trade index for any individual sub-group has limited significance, as long as the value of the intra-industry trade indices are systematically correlated with product differentiation, they can be used as proxies for product differentiation.

5.6 Appendix A

5.6.1 Data Source

The data are exports and imports for 25 countries with the rest of the world for 1982 and 1992, sourced from the United Nations COMTRADE data base. The data are comprised of value of exports and imports in $US (current) at the 4 digit level of the SITC (revision 2). The 4 digit level of the SITC revision 2 constitutes 786 sub groups.

The countries covered are the then OECD[22] countries with the exception of Turkey, with the addition of Hong Kong, South Korea, and Singapore. Turkey was excluded because trade data for this country were not available at revision 2 level for 1982.

The selection of the OECD countries was to use an already defined group of high income countries, and thereby avoid the risk of subjective bias in country selection. Product group specific attributes were determined using the 22 OECD countries. The other three countries were included as a sample of (at that time) high growth newly industrialized countries.

5.6.2 Data Preparation

Reexport data are provided for four countries (Australia, Hong Kong, New Zealand, US). Reexports purport to represent the value of goods imported which are subsequently exported. The import value of such goods is included in import data, but the export value not included in export data. The definition of reexports is apparently at the discretion of each reporting country. Table 5A.1 summarises the extent and significance of reexport data for these countries.

Table 5A.1. Total Reexports Relative to Total Imports and Exports.

Country	1982			1992		
	N	Reexports as percentage of		N	Reexports as percentage of	
		Imports	Exports		Imports	Exports
Australia	609	1.5	1.6	642	9.0	9.4
Hong Kong	697	31	53	714	70	295
New Zealand	527	4.3	4.9	568	4.2	4.1
United States	692	2.0	2.5	723	4.1	5.3

N: Number of 4 digit subcategories for which reexport data are provided.

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[22] Australia, Austria, Belgium/Luxembourg, Canada, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Italy, Japan, Netherlands, New Zealand, Norway, Portugal, Spain, Sweden, Switzerland, (Turkey), United Kingdom, United States.

It is apparent that reexports are too high a proportion of total trade to be ignored, particularly so for Hong Kong. While the simplest approach would be to add reexports to exports for the individual sub-group, this courts the risk of over stating the degree of intra-industry trade. It could also influence trade growth figures. Table 5A.2 is a summary of the varying ratios of reexports to imports at the individual sub group level.

Table 5A.2. Analysis of Reexports Relative to Imports for the Same Sub-category.

Country	N		Ratio of reexports to imports					
			1982			1992		
	1982	1992	Min	Median	Max	Min	Median	Max
Australia	27	8	2.5x10^{-5}	6.8x10^{-3}	10.6	3.7x10^{-5}	1.8x10^{-2}	15.2
Hong Kong	54	116	2.2x10^{-4}	3.0x10^{-1}	65.5	1.6x10^{-3}	6.0x10^{-2}	9.8
New Zealand	7	10	6.2x10^{-5}	9.5x10^{-3}	32.7	4.5x10^{-6}	1.5x10^{-2}	36.7
United States	53	5	9.7x10^{-6}	1.3x10^{-2}	101.8	3.3x10^{-6}	1.7x10^{-2}	8.6

N: The number of 4 digit SITC sub categories for which reexports exceed imports.

The preferred approach was to adjust for reexports by subtracting the reexport figure from the import figure for each affected sub-group, but the incidence of cases where reexports exceed imports prevented this from being applied universally. The solution implemented was to subtract reexports from imports, where reexports are not greater than imports; otherwise to add reexports to exports.

Table 5A.3 provides an example of this for SITC 751.2. There is nothing particularly significant about this sub-group; it is one of many which would serve to demonstrate the two methods of dealing with the reexport data. For Australia, New Zealand and the United States the value of reexports is less than that of imports (which is as expected), and the reexport value is subtracted from the import value. For Hong-Kong this is not possible because the value of reexports exceeds that of imports, and consequently the value of reexports is added to the export value.

Table 5A.3. Example of Reallocation of Reexport Data.

	Before Redistribution of Reexports			After Reexport Redistribution	
	Reexports	Exports	Imports	Exports	Imports
Australia	909	1395	41557	1395	40468
Austria		17586	27663	17586	27663
Belgium		13194	34876	13194	34876
Canada		49550	122642	49550	122642
Denmark		2060	18847	2060	18847
Finland		3715	8013	3715	8013
France		44967	143788	44967	143788
Germany		92246	220672	92246	220672
Greece		649	20635	649	20635
Hong Kong	298545	20009	277838	318554	277838
Iceland		12	1452	12	1452
Ireland		1779	8008	1779	8008
Italy		154918	97131	154918	97131
Japan		576619	112693	576619	112693
Korea		40789	41529	40789	41529
Netherlands		18516	51946	18516	51946
New Zealand	1580	464	7472	464	5892
Norway		12238	14506	12238	14506
Portugal		919	23696	919	23696
Singapore		129963	101293	129963	101293
Spain		2883	88434	2883	88434
Sweden		24842	33603	24842	33603
Switzerland		38705	33792	38705	33792
UK		92817	116133	92817	116133
United States	32173	176528	854298	176528	822125

Data are for 1992, for SITC 7512 (Calculating machines; accounting machines, cash registers, postage-franking machines, ticket-issuing machines and similar machines, incorporating a calculating device). Units are $US1000 (current).

Table 5A.4 summarizes the affect on aggregate imports and exports of reexports being redistributed in this manner. The large increase in the value of exports for 1992 for Hong-Kong shown in this Table reflects the relatively high incidence of reexports exceeding imports and therefore having to be reallocated to exports, as shown in Table 5A.2.

Table 5A.4. Aggregate Data After Reexport Redistribution.

Country	% of reexports redistributed to				% decrease in imports		% increase in exports	
	imports		exports					
	1982	1992	1982	1992	1982	1992	1982	1992
Australia	96.6	98.7	3.4	1.3	1.4	8.9	0.05	0.13
Hong Kong	90.2	63.9	9.8	36.1	28.0	44.8	4.4	105
New Zealand	78.4	90.8	21.6	9.2	3.4	3.8	1.0	0.4
United States	94.7	99.5	5.3	0.5	1.9	4.0	0.1	0.02

5.6.3 Data Correction

In the disaggregation of 3-digit groups to 4-digit sub-groups within the SITC, the only sub-groups having an identifier with zero as the last character are those for which there is no disaggregation between the group and sub-group - that is, there is only one sub group within the group (however, this sub-group may be further disaggregated). It is, however, suggested that, in those cases where trade volume is sufficiently low, all trade data within a group can be aggregated by the reporting country into one sub group, identified as the group identifier with a zero appended.

An analysis of the data showed 105 such sub-groups. Of these, 103 occurred in cases where the reporting country had reported trade data for defined sub-groups within the group - 96 for 1982 , 29 for 1992, and 22 for both. Only in three (all 1982) cases were data reported in this manner in the absence of data for any other sub-group within that group (one sub-group occurs in both categories). For the purposes of determining any sub-group specific attributes, such as an intra-industry trade index or growth in the aggregate import to GDP ratio, data for these sub groups were ignored - because such sub groups are not officially defined and, in any event, data was reported for any such sub-groups by only one or two countries.

The more difficult issue was how to treat data reported by a country in other sub-groups within a group where this had occurred. A visual examination showed that in some case exports had been reported at the aggregated level and imports at the disaggregated level (or *vice versa*), rendering the use of such data potentially misleading. In some cases, the volume of trade reported at the aggregated level was minor compared with that at the disaggregated level. The problem was resolved, when calculating SITC sub-group specific attributes, by ignoring any disaggregated sub-group data (both exports and imports) where that country had, for the same time period, reported data at the aggregate sub-group level and the value of either exports or imports at the aggregate level exceeded 1% of those at the disaggregated level. This may appear conservative but, where an intra-industry trade index is calculated on the basis of the difference between imports and exports, a small percentage error in either can translate into a large one in the final result.

Table 5A.5 is included to provide an example of this. To simplify presentation, only data for 1992 are included.

Table 5A.5. Example of Treatment of Undefined SITC Sub-Category Data

Country	SITC	Imports	Exports	Undefined SITC	Invalid data 1992
Germany	6950	.	2864	1	
Germany	6951	41789	49476		1
Germany	6953	537091	985714		
Germany	6954	1076316	12729870		
Spain	6950	165	.	1	
Spain	6951	11119	7940		1
Spain	6953	133423	81539		
Spain	6954	278812	211363		

Units are in $US10,000. "." indicates no data provided, assumed zero.

SITC 695.0 is undefined because there are three sub-groups defined for category 695. All records for 695.0 are marked accordingly. The export value recorded against 695.0 for Germany exceeds 1% of that recorded against 695.1, and consequently this record (695.1/Germany) is marked as having invalid data for 1992. Similarly, the import value recorded against 695.0 for Spain exceeds 1% of that recorded against 695.1 for Spain, and consequently the record (695.1/Spain) is marked as having invalid data for 1992.

Records marked as being an undefined SITC sub-group are not used for any analysis at the SITC sub-group level, although they are included, for example, in determining total imports and exports by country. Records for defined SITC sub-groups which are marked as containing invalid data are not included in any SITC sub-group specific analysis; such as the determination of the value of the intra-industry trade indices by SITC sub-group, or the determination of import and export growth rates by SITC sub-group. The categorization of an SITC sub-group/country record as containing invalid data is year specific; those records categorized in this way for 1992 in Table 5A.5 might well be considered valid for 1982. Only those records considered valid for both years are included in the calculation of growth rates. Records for defined SITC sub-groups which are categorized as containing invalid data are still used in determining total imports and exports by country.

Of the 19436 SITC sub-group/country records for defined SITC sub-groups 237 (1.2%) were categorized as invalid for 1982 data, and 80 (0.4%) were categorized as invalid for 1992 data. Of these, two (0.01%) were categorized as invalid for both 1982 and 1992.

5.6.4 Statistical Methods

The analyses presented in this thesis are carried out using the SAS® software, Release 6.12, operating under Unix System V Release 4.0.

Both the Pearson and Spearman rank correlation coefficients are estimated using the CORR procedure. The probability value is the probability of obtaining the estimated value, or higher, of the sample correlation coefficient if the null hypothesis, that the two variables are uncorrelated, is true. The probability value is based on the t distribution with (n-2) degrees of freedom. The t-statistic is calculated as $t_{n-2} = \frac{\rho\sqrt{(n-2)}}{\sqrt{(1-\rho^2)}}$, where ρ is the estimated value of the correlation coefficient. The probability value is calculated and reported by the software. In a number of cases both the Pearson and Spearman rank correlation coefficients are reported. This is because the Pearson correlation coefficient measures linear correlation, whereas the Spearman rank correlation coefficient is non-parametric and, while the value of the Pearson correlation coefficient is susceptible to influence by extreme observations, the Spearman rank correlation coefficient is not.

Regressions with continuous dependent variables are carried out with the REG procedure, using ordinary least squares. The probability value for each estimated coefficient, ($\hat{\beta}_i$), is the probability of obtaining an estimate further from zero than the estimated value for β_i if the null hypothesis, $\beta_i = 0$, is true, and is based on the t distribution with (N-k-1) degrees of freedom, where N is the number of observations and k the number of explanatory variables, with the t-statistic being calculated as $t_{N-k-1} = \frac{\hat{\beta}_i}{SE_{\hat{\beta}_i}}$. The probability value is calculated and reported by the software. In the interests of brevity, and clarity of presentation, only the estimated value of each coefficient, the standard error of the estimate, and the probability value rounded up to 1%, 5% or 10% (indicated as ***,**,* respectively), are reported for each dependent variable. Should the value of the t-statistic be required, this can be obtained by dividing the value of the estimate by that of the standard error.

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Regressions with binary dependent variables are carried out with the LOGISTIC procedure, which estimates a logistic model using maximum likelihood. The probability value for each estimated coefficient, $\hat{\beta}_i$, is the probability of obtaining an estimate further from zero than the estimated value for β_i if the null hypothesis, $\beta_i = 0$, is true, and is based on the Wald statistic with a χ^2 distribution with one degree of freedom, being calculated as $\chi_i^2 = (\frac{\hat{\beta}_i}{SE_{\hat{\beta}_i}})^2$. The probability value is calculated and reported by the software. Again, only the estimated value of each coefficient, the standard error of the estimate, and the probability value rounded up to 1%, 5% or 10% (indicated as ***,**,* respectively), are reported for each dependent variable. Should the value of the χ^2 statistic be required, it can be determined as $\chi_i^2 = (\frac{\hat{\beta}_i}{SE_{\hat{\beta}_i}})^2$.

The statistical significance of the difference between sample means is, where applicable, based on the paired difference test. It is based on the t-distribution with (n-1) degrees of freedom, where n is the number of observations. The test statistic is calculated as $t_{n-1} = \frac{\bar{d}}{s_{\bar{d}}}$ where $\bar{d} = \frac{\sum_{i=1}^{n} d_i}{n}$, $d_i = x_i^A - x_i^B$, where x_i^A and x_i^B are the i^th values from samples A and B respectively, and $s_{\bar{d}} = \sqrt{\frac{(d_i - \bar{d})^2}{n(n-1)}}$. The probability value is the probability of obtaining this value or one further from zero if the null hypothesis, that the two means are the same , is true.

Tests of statistical significance of the difference between the mean of a set of observations, and the mean of a sub-set of those observations, are based on the probability of obtaining the measured mean of the sub-set, or one further from the mean of the parent set, if the sub-set being considered was a random sample of the same size drawn from the parent set. The determination of this probability is based upon the standard normal distribution of $\frac{\bar{X}}{\sigma_{\bar{X}}}$, where $\sigma_{\bar{X}} = \frac{\sigma}{\sqrt{n}}$, and σ, the standard deviation of the parent set, is known. If σ is not known, the t distribution is used, with (n-1) degrees of freedom, of $\frac{\bar{X}}{s_{\bar{x}}}$, where $s_{\bar{x}} = \frac{s}{\sqrt{n}}$, and s is the standard deviation of the sub-set. $\bar{X}$ is the mean of the sub-set and n the number of observations. The expected value of $\bar{X}$ is the mean of the parent set.

Tests of statistical significance of the difference between the variance of a set of observations, and the variance of a sub-set of those observations, are based on the probability of obtaining the measured variance of the sub-set, or one further from the variance of the parent set, if the sub-set being considered was a random sample of the same size drawn from the parent set. The determination of this probability is based upon $\frac{(n-1)s^2}{\sigma^2}$ being distributed as χ^2_{n-1}, where n is the number of observations in the sub-set, s^2 is the variance of the sub-set, and σ^2 is the variance of the parent set.

Hypothesis testing concerning sample proportions is based on the standard normal distribution of the test statistic $\frac{\pi_0 - p}{\sqrt{\frac{\pi(1-\pi_0)}{n}}}$, where π_0 is the proportion specified in the null hypothesis, n is the sample size and p the sample proportion. The probability value is the probability of obtaining the measured sample proportion or one further from that specified in the null hypothesis, if the null hypothesis is true. Normality of the test statistic is assumed where $n\pi_0 \geq 5$ and $n(1-\pi_0) \geq 5$.

5.7 Appendix B

This appendix describes the reasoning behind the use of the Glejser import and export indices as proxies for product differentiation. The discussion is based on the import index, and similar reasoning is applicable to the export index.

The value of the import index for product group i is determined by the variance in $\log(\frac{M_{ij} / M_{.j}}{M_{i.} / M_{..}})$. For any given product group i, the value of the denominator is constant for all countries (j).

From Chapter 3 (3.6.4),

$$\frac{M_{ij}}{Y_j} = g_i (1 - s_{ij}) I_j^{\eta_i - 1} \text{ where}$$

M_{ij} is the import of product group i into country j

Y_j is the GDP of country j

g_i is the expenditure share on product group i

s_{ij} is the share of that expenditure devoted to goods produced in country j

I_j is the per capita income of country j

η_i is the income elasticity of demand for product group i

Assuming, for simplicity, unit income elasticity of demand, this becomes

$$\frac{M_{ij}}{Y_j} = g_i (1 - s_{ij})$$

Ignoring, for the moment, undifferentiated goods, total imports for country j ($M_{.j}$) is given by

$$M_{.j} = \sum_i M_{ij} = [\sum_i g_i (1 - s_{ij})] Y_j = g(1 - s_j^w) Y_j$$

where $g=\sum_i g_i$ (total share of expenditure on differentiated goods) and s_j^w is the weighted average of s_{ij} for country j (weighted by the value of g_i)[23].

Then

$$\frac{M_{ij}}{M_{.j}}=\frac{g_i(1-s_{ij})}{g(1-s_j^w)}. \qquad 5.B.1$$

If for any product group i , $s_{ij}=s_j^w$ for all j, then the value of the variance, and of the Glejser import index, will be zero. Variation of s_{ij} around the value of s_j^w will give a non-zero value.

Including undifferentiated goods in total imports, expression 5.B.1 for a differentiated good becomes $\frac{M_{ij}}{M_{.j}}=\frac{g_i(1-s_{ij})}{g(1-s_j^w)+u_{.j}}$ 5.B.2

where $u_{.j}$ is the total imports of undifferentiated goods into country j, as a proportion of GDP. This value of this variable can be expected to vary between countries and increase the variance of $\frac{M_{ij}}{M_{.k}}$, but its contribution will be the same for all goods, differentiated or undifferentiated.

For an undifferentiated good, 5.B.2 can be expressed as

$$\frac{M_{ij}}{M_{.j}}=\frac{u_i(f_{ij})}{g(1-s_j^w)+u_{.j}} \qquad 5.B.3$$

where u_i is the expenditure share on undifferentiated product group i and f_{ij} is the proportion of that expenditure on imports in country j. Variations in the value of this variable between countries for any given i will determine the value of the Glejser index. There is no reason to limit the value of f_{ij} to any range smaller than $0\leq f_{ij}\leq 1$.

---

[23] $\frac{M_{ij}}{M_{.j}}=\frac{g_i(1-s_{ij})}{\sum_i[g_i(1-s_{ij})]}=\frac{(1-s_{ij})g_i}{(1-s_j^w)\sum_i g_i}=\frac{(1-s_{ij})g_i}{\left(1-s_j^w\right)g}$

$s_j^w=\frac{\sum_i g_i s_{ij}}{\sum_i g_i}$, therefore $\sum_i g_i s_{ij}=s_j^w g$

The equivalent term for differentiated goods is $(1-s_{ij})$. For the smallest 20 of the 22 OECD countries the expected value of s_{ij} is in the range $0\leq s_{ij} \leq 0.1$ and correspondingly $0.9\leq (1-s_{ij}) \leq 1$. Allowing the value of s_{ij} to vary between 50% and 200% of the expected value gives the expected range of $(1-s_{ij})$ as $0.8\leq (1-s_{ij}) \leq 1$, a considerably smaller range than for f_{ij}. Accordingly, it is expected that the value of the Glejser import index will be less for differentiated than for undifferentiated goods.

To enable valid comparisons of the variances for various product groups i they must be normalized by the respective values of g_i or u_i. This is the function of the demominator, which is $\frac{M_{i.}}{M_{..}}$. For a differentiated product group the value of $M_{i.}$ is given by

$M_{i.} = g_i(1-s_i^w)Y_T$, where s_i^w is the average value of s_{ij} weighted by y_j, the share of of country j in total GDP (Y_T),

and for an undifferentiated product group

$M_{i.} = u_i(f_i^w)Y_T$ where f_i^w is analogous to s_i^w.[24]

And total imports ($M_{..}$) are given by

$M_{..} = [g(1-s^w)+u(f^w)]Y_T$ where s^w and f^w are respectively the averages of s_i^w and f_i^w, weighted by the corresponding values of g_i or u_i. g and u are expenditure shares on differentiated and undifferentiated goods.

The value of $\frac{M_{i.}}{M_{..}}$ is either $\frac{g_i(1-s_i^w)}{[g(1-s^w)+u(f^w)]}$ or $\frac{u_i(f_i^w)}{[g(1-s^w)+u(f^w)]}$

and the use of $\frac{M_{i.}}{M_{..}}$ as a denominator normalizes the variances around the corresponding values of g_i or u_i.

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[24] $M_{ij} = u_i f_{ij} Y_j \quad M_{i.} = \sum_j u_i f_{ij} Y_j = u_i Y_T \sum_j f_{ij} y_j = u_i f_i^w Y_T$

A similar argument can be presented for the export index, but leads to an expectation of higher values for differentiated goods than for the import index. The Glejser export index is calculated as the standard deviation of $\log(\frac{X_{ij} / X_{.j}}{X_{.j} / X_{..}})$

5.8 Appendix C:

The objective of this appendix is to analyze the relationship between the value of B_i and the variance of the component B_{ij} - specifically, to examine the proposition that the higher values of B_i will be associated with a lower variance of the component B_{ij}.

The values of the intra-industry trade index at the country/SITC sub-group level (the B_{ij}) are bounded by 0 and 1 and do not conform to any well known distribution which could be used as a point of reference when considering the joint distribution of the value of the mean intra-industry trade index across countries and the standard deviation thereof.

It is desirable to have some basis for comparison because with the values of B_{ij} being bounded ($0 \leq B_{ij} \leq 1$) it is not clear that the mean and variance of random samples from such a population would be independent, in which case no conclusions could be drawn from any observed relationship between these two variables when determined on a SITC sub-group basis. Rather than use a known distribution, the basis of comparison was the maximum number of random samples (without replacement) of size 22 from the population of B_{ij}

Table 5C.1 summarizes the original population of B_{ij}, the values of B_i obtained as the means of random samples, and the actual values of B_i obtained by determining B_i as the mean value of B_{ij}.

Table 5C.1 Mean Values of B_{ij}: Distribution for SITC Sub-Groups and for Random Samples

	Non-manufactured			Manufactured		
	Mean	Std Dev	Range	Mean	Std Dev	Range
IIT Index						
B_{ij} (Country/sitc sub-grp)	0.320	0.315	0 - 1	0.478	0.316	0 - 1
B_i for Random Samples	0.321	0.063	0.19-0.54	0.478	0.070	0.30-0.68
B_i for SITC sub-groups	0.317	0.142	0.001-0.69	0.476	0.120	0-0.76
Intra-sample Std Dev						
Random Samples	0.315	0.036	0.22-0.40	0.314	0.030	0.22-0.40
SITC sub-groups	0.281	0.063	0.003-0.38	0.298	0.035	0.16-0.39

The B_i generated from random samples are approximately normally distributed[25], with variance not significantly different from that expected for the distribution of the sample mean. The B_i calculated as the mean values of SITC sub-groups have variance of approximately three times that expected for random samples, with the null hypothesis of normal distribution rejected at the 5% but not 1% level of significance.

The relationship between the standard deviation and the value of the Grubel-Lloyd intra-industry trade index was estimated using a quadratic model[26] for both the actual data and the simulated samples. Separate estimates were made for non-manufacturing and manufacturing data. The results are summarized in Table 5C.2.

Table 5C.2 Estimates of Std Dev as Function of Intra-Industry Trade Index Value

	Intercept	IIT Index	(IIT Index)^2	R^2	VIF
Random Samples					
Non-manufactured	0.073 ** (0.036)	1.220 *** (0.215)	-1.395 *** (0.320)	0.33	54.76
Manufactured	0.082 * (0.047)	1.027 *** (0.200)	-1.110 *** (0.209)	0.06	117.6
SITC Sub-Groups					
Non-manufactured	0.073 *** (0.009)	1.218 *** (0.061)	-1.471 *** (0.0915)	0.69	15.4
Manufactured	0.110 *** (0.015)	0.871 *** (0.066)	-0.940 *** (0.071)	0.25	34.1

Non-manufacturing, N=235. Manufacturing, N=535.
VIF: variance inflation factor, inflation of the variance of the estimates due to multicollinearity between the explanatory variables.
All four estimates are significant at less than 0.01%. ***,**; significant at 1%, 5%. No evidence of heteroscedasticity for explanatory or dependent variables. Durbin-Watson statistic with sorted input not significant.

For all four estimations, the results are consistent with the expectation that the standard deviation is not independent of the mean value - that there is an inverted U effect.. On the basis of the estimates shown, Diagram 5C.1 shows the predicted relationship between the value of the Grubel-Lloyd index and its standard deviation, both for random samples and SITC sub-groups.

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[25] A normal distribution of the sample mean is predicted by the Central Limit theorem under these conditions.

[26] The use of a quadratic function was based on the expectation, discussed earlier, that due to the values of the B_{ij} being bounded, a mean value at either extremity would require a variance of zero.

Diagram 5C.1a. Standard Deviation of the Grubel-Lloyd Intra-Industry Trade Index

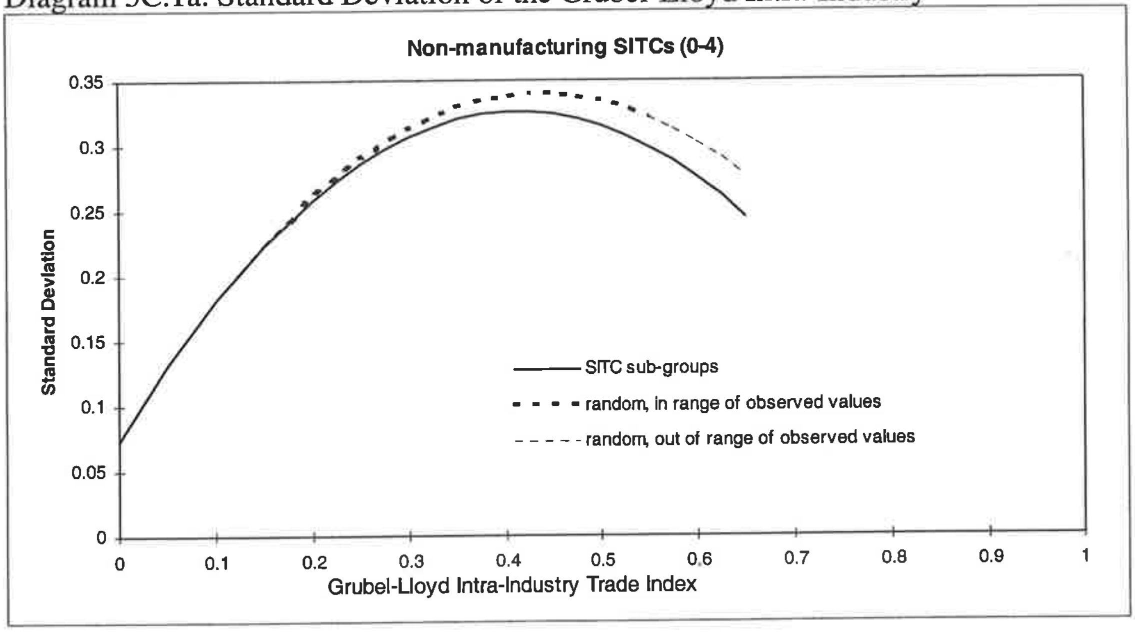

Diagram 5C.1b. Standard Deviation of the Grubel-Lloyd Intra-Industry Trade Index

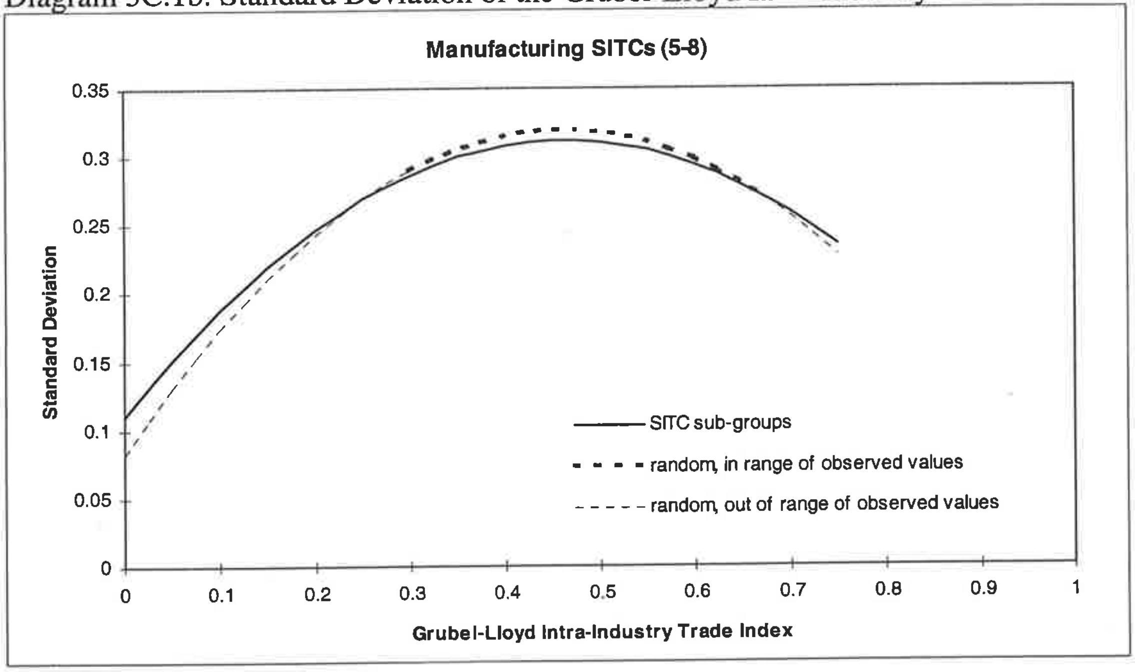

Diagram 5C.1 shows that, as anticipated, the standard deviation is greater for the intermediate values of the Grubel-Lloyd index than for the lower and higher values. The close fit between the curves based on the estimates using the SITC sub-groups and the curves based on the random sample suggest that this effect is due to the values of the B_{ij} being bounded.

The effect of the non-random composition of the SITC sub groups can be seen in the wider range of values observed for these than for the random samples. This results from there being less variation in the values of the Grubel-Lloyd index for any one SITC sub-group over the countries analyzed than would be expected if the Grubel-Lloyd index was measuring only random effects.

5.9 Appendix D

5.9.1 Calculation of the Grubel-Lloyd Intra-Industry Trade Index

Table 5D.1. Calculation of the Grubel-Lloyd Intra-Industry Trade Index.

Country	Imports for SITC 7512 (A)	Exports for SITC 7512 (B)	Grubel-Lloyd Index	Total Country Imports (C)	Total Country Exports (D)
Australia	40648	1395	0.06636	38314819	40421954
Austria	27663	17586	0.77730	54021992	44342147
Belgium	34876	13194	0.54895	125121820	123459388
Canada	122642	49550	0.57552	122441029	134441064
Denmark	18847	2060	0.19706	32881381	38938315
Finland	8013	3715	0.63353	21176028	23952175
France	143788	44967	0.47646	238907563	231940091
Germany	220672	92246	0.58959	408035240	426373405
Greece	20635	649	0.06098	23451600	9838269
Iceland	1452	12	0.01639	1679945	1527066
Ireland	8008	1779	0.36354	22482718	28334543
Italy	97131	154918	0.77073	188705907	178401647
Japan	112693	576619	0.32697	233021529	339650790
Netherlands	51946	18516	0.52556	134469984	139934354
New Zealand	5892	464	0.14600	8851199	9475511
Norway	14506	12238	0.91520	25984078	33956059
Portugal	23696	919	0.07467	30610475	18057546
Spain	88434	2883	0.06314	99746776	64310959
Sweden	33603	24842	0.85010	49647610	54937885
Switzerland	33792	38705	0.93223	65743870	65675018
UK	116133	92817	0.88841	216699603	181493041
United States	822125	176528	0.35353	531139589	424973276
Mean			0.46147		
Total	2047195 (E)	1326602 (F)		2673134755 (G)	2614434503 (H)

Export and import values are for 1992 and are expressed in $US1000, current.

The first three columns of Table 5D.1 demonstrate the calculation of the Grubel-Lloyd index. This index and the Glejser indices are calculated using only the 22 OECD countries, and so only these countries are included in Table 5D.1. There are no data for SITC 7510 recorded for any of these countries for 1992, so there are no records which need to be excluded for the calculation of the intra-industry trade indices for the reason described in 5.5.3. The import and export values shown in Table 5D.1 are from Table 5A.3, after the redistribution of reexport values.

The column headed "Grubel-Lloyd Index" shows the individual B_{ij}, where in this case i refers to SITC sub-group 7512, and j to the individual country, calculated as $B_{ij} = 1 - \frac{|X_{ij} - M_{ij}|}{X_{ij} + M_{ij}}$, where the values of X_{ij} and M_{ij} are shown in columns (B) and

(C) respectively. The value of B_i, the Grubel-Lloyd index for SITC sub-group i, where in this example i refers to SITC 7512, is the mean value of the corresponding B_{ij}, shown at the foot of the column.

5.9.2 Calculation of the Glejser Intra-Industry Trade Indices

Table 5D.2. Calculation of the Glejser Intra-Industry Trade Indices.

Country	$M_{i.}$ $\sum_{k=1}^{m,k\neq j} M_{i,k}$ (E)-(A)	$X_{i.}$ $\sum_{k=1}^{m,k\neq j} X_{i,k}$ (F)-(B)	$M_{..}$ $\sum_{k=1}^{m,k\neq j} M_{.k}$ (G)-(C)	$X_{..}$ $\sum_{k=1}^{m,k\neq j} X_{.k}$ (H)-(D)	μ_{ij}	ξ_{ij}
Australia	2006547	1325207	2634819936	2574012549	0.33151	-2.70258
Austria	2019532	1309016	2619112763	2570092356	-0.40933	-0.25017
Belgium	2012319	1313408	2548012935	2490975115	-1.04146	-1.59610
Canada	1924553	1277052	2550693726	2479993439	0.28331	-0.33444
Denmark	2028348	1324542	2640253374	2575496188	-0.29290	-2.27430
Finland	2039182	1322887	2651958727	2590482328	-0.70905	-1.19165
France	1903407	1281635	2434227192	2382494412	-0.26175	-1.02054
Germany	1826523	1234356	2265099515	2188061098	-0.39947	-0.95839
Greece	2026560	1325953	2649683155	2604596234	0.14015	-2.04346
Iceland	2045743	1326590	2671454810	2612907437	0.12104	-4.16835
Ireland	2039187	1324823	2650652037	2586099960	-0.77005	-2.09916
Italy	1950064	1171864	2484428848	2436032856	-0.42195	0.59079
Japan	1934502	749983	2440113226	2274783713	-0.49427	1.63885
Netherlands	1995249	1308086	2538664771	2474500149	-0.71027	-1.38506
New Zealand	2041303	1326138	2664283556	2604958992	-0.14061	-2.34144
Norway	2032689	1314364	2647150677	2580478444	-0.31880	-0.34590
Portugal	2023499	1325683	2642524280	2596376957	0.01087	-2.30584
Spain	1958761	1323719	2573387979	2550123544	0.15253	-2.44920
Sweden	2013592	1301760	2623487145	2559496618	-0.12575	-0.11757
Switzerland	2013403	1287897	2607390885	2548759485	-0.40702	0.15385
UK	1931062	1233785	2456435152	2432941462	-0.38313	0.00843
United States	1225070	1150074	2141995166	2189461227	0.99561	-0.23472
Standard Deviation					0.44763 $s_{\mu(i)}$	1.32936 $s_{\xi(i)}$

Export and import values are for 1992 and are expressed in $US1000, current.

The Glejser export index for SITC sub-group i is the standard deviation of ξ_{ij} for all 22 OECD countries shown in Table 5D.2, where ξ_{ij} is calculated as:

$$\xi_{ij} = \log(\frac{X_{ij} / X_{.j}}{X_{i.} / X_{..}}) \text{ where}$$

X_{ij} = export of sub-group i by country j

$X_{.j}$ = total exports all sub-groups from country j ($\sum_i X_{ij}$)

$X_{i.}$ = total exports of sub-group i from all countries in the group *except* country j ($X_{i.} = \sum_{k=1}^{m,k\neq j} X_{i,k}$)

$X_{..}$ = total exports of all sub-groups from all countries in the group *except* country j ($X_{..} = \sum_{k=1}^{m,k\neq j} X_{.k}$)

The values of X_{ij} (i referring to SITC 7512) and $X_{.j}$ are shown in columns (B) and (D) from Table 5D.1. Values of $X_{i.}$ and $X_{..}$ are shown in the indicated columns in Table 5D.2, as are the values of ξ_{ij}. The value of the Glejser export index for SITC sub-group 7512 is shown at the foot of the ξ_{ij}, denoted $s_{\xi(i)}$, and is the standard deviation of the 22 values of ξ_{ij} for SITC 7512. The calculation of the standard deviation is on the basis of there being 21 degrees of freedom.

The Glejser import index, denoted $s_{\mu(i)}$, is calculated in a similar manner using the corresponding import values, and is shown at the foot of the μ_{ij} column.

6. Intra-Industry Trade Indices as Proxies for Differentiated Products: An Empirical Analysis

6.1 Introduction

The objective of this chapter is to elicit empirical support for the argument that the intra-industry trade indices can be used as proxies for product differentiation. This chapter contributes to the thesis in the following way.

The overarching argument being developed and examined within this thesis deals with the contribution of the production of innovative goods to economic growth within a country. As the attribute of "innovative" is not directly observable, empirical analysis requires the use of a proxy. It has been argued, in Chapter 3, that innovative goods will have the same properties as those associated with differentiated goods, including that of trade motivated by product differentiation. In Chapter 5 (5.2.1 and 5.2.3) it has been argued that trade driven by product differentiation will give rise to intra-industry trade, as measured by both the Grubel-Lloyd and Glejser intra-industry trade indices, and that, as a consequence, these indices can be used as proxies for differentiated and, hence, innovative product groups. As discussed in Section 5.3.3, the SITC sub-group will be used as the empirical counterpart of the notional product group[1].

It is not uncommon to base the use of a proxy on theory or reasoning alone, but advantage should be taken of any opportunity to independently verify the empirical usefulness of a proxy. This chapter attempts such a verification. The approach taken is to consider two additional, and independent, characteristics of trade driven by product differentiation, and to determine if those SITC sub-groups which exhibit these characteristics also exhibit high levels of intra-industry trade, as measured by the three intra-industry trade indices. These additional two characteristics are derived from the expression for imports of differentiated goods (3.6.1) derived in Chapter 3.

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[1] The SITC sub-group is the 4 digit level of the Standard International Trade Classification. For the second revision of the SITC, used here, this comprises 786 categories, 520 of which are for manufactured goods.

This expression is

$$M_{ij} = g_i(1 - s_{ij})I_j^{\eta_i}L_j \qquad 6.1.1$$

where

M_{ij}	is the value of imports of product group i into country j
g_i	is the share of total expenditure devoted to product group i
s_{ij}	is the share of expenditure on product group i devoted to those varieties produced in country j.
I_j	is the per capita income of country j
η_i	is income elasticity of demand for product group i
L_j	is the population of country j

As discussed in (3.6), 6.1.1 is a model in that it represents "A simplified or idealized description or conception of a particular system, situation or process (often in mathematical terms: *so mathematical model*) that is put forward as a basis for calculation, predictions, or further investigation"[2] (italics from original). The idealization in this case results from a number of simplifying assumptions, including the following.

(i) Each variety is produced in only one country.
(ii) Identical tastes.
(iii) Costless and unimpeded trade.
(iv) Identical prices in all countries.

The significance of these assumptions, or idealizations, are discussed later in this chapter.

One implication which can be derived from the model (6.1.1) is that the coefficient of variation of $\frac{M_{ij}}{Y_j}$ will, on average, be lower where i represents a differentiated product group. Accordingly, if the measured level of intra-industry trade is a useful proxy for product differentiation, it would be expected that the measured level of intra-industry trade would be negatively correlated with the coefficient of variation of $\frac{M_{ij}}{Y_j}$. This

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[2] *The Oxford English Dictionary* (1989) **9** p941 (2nd edition) Clarendon Press, Oxford

relationship is examined in Section 6.2. The correlation between the coefficient of variation of $\frac{M_{ij}}{Y_j}$ and each of the three intra-industry trade indices is as expected, and statistically significant.

The second approach, in Section 6.3, is to analyze the ability of the three intra-industry trade indices to predict those SITC sub-groups for which trade is consistent with (6.1.1). There are a number of practical issues which render this analysis other than straightforward. The model (6.1.1), and its counterpart for exports (see Appendix A to this chapter), are based on some simplifying assumptions, listed earlier. It should be remembered that these are simplifying assumptions only, and are not required for trade motivated by product differentiation[3]. Consequently, it would be unnecessarily restrictive to require that, in order for any SITC sub-group to be considered a differentiated product group, observed trade be absolutely consistent with (6.1.1). Accordingly, some relaxation of the criteria by which observed trade is considered consistent with that predicted from trade driven by product differentiation is required. Some relaxation of the criteria is also required in order to accommodate some statistical restrictions. There appears no reason to believe, however, that by so doing the results will be biased towards producing support for the use of the proxies. When the requirements are relaxed to allow for these considerations, the results are positive and do support the use of the three intra-industry trade indices as proxies for differentiated product groups. If the requirements are not relaxed - that is, (6.1.1) is rigidly adhered to and the statistical considerations ignored, then the results are inconclusive.

6.2 Coefficient of Variation of Import to GDP Ratio, and its Relationship with the Intra-Industry Trade Indices

If the GDP of country j is given by $Y_j = L_j I_j$ then (6.1.1) can be expressed as

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[3] If the data set used in this analysis contained bilateral, rather than multilateral, trade data, it might be possible to relax one key assumption - that each unique differentiated good be produced in only one country.

$$\frac{M_{ij}}{Y_j} = g_i(1 - s_{ij})I_j^{\eta_i - 1} \qquad 6.2.1$$

It is expected that the coefficient of variation of $\frac{M_{ij}}{Y_j}$ for any SITC sub-group (indexed by i) will be negatively correlated with the degree to which trade in that sub-group conforms to that of a differentiated product group and, consequently, that the coefficient of variation will be correlated negatively with the Grubel-Lloyd index and positively with both Glejser indices.

The reasoning behind this is as follows:

Assuming unit income elasticity of demand for all product groups (i), 6.2.1 simplifies to

$$\frac{M_{ij}}{Y_j} = g_i(1 - s_{ij}) \qquad 6.2.2$$

and hence the only source of variation in $\frac{M_{ij}}{Y_j}$ across countries (j) is variation in s_{ij}.

The elasticity of M_{ij} (and M_{ij}/Y_j) with respect to s_{ij} is $s_{ij}/(1-s_{ij})$. If the expected value of s_{ij} is y_j (where y_j is the share of GDP of country j in the total GDP of all countries under consideration), and given that for 23 of the 25 countries $y_j<0.1$, then for these 23 countries at least the elasticity will be 0.1 or less. It follows that, if the variation of s_{ij} around y_j is the only source of variation in M_{ij}/Y_j for any given i, the variance of M_{ij}/Y_j will be low and therefore that the lower the standard deviation of M_{ij}/Y_j the greater the probability that i is a differentiated product group.

If i is a differentiated product group, and behaves in accordance with (6.2.2), then the standard deviation of M_{ij}/Y_j, for any i, will be $g_i\xi_i$, where ξ_i is the standard deviation of $(1-s_{ij})$ over all j for that value of i. The variable of interest is ξ_i, but only the standard deviation of M_{ij}/Y_j, or $g_i\xi_i$, is observable. Therefore, making meaningful comparisons across various values of i requires normalizing the standard deviation of M_{ij}/Y_j by correcting for the value of g_i.

It is possible to produce an estimate of g_i. From (6.2.2),

$\sum_{j=1}^{n}\frac{M_{ij}}{Y_j} = g_i \sum_{j=1}^{n}(1 - s_{ij}) = g_i(1-n)$, given that $\sum_{j=1}^{n} s_{ij} = 1$, and therefore it is possible to normalize the standard deviation of M_{ij}/Y_j by $\frac{\sum_j \frac{M_{ij}}{Y_j}}{n-1}$ to produce ξ_i.

But, by definition, the coefficient of variation, the standard deviation normalized by the mean, is $\frac{\sum_j \frac{M_{ij}}{Y_j}}{n}$. The two differ only by the factor $\frac{n}{n-1}$, so that, for the purpose of comparison across values of i, there is effectively no difference. The coefficient of variation is a standard measure so it is that which has been used.

This calculation is similar to that of the Glejser import index, the difference being that here it is the ratio of the standard deviation of the import to GDP ratio, relative to the mean, that is being measured. This is in contrast to the Glejser index, where it is the standard deviation of the ratio of the product group import to total import for each country, relative to the mean, which is being measured.

Where income elasticity of demand is not equal to one, variations in per capita income across countries could make a further contribution to the variance of $\frac{M_{ij}}{Y_j}$.

Correlation coefficients were estimated between the coefficient of variation of $\frac{M_{ij}}{Y_j}$ and each of the three intra-industry trade indices, both for all the SITC sub-groups and for the manufacturing SITC sub-groups (5-8) separately. The results are shown in Table 6.1.

Table 6.1. Correlation of Coefficient of Variation of M_{ij}/Y_j with the Intra-Industry Trade Indices.

	Grubel-Lloyd		Glejser Import		Glejser Export	
All (SITCs 0-9)	-0.30	(-0.31)	0.42	(0.48)	0.23	(0.27)
Manufacturing only (5-8)	-0.22	(-0.20)	0.37	(0.33)	0.19	(0.19)

Figures are Pearson correlation coefficients, with Spearman rank correlations in parentheses. All correlations are significant at the 0.01% level.

The results are as expected, but the correlations are not particularly strong. Given the similarity in construction of the coefficient of variation and the Glejser import index, some correlation is to be expected, and it is possible that the correlation with the other two indices is as a result of the correlation between them and the Glejser import index.

6.3 Prediction of Trade Consistent with Product Differentiation

This section analyzes the power of the intra-industry trade indices to predict those SITC sub-groups for which observed trade is consistent with that expected from trade driven by product differentiation. The procedure is to classify each manufacturing SITC sub-group into one of two categories - those which do and those which do not trade as differentiated goods - and then to determine whether the intra-industry trade indices can predict that category into which each SITC sub-group has been allocated.

The determination as to whether or not each SITC sub-group trades as a differentiated product group is made using the model (from 6.2.1)

$$\frac{M_{ij}}{Y_j} = g_i(1-s_{ij})I_j^{\eta_i-1} \qquad 6.3.1$$

This model attempts to explain the variation in the import to GDP ratio ($\frac{M_{ij}}{Y_j}$) between countries (j) for any differentiated product group (i). The term ($I_j^{\eta_i-1}$) takes into account the per capita income of country j in conjunction with the income elasticity of demand of product group i. Any such effect could not be held to be unique to differentiated goods. The term ($1-s_{ij}$) captures the essence of the theory of trade driven by product differentiation - that a country will export those varieties which it produces, and import all other varieties produced elsewhere. The decision as to whether or not trade in any SITC sub-group is consistent with that expected from trade driven by product differentiation should therefore be centred on this term.

It is not possible to directly observe or measure the value of s_{ij}. Nevertheless it is possible, as detailed in Appendix A, to produce an estimate of s_{ij}. This estimate is, however, based on the assumption that each unique differentiated good is produced in only one country. This assumption was introduced (in Section 3.6) as a simplifying assumption. It is not a domain assumption, and is not necessary for trade driven by product differentiation. The model (6.3.1) does not require it. The expression for exports, $X_{ij} = g_i s_{ij} I_{wj}^{\eta_i - 1} (Y_T - Y_j)$, (from 3.6.5), does require the assumption that each unique differentiated good is produced in only one country, and it is this expression which forms the basis of the estimation of s_{ij}. Using multilateral trade data, as is the case here, this is the best that can be done. Had bilateral data been used, some refinements would have been possible.

With the availability of an estimate for s_{ij}, it is possible to estimate (6.3.1) in the form

$$\log\left(\frac{M_{ij}}{Y_j}\right) = \beta_0 + \beta_1 \log(1 - s_{ij}) + \beta_2 \log(I_j) + u_{ij} \qquad 6.3.2$$

For any differentiated product group (i) the value of β_1, under ideal conditions, would be expected to be one. Ideal conditions would include that the value of s_{ij} used in the estimation was the true value; that trade in the particular SITC sub-group being studied was driven entirely by product differentiation; that there are identical tastes in all countries included in the analysis; and that trade is costless and unimpeded. For the purposes of empirical analysis, it cannot be assumed that any of these conditions hold.

The method of estimating s_{ij} assumes that each variety, or unique differentiated good, is produced in only one country. The assumption that each variety be produced in only one country is a simplifying one, and one not necessary for trade based on product differentiation. Licensing or direct foreign investment would cause individual varieties to be produced in more than one country, but this does not prevent trade driven by product differentiation. The minimum requirement is that each variety not be produced in every country. Where one or more varieties produced within a country are also produced elsewhere, the estimate for s_{ij} obtained from the procedure specified in Appendix A will be low, and consequently the estimate for $(1-s_{ij})$ high. The log of $(1-s_{ij})$ is negative, and captures the effect of a country importing all varieties other than those which it produces, which it exports. A high estimate of $(1-s_{ij})$ produces an estimate of log $(1-s_{ij})$ closer to zero than the true value, which in turn will bias the estimate of β_1 upwards.

As a hypothetical, and extreme, example, consider a world of 20 identical countries. As a result of direct foreign investment, each country produces one half of the total varieties in a given differentiated product group, and that, accordingly, these are exported to only one country. The procedure detailed in Appendix A will give an estimate for s_{ij} for each country of 0.05, whereas it is in fact 0.5, and an estimate for $(1-s_{ij})$ of 0.95 rather than 0.5. The log of 0.95 is -0.051, and the log of 0.5 is -0.69, so the estimate of β_1 will be biased upwards accordingly, in this case to 13.5.

This analysis is not dealing with theoretically defined product groups but with SITC sub-groups. In the interest of combining theory and empiricism, it has been argued that an SITC sub-group can be reasonably thought of as the empirical equivalent of a product group, but it would not be reasonable to assume that a sub-group is entirely either differentiated or undifferentiated. It was pointed out in Section 5.4 that varieties which were at one time "owned" by one firm may cease to be so[4], in which case not all trade will be driven by product differentiation, and $\beta_1=1$ cannot be anticipated. Where there is no trade driven by product differentiation, the expected value of β_1 is zero, with this expected value increasing with the proportion of trade driven by product differentiation, all else being constant.

To the extent that tastes are not identical in all countries, and that trade is not costless and unimpeded, estimates of β_1 can be expected to vary from one in the case of an otherwise ideally differentiated good, but with the direction of variation not readily predictable. Given these qualifications of the simplifying assumptions, it cannot be argued that, for any SITC sub-group to be considered a differentiated product group,

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[4] Where there are no intellectual property rights copying may occur after a delay, patents may be "invented around", or patents may expire or be allowed to lapse.

β_1 must equal one and, accordingly, if β_1 cannot be shown to equal one that it cannot be considered to be a differentiated product group.

The objective of estimating the model is to determine, based on the estimated value of β_1 for each SITC sub-group, that set of SITC sub-groups for which the observed pattern of trade is consistent with that expected from trade driven by product differentiation, in order to determine the ability of the intra-industry trade indices to predict that set. There is no point in carrying out one estimation for the entire data set (that is, for all manufacturing SITC sub-groups), because this would produce one overall estimate of β_1, and the interest lies in the individual values of β_1 for each SITC sub-group. Further, because it is not being argued that the model applies to all SITC sub-groups, one set of estimates for the entire data set would be meaningless. And for the same reason, a panel data estimation would serve no useful purpose, even though, there being multiple observations for each SITC sub-group, the data set might resemble a panel data set.

Two steps are required for this analysis. The first is to determine those SITC sub-groups for which trade is consistent with the essential characteristic of trade driven by product differentiation, and the second is to estimate how well the intra-industry trade indices predict this sub-set. The first step is achieved by means of a separate OLS estimation of (6.3.2) for each SITC sub-group, and the second with a logit regression, with one observation for each SITC sub-group. In the second step, the dependent variable is a binary variable, with value zero or one depending on the results of the first stage, with the explanatory variables being the three intra-industry trade indices. This might seem an unusual approach, but if the philosophy of fitting the solution to the problem is followed, and the problem is a non-standard one, then a non-standard solution might well emerge. The alternative is to deal only with problems for which there are standard solutions.

In view of the earlier discussion concerning the expected value of the coefficient β_1, where a SITC sub-group consists of a differentiated product group, it was not possible to specify one prior criterion by which each SITC sub-group will be considered to be a differentiated product group, or not. Rather, the analysis was carried out based on each of three criteria, and the results from each are analyzed and discussed. The statistical issues associated with each are also analyzed and discussed. The three criteria are:

(i) The estimated coefficient ($\hat{\beta}_1$) not significantly different from one.

(ii) $\hat{\beta}_1$ significantly greater than zero and not significantly different from one

(iii) $\hat{\beta}_1$ significantly greater than zero.

The interpretation of the results of 518[5] regressions, one for each SITC sub-group, raises another issue. Hypothesis testing is based on the probability of an observed event occurring if the null hypothesis is true. The level of significance is the probability of rejecting the null hypothesis if it is true. Where there is a large number of independent (in this case 518) regressions, then it is expected that the null hypothesis will be rejected for a proportion of these (the proportion given by the significance level), even if the null hypothesis is true in all cases. From this it follows that those instances where the null hypothesis is rejected are only significant if, as a group, they represent a statistically significantly larger proportion than that represented by the significance level. For this reason, the significance level in this analysis is selected on the basis of an analysis of the distribution of the probability value (P value) associated with the t-statistic, based on the null hypothesis. Diagram 6.1 shows the results of such an analysis based on the null hypothesis $\beta_1=0$.

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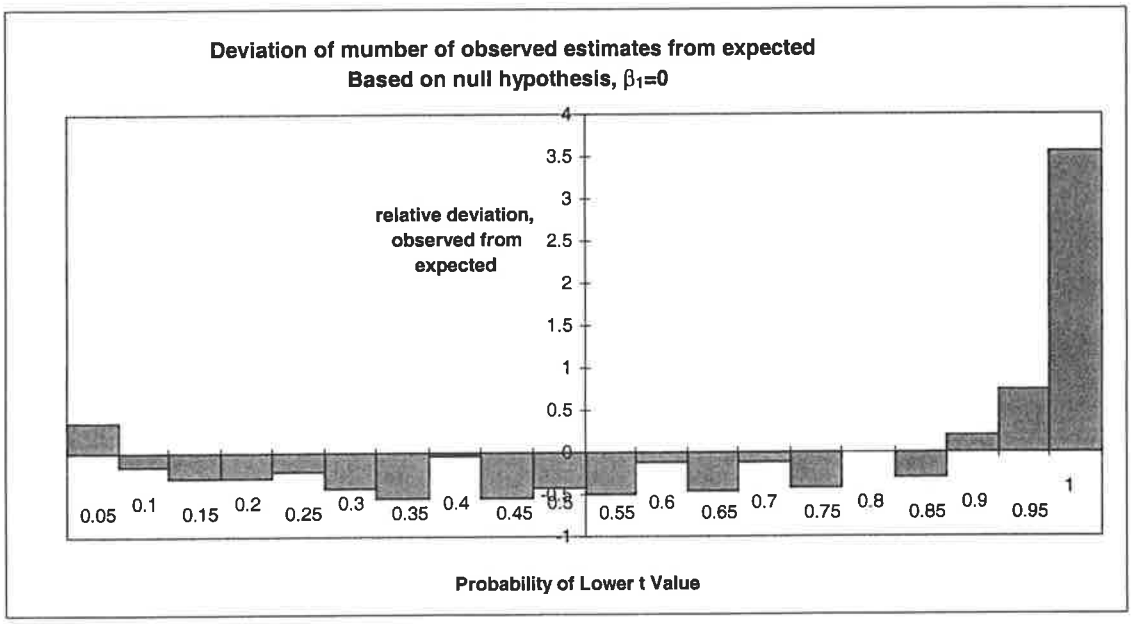
[5] This number is less than the previously used number of manufacturing SITC sub-groups for two reasons. One being that only SITCs 5-8 are used, and the other being that there is a small number of SITC sub-groups for which there are insufficient observations to carry out the estimation.

Diagram 6.1. Distribution of Probability Values; H_0: $\beta_1=0$.



There are 163 SITC sub-groups for which the P value is greater than 0.9, compared with the 52 which would be expected if the null hypothesis, $\beta_1=0$ for all SITC sub-groups, were true. Based on the normal distribution of a sample proportion, this is statistically significant at 0.01%. Similarly, there are 35 SITC sub-groups for which the P value is less than 0.05, compared with the expected 26 if the same null hypothesis were true. This is statistically significant at the 5% (1-tailed) level. On the basis of these results, the criterion for rejecting the null hypothesis, $\beta_1=0$, for any SITC sub-group should be $P<0.05$ or $P>0.9$.

To reduce the risk of using results that were biased by one or two extreme observations, the regressions were carried out three times. After each of the first two the observation having the highest value for the Cook's D statistic[6] was deleted, and the model reestimated.

Test (i), $\hat{\beta}_1$ not significantly different from 1

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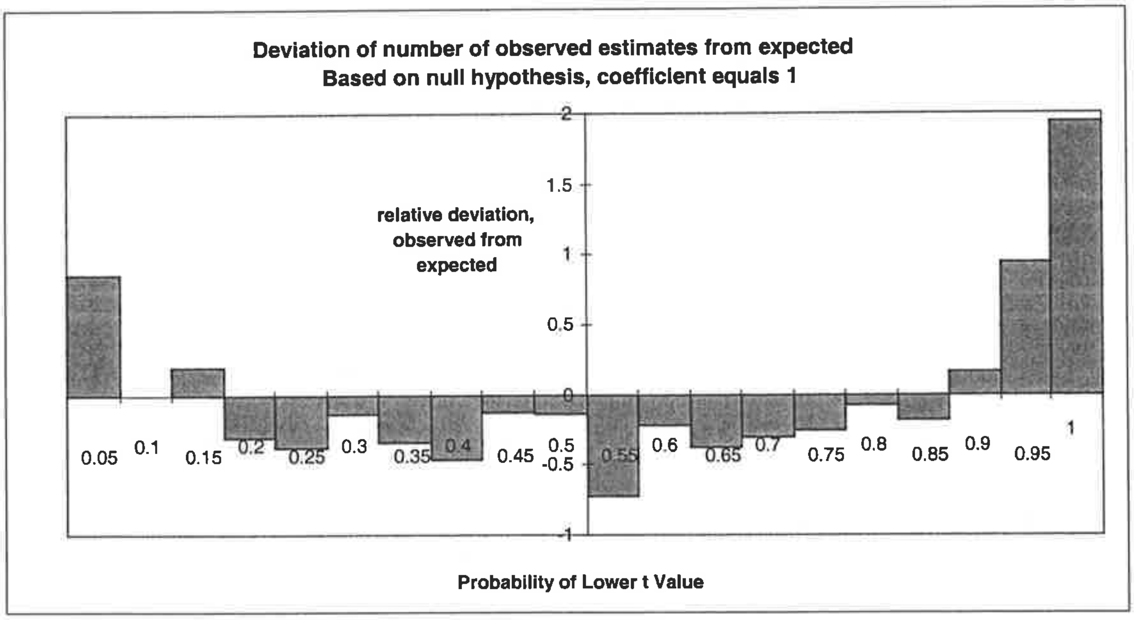
[6] A method for detecting influential observations. Cook (1977,1979)

To pass the test $\hat{\beta}_1$ not significantly different from 1 requires that the absolute value of the t statistic, given by $|\frac{\hat{\beta}_1 - 1}{\mathrm{SE}(\hat{\beta}_1)}|$, be less than some value determined by the significance level. While this value is decreasing with the proximity of $\hat{\beta}_1$ to 1, it is also decreasing in the standard error of the estimate, $\mathrm{SE}(\hat{\beta}_1)$. All else being equal, the higher the explanatory power of the model, the lower the standard error of the estimate, and the lower the probability of passing this test for observed trade being consistent with that driven by product differentiation.

Another issue is that selection using this criterion will include some sub-groups for which the estimate of β_1 is not significantly different from zero, and where this is the case, the term $(1-s_{ij})$ cannot be held to have any explanatory power. Nevertheless, this approach was explored.

The first step is to specify the significance level to be used, taking into account the earlier discussion on this point. Diagram 6.1 shows the distribution of the observed P-value for the null hypothesis $\beta_1=1$ relative to that which would be expected if the null hypothesis was true for all SITC sub-groups.

Diagram 6.2. Distribution of Probability Values; H_0: $\beta_1=1$.



The P values for which the observed frequency is significantly greater than expected are $P>0.9$ (126 actual, 52 expected) and $P<0.05$ (48 actual, 26 expected). Based on the normal distribution of a sample proportion, both of these differences are statistically significant at the 0.01% level. On this basis, the criterion for β_1 not significantly different from one should be $0.05<P<0.9$. When this was applied, the null hypothesis was rejected for only 174 of the 518 SITC sub-groups, meaning that 344 (66%) of the manufacturing SITC sub-groups the estimate for $\hat{\beta}_1$ is not significantly different from one, implying that, for over 66% of the manufacturing SITC sub-groups, trade is driven by product differentiation.

This number of SITC sub-groups for which the null hypothesis is rejected will be influenced by the probability of a type I error (rejecting the null hypothesis when it is true) and the probability of a type II error (not rejecting the null hypothesis when it is false). If the probability of a type I error is α, and that of a type II error β, then, for any SITC sub-group for which the true value of β_1 is one, the probability of rejecting the null hypothesis is α, and, where it does not equal one, the probability of rejecting the null hypothesis is $(1-\beta)$. If the actual proportion of all manufacturing SITC sub-groups for which $\beta_1=1$ is π, then the probability of the null hypothesis being rejected for any one SITC sub-group is $\pi\alpha+(1-\pi)(1-\beta)$.

The value of α is the same for all SITC sub-groups, and has the value 0.15. The value of β is not known. It depends on the true value of the parameter β_1, and on the standard error of the estimate of β_1. Consequently, the value of β could be expected to vary between SITC sub-groups. However, assuming, for the sake of discussion, that the value of β is constant for all estimations, then if r is the proportion of estimations for which the null hypothesis is rejected, the expected value of r is given by $E[r]=\pi\alpha+(1-\pi)(1-\beta)$. If the observed value of r is the expected value of r, then the value of π is given by

$$\pi=\frac{r+\beta-1}{\alpha+\beta-1}.$$

Ignoring, for the moment, the type II errors (by setting $\beta=0$), then by using the observed value of r (0.34) and the selected value of α (0.15), the value of π is estimated at 0.78. While there is no basis on which to form a prior expectation of the proportion of manufacturing SITC sub-groups for which trade is driven by product differentiation, 78% does seem to be high. One reason for this is that the probability of a type II error (β) cannot be expected to be zero.

The value of β cannot be expected to be constant for all estimations, and the higher the value of β, the lower the probability of rejecting the null hypothesis. All else being equal, the higher the value of the standard error of the estimate, the higher the value of β, so that in this case, where model consistency is based on the null hypothesis not being rejected, the selection is biased towards those SITC sub-groups for which the estimations yield a higher standard error of the estimate. That this is the case can be seen from the distributions of the standard errors of $\hat{\beta}_1$ for the two groups. For that group for which $\hat{\beta}_1$ is significantly different from one, the mean value of the standard error is 3.58, with variance 3.09; while for that group for which $\hat{\beta}_1$ is not significantly different from one, the mean value of the standard error is 4.36, with variance 7.38. The differences between the two means and the two variances are both statistically significantly at less than 0.01%.[7] Given that, all else being equal, the higher the explanatory power of the estimated model, the lower the standard error of the estimate, this bias is an undesirable one.

A particularly severe case of a type II error is not rejecting the null hypothesis $\beta_1=1$ when $\beta_1=0$, because in this case the term $(1-s_{ij})$ cannot be claimed to have any explanatory power. Of that group of SITC sub-groups for which the null hypothesis $\beta_1=1$ was not rejected, 42% of the estimates of β_1 were less than zero. Given that, where the estimate is negative, if the null hypothesis $\beta_1=1$ cannot be rejected then neither could the null hypothesis $\beta_1=0$ be rejected, the incidence of this particular case of a type II error could be expected to be high.

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[7] Statistical significance of the difference between the two variances is based on the F statistic. Statistical significance of the difference between the two means is based on the Z test for the difference between the means of two large samples. The skewness of the standard error of the estimate, measured as $E[(x-\mu)^3/\sigma^3]$, is 1.41 for that group for which the estimate is significantly different from 1, and 4.12 for that group for which it is not.

The probability of $\beta_1=1$ was estimated with a logit model, using maximum likelihood, against the three measures of intra-industry trade individually. While the estimated coefficient of each intra-industry trade measure had the expected sign, the estimate was significant only in the case of the Glejser export index, and then only at the 10% level.

Test (ii). (a) $\hat{\beta}_1$ not significantly different from 1 *and*

(b) $\hat{\beta}_1$ significantly different from zero, effectively $\hat{\beta}_1$ significantly >0.

If none of the assumptions are relaxed, then it can be argued that, for trade within any one SITC sub-group to be considered consistent with that driven by product differentiation, both of these conditions are necessary. Including condition (b) eliminates those sub-groups for which $\hat{\beta}_1$ is not significantly different from zero. However, the two conditions cannot be considered independent, because the difference between zero and one is too small relative to the range of values of the standard error (SE) of $\hat{\beta}_1$.

In Appendix B it is shown that, given the range of the standard errors of the estimates of β_1, relative to the difference between zero and one, only a relatively narrow range of estimates could pass this test at any given level of significance, and that the bounds of this interval are significantly influenced by the level of significance used. For example, at the mean value of the standard error of the estimate, non-intersecting sets of SITC sub-groups would be selected at each of the 1%, 5% and 10% levels of significance. Further, it is shown that the probability of any SITC sub-group for which $\beta_1=1$ passing test (ii) is, at best, less than 50%, and expected to be closer to 10%. There is, therefore, little to be achieved in applying test (ii). This is not a reflection on the validity of the argument being evaluated, but is a direct consequence of the range of the standard errors of the estimates of β_1 relative to the constant against which the value of the estimate is being tested.

If $\hat{\beta}_1$ significantly greater than zero is a necessary condition, and $\hat{\beta}_1$ not significantly different from one is also a necessary condition - and let us assume just for the moment that it is , but it is not possible to test for both, then the best that can be done is to test for either one or the other. It has already been shown that $\hat{\beta}_1$ not significantly different from one, by itself, is not an adequate test, and so the remaining course of action is to test for $\hat{\beta}_1$ significantly greater than zero, alone. The implications and consequences of so doing are now examined.

Test (iii), $\hat{\beta}_1$ significantly >0.

To use the result of this test as the dependent variable in a regression against the intra-industry trade indices is, at the very least, to estimate the probability of satisfying one of the necessary conditions for consistency with trade driven by product differentiation, as a function of the intra-industry trade indices. This is a valid exercise, even if it could be argued that $\beta_1=1$ is also a necessary condition. If it can be shown that the probability of meeting the necessary condition, $\beta_1>0$, is an increasing function of the level of measured intra-industry trade, and if the probability that an SITC product group is a differentiated product group is higher for one which meets this necessary condition than for one which does not, then the argument being examined, that the probability that an SITC sub-group is a differentiated product group is an increasing function of the measured level of intra-industry trade, is supported.

This argument applies even to the case where $\beta_1=1$ is also a necessary condition. But to require that $\beta_1=1$ is to hold to some assumptions invoked for the sake of simplicity, but which are not essential for trade driven by product differentiation. This point was discussed earlier in this chapter.

Given that, within the model, imports (M_{ij}) are an increasing function of ($1-s_{ij}$), which in turn is a decreasing function of exports (X_{ij}), (see Appendix A) then a weak prediction of the model is that, all else being equal, a country's imports of a differentiated product group are a decreasing function of exports in that group.

$\hat{\beta}_1$ significantly >0 is consistent with this prediction. It could be argued that this prediction need not be unique to differentiated goods and that, consequently, the probability of selecting SITC sub-groups which do not represent a differentiated product group is increased. The effect of this on the validity of the test should be considered.

Imports being a decreasing function of exports would not in itself be expected to produce high levels of intra-industry trade. The maximum value of the Grubel-Lloyd index occurs when exports and imports are equal, and the closer they are, the higher the measured value of intra-industry trade. Accordingly, a high value for this index cannot be anticipated solely as a result of imports being a decreasing function of exports. The two Glejser indices are each based on either import or export values alone, so again there is no reason to expect that imports being a decreasing function of exports will, of itself, lead to high levels of intra-industry trade as measured by the Glejser indices. It can be seen, then, that using the weaker test does not bias the results towards establishing the anticipated relationship between the intra-industry trade indices and trade driven by product differentiation. If using the weaker test leads to the selection of SITC sub-groups which do not represent a differentiated product group, then establishing the anticipated relationship is made less probable.

The coexistence of other forms of trade within the same sub-group will have no bearing on this if exports and imports arising from such trade are not systematically correlated in any manner[8]. However, the smaller the proportion of trade within the sub-group which is based on product differentiation, the lower the probability of obtaining $\hat{\beta}_1$ significantly >0[9].

If it is argued that, holding to all other assumptions, the expected value of $\hat{\beta}_1$ is one for any SITC sub-group where trade is driven entirely by product differentiation, and

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[8] This would be expected for example where simultaneous imports and exports within the one sub-group occur not from product differentiation but as the result of aggregation.

[9] Based on the proposition that if two-way trade within a sub-group is not driven by product differentiation it must be as a result of the aggregation of goods for which trade is based on factor

zero where no trade is driven by product differentiation, then it follows that the expected value of $\hat{\beta}_1$ is increasing in the proportion of trade driven by product differentiation, in the interval zero to one. This being the case, it might seem reasonable to estimate the value of $\hat{\beta}_1$ against the intra-industry trade indices. This, however, raises once again the statistical significance of $\hat{\beta}_1$. At the very least, to be of any value, it should be statistically significantly greater than zero. But it is shown in Appendix B that no estimate of β_1 less than one can be shown to be statistically significantly greater than zero, so that this approach is not viable. However, given that, all else being equal, the lower the estimate of β_1 then the lower the probability that $\hat{\beta}_1$ is significantly greater than zero, basing the test on $\hat{\beta}_1$ being significantly greater than zero encompasses this argument. A discussion of the results of estimating $\hat{\beta}_1$ against the intra-industry trade indices, for those instances where $\hat{\beta}_1$ is significantly greater than zero, is presented at the end of this chapter.

The distribution of the P values based on the null hypothesis $\beta_1=0$ is shown in Diagram 6.1, and on the basis of that distribution a significance level of 10% (1 tailed) has been selected for $\beta_1>0$ and 5% for $\beta_1<0$. On this basis, 163 positive estimates and 35 negative estimates for β_1 are obtained. Because, for this test, selection is based on rejection of the null hypothesis, as opposed to non-rejection in test (i), the selection bias arising from the SE($\hat{\beta}_1$) is reversed - a lower value of the standard error now increases the probability of selection, all else being equal.

Table 6.2 summarizes the results of estimating the probability of $\beta_1>0$ against the various intra-industry trade measures.

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proportions. Because the commodity content of trade driven by factor proportion is indeterminate, then such two-way trade will appear random in nature.

Table 6.2. Estimation of Probability of Positive Estimate of β_1.

	A	B	C	D	E	F
Intercept	-2.49 ***	0.70 ***	1.47 ***	4.77 ***	5.92 ***	6.28 ***
	(0.44)	(0.257)	(0.375)	(1.04)	(1.48)	(1.84)
GL	3.51 ***				-1.31	-3.36
	(0.86)				(1.19)	(6.39)
$(GL)^2$						2.13
						(6.56)
G_M		-2.06 ***		-2.93 ***	-3.03 ***	-3.04 ***
		(0.36)		(0.793)	(0.802)	(0.805)
$(G_M)^2$				0.63 **	0.63 **	0.63 **
				(0.319)	(0.32)	(0.32)
G_X			-1.37 ***	-3.84 ***	-4.21 ***	-4.08 ***
			(0.229)	(1.16)	(1.21)	(1.27)
$(G_X)^2$				0.84 ***	0.90 ***	0.86 ***
				(0.322)	(0.33)	(0.35)
-2 log L	627.5	599.0	601.9	573.4	572.2	572.1
R^2	0.047	0.12	0.11	0.18	0.18	0.18
AIC	631.4	603.0	605.9	583.4	584.2	586.1
HL	11.75	14.2	6.04	9.71	7.16	5.61

N=518. GL: Grubel Lloyd IIT index. G_M and G_X: The Glejser Import and Export Indices respectively. *,**,***, significant at 10%, 5% and 1% (2 tailed) respectively. Figures in parentheses are standard errors. R^2 is calculated using the method of Cox and Snell (1989) modified by the method of Nagalkerke (1991) to give a maximum value of 1. AIC: Akaike Information Criterion. HL : Hosmer and Lemeshow goodness of fit test (Hosmer and Lemeshow 1989), distributed as χ^2_8 .

Models A, B and C show the estimates with each measure of intra-industry trade individually. In each case, the estimated coefficient is significant and of the expected sign. Model D, which does not include the Grubel-Lloyd index, is, as indicated by the value of the AIC, the model which provides the best fit. Models E and F show that the estimated coefficients of the Grubel-Lloyd index and its square, when included in conjunction with the other two indices, are not significant. In Model D, the specific point of interest is the sign of the partial derivative of the dependent variable with respect to each of the two Glejser indices; expected to be negative. The partial derivative of the dependent variable with respect to the Glejser import index is $(-2.93+1.26(G_M))$. This is negative up to the value of 2.325 for that index, which is above the 98th percentile. The partial derivative of the dependent variable with respect to the Glejser export index is $(-3.84+1.68(G_X))$. The value of this derivative is negative up to the value of 2.286 for that index, which is above the 85th percentile. These results suggest that the probability of $\beta_1>0$ is decreasing in the value of both Glejser indices, as expected. The estimated coefficients of the squared terms of both of these variables suggest that this effect is not linear, and tends to disappear towards the upper end of the range of values of these indices. These results are therefore consistent with the expectation that the probability of $\beta_1>0$, consistent with trade driven by product differentiation, is decreasing in the values of Glejser import and export indices.

Table 6.3 summarizes the results of a similar estimation of the probability of $\beta_1<0$.

Table 6.3. Estimation of Probability of Negative Estimate of β_1.

	A	B	C	D	E	F
Intercept	-0.83 (0.64)	-3.91 *** (0.36)	-5.33 *** (0.65)	-8.1 *** (1.17)	-8.4 *** (2.33)	-9.25 *** (1.79)
GL	-3.95 *** (1.44)					1.69 (1.93)
G_M		1.40 *** (0.30)		6.53 *** (1.79)	6.45 *** (1.84)	6.60 *** (1.81)
$(G_M)^2$				-1.97 *** (0.66)	-1.94 *** (0.68)	-1.96 *** (0.67)
G_X			1.43 *** (0.30)	0.75 ** (0.38)	1.14 (2.29)	0.92 ** (0.43)
$(G_X)^2$					-0.09 (0.53)	
-2 log L	248.7	235.3	234.3	212.4	212.4	211.6
R^2	0.037	0.10	0.11	0.21	0.21	0.21
AIC	252.7	239.3	238.3	220.4	222.4	221.6
HL	2.6	19.6	11.23	8.5	4.36	4.24

N=518. GL: Grubel Lloyd IIT index. G_M and G_X: The Glejser Import and Export Indices respectively. *,**,***, significant at 10%, 5% and 1% (2 tailed) respectively. Figures in parentheses are standard errors. R^2 is calculated using the method of Cox and Snell (1989) modified by the method of Nagalkerke (1991) to give a maximum value of 1. AIC: Akaike Information Criterion. HL : Hosmer and Lemeshow goodness of fit test (Hosmer and Lemeshow 1989), distributed as χ^2_8.

Again, Models A, B and C show that the estimated coefficients for each of the three individual measures of intra-industry trade are significant, and have the opposite sign to that obtained when estimating the probability of obtaining a positive estimate. The squared value of the Grubel-Lloyd index is not significant. Model D offers the best explanatory power, again with the Grubel-Lloyd index being omitted. The estimated coefficient of the Glejser export index is significant and of the expected sign. The partial derivative of the dependent variable with respect to the Glejser import index is $(6.53-3.94(G_M))$, positive up to the vale of 1.66 for that index. This value is above the 90th percentile. Model E shows the low significance of the squared Glejser export index when included, and enables comparison with Model D in Table 2. Model F shows that again the Grubel-Lloyd index in conjunction with the other two is not significant. This is discussed below.

In summary, for any given SITC sub-group, $\hat{\beta}_1$ significantly >0 is a necessary condition for trade to be considered consistent with that driven by product differentiation, and $\hat{\beta}_1$ significantly <0 a sufficient condition for trade to be considered inconsistent with that driven by product differentiation. The result $\hat{\beta}_1$ not significantly >0 or <0 is indeterminate. These results show both that the probability of conforming with the expectations of trade driven by product differentiation is increasing in the level of intra-industry trade, and of explicitly not conforming decreasing in the level of intra-industry trade.

The lack of significance of the Grubel-Lloyd index, both for β_1 positive and negative, when used in conjunction with the two Glejser indices, is of some interest and merits investigation. This lack of significance also occurs in models including the Grubel-Lloyd and either one of the Glejser indices. Table 6.4 the shows the incidence of significant positive estimates for β_1 categorized jointly by the Grubel-Lloyd and Glejser indices. Quintiles are used in order to reduce the disparity in the number of observations per cell.

Table 6.4. Frequency (%) of Incidence of Positive Estimates (10% 1 tailed) of β_1.

GL	Glejser Import Index - quintile					Glejser Export Index - quintile					
IIT	q1	q2	q3	q4	q5	q1	q2	q3	q4	q5	Σ
q1	50 (4)	23 (13)	31 (16)	14 (22)	19 (47)	0 (1)	57 (7)	38 (13)	22 (23)	14 (58)	22
q2	25 (16)	40 (20)	37 (19)	17 (24)	4 (25)	0 (2)	35 (20)	29 (21)	21 (34)	19 (27)	23
q3	43 (21)	35 (23)	28 (25)	22 (18)	12 (17)	38 (13)	41 (32)	28 (25)	14 (21)	15 (13)	29
q4	59 (29)	37 (27)	32 (19)	16 (19)	10 (10)	59 (32)	32 (22)	23 (30)	20 (15)	20 (5)	36
q5	73 (33)	57 (21)	40 (25)	19 (21)	0 (4)	60 (55)	30 (23)	40 (15)	36 (11)		48
Σ	54	39	34	17	13	55	37	30	21	16	31

Figures in parentheses are the number of observations.

Examining the categorization by the Grubel-Lloyd and Glejser import indices, it appears that, for the first two Glejser import quintiles (indicating higher levels of intra-industry trade), the incidence of positive estimates is increasing with the value of the Grubel-Lloyd index. The frequencies for the intersection of the first two Glesjer import index quintiles with the fifth Grubel-Lloyd index quintile are both statistically significantly higher than the corresponding column percentages[10]. For the third and fourth quintiles, there is no clear evidence of an increasing incidence of positive estimates with the increasing value of the Grubel-Lloyd index. For the fifth quintile, the effect appears to be reversed - the incidence of positive estimates is highest in the lowest quintile for the Grubel-Lloyd index. However, there is no statistical significance in the variation between any of the individual frequencies in this column, and the column frequency. A similar overall pattern is evident for the Glejser export index.

This suggests that the Grubel-Lloyd index does some have explanatory power in conjunction with either Glejser index, but only at lower values of the Glejser indices (higher values of intra-industry trade). The structure of the estimated models is such that this selective effect is not detectable, and this could account for the lack of significance of the Grubel-Lloyd index when used in conjunction with either or both Glejser indices.

It was argued earlier in this chapter that, even where trade driven by product differentiation occurs, the further away an SITC sub-group is from the idealized representation of such trade, the lower the probability that $\hat{\beta}_1 = 1$. This proposition is tested by regressing the values of $\hat{\beta}_1$ which are significantly >0 against the three intra-industry trade indices individually, using OLS. Only the Glejser import index was significant, with the results as follows.

$$\begin{array}{lllll} \hat{\beta}_1 & = & \text{intercept} & + \ \text{(Glejser import index)} & R^2=0.13 \\ & & 4.6\ {}^{***} & \quad 4.43\ {}^{***} & N=163 \\ & & (0.63) & \quad (0.92) & {}^{***}\ \text{significant at 1\%} \end{array}$$

This estimation suggests that, as the Glejser import index approaches zero ("perfect" intra-industry trade), the value of $\hat{\beta}_1$ approaches 4.6 from above. The value of 4.6 is significantly greater than 1 but, as this regression includes only those for which $\hat{\beta}_1 > 0$

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[10] Based on the normal distribution of a sample proportion, the probability values are less than 5%, 1-tailed.

at the 10% 1 tailed level, and given that the mean value of SE($\hat{\beta}_1$) for this group is 3.3, then the expected minimum value of $\hat{\beta}_1$ is 4.4, which can explain the estimated value of the intercept for this sample.

6.4 Conclusions

There are some limitations associated with these analyses, discussed earlier in this chapter, and these limit the interpretation of the results. But the analyses in this chapter tested two falsifiable propositions - one being the correlation of the coefficient of variation of $\frac{M_{ij}}{Y_j}$ with the intra-industry trade indices, the other the ability of the intra-industry trade indices to predict a trade pattern consistent with that expected of trade driven by product differentiation. The results were statistically significant and as predicted, and can be interpreted as support for the use of the three intra-industry trade indices, jointly and individually, as proxies for trade driven by product differentiation.

6.5 Appendix A

The value of exports from country j of product group i to the rest of the world has been previously derived to be

$$X_{ij}=g_i s_{ij}\Sigma_{k\neq j}(I_k^{\eta_i} L_k)$$

$$= g_i s_{ij} I_{wj}^{\eta_i -1}\Sigma_{k\neq j}Y_k$$

$$= g_i s_{ij} I_{wj}^{\eta_i -1}(Y_T-Y_j) \qquad 6.5.1$$

where I_{wj} is average per capita income over all countries other than country j, weighted by Y_k, η_i is income elasticity of demand for product group i, and s_{ij} is the share of product group i produced in country j.

By assuming that I_{wj} is constant for all j, and that $Y_T=\Sigma Y_j$ over all the 25 countries being considered here, it is possible to calculate s_{ij} for all i and j, in the following manner.

Let

$$I_{wj}^{\eta_i -1}=I_w^{\eta_i -1}\ \forall j$$

and

$$Y_T=\Sigma Y_j$$

Then, from (6.5.1),

$$\frac{X_{ij}}{Y_T-Y_J}=g_i s_{ij} I_w^{\eta_i -1} \qquad 6.5.2$$

$$\sum_j \frac{X_{ij}}{Y_T-Y_J}=\sum_j g_i s_{ij} I_w^{\eta_i -1}$$

$$=g_i I_w^{\eta_i -1}\sum_j s_{ij}$$

$$=g_i I_w^{\eta_i -1} \qquad 6.5.3$$

the last step relies on the assumption that all varieties are produced within the 25 countries and that, consequently, $\sum_j s_{ij}=1$

From (6.5.2),

$$s_{ij} = \frac{X_{ij}}{Y_T - Y_J} \cdot \frac{1}{g_i I_w^{\eta_i - 1}} \qquad 6.5.4$$

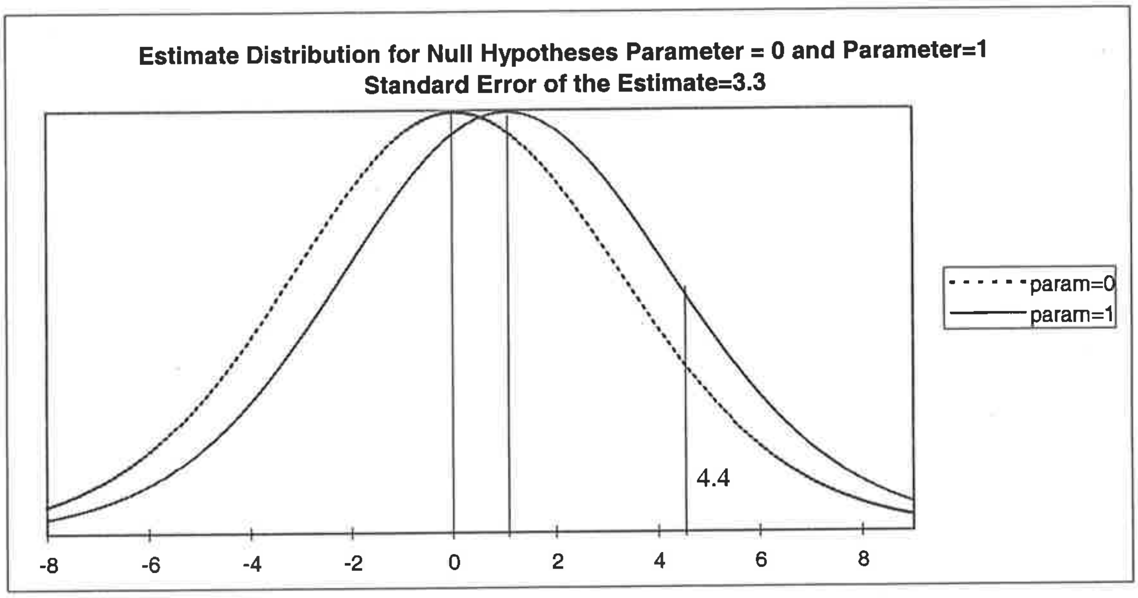
substituting for $g_i I_w^{\eta_i - 1}$ from 6.5.3 into 6.5.4, s_{ij} can be estimated as

$$s_{ij} = \frac{X_{ij} / (Y_T - Y_j)}{\sum_{j=1}^{j=25} [X_{ij} / (Y_T - Y_j)]}$$

6.6 Appendix B

The requirement for $\hat{\beta}_1$ significantly greater than zero is that $\frac{\hat{\beta}_1}{\mathrm{SE}(\hat{\beta}_1)} > t^*$, where for a 1-tailed test at the 10% significance level with 20 df., $t^*=1.33$. For those estimates for which $\hat{\beta}_1$ are significantly greater than zero, the range of standard errors of $\hat{\beta}_1$ is 0.86 to 9.5, so that even at the minimum observed value of the SE($\hat{\beta}_1$), a minimum value for $\hat{\beta}_1$ of 1.14 is required for the estimate to be considered significantly greater than zero. The requirement for $\hat{\beta}_1$ not significantly different from 1 then becomes $\frac{\hat{\beta}_1 - 1}{\mathrm{SE}(\hat{\beta}_1)} < t^*$, and for both to hold , $t^*.\mathrm{SE}(\hat{\beta}_1) < \hat{\beta}_1 < t^*.\mathrm{SE}(\hat{\beta}_1)+1$. To pass both tests, the value of $\hat{\beta}_1$, for any given level of significance and value of the standard error, must fall within an interval of width one, with upper and lower bounds determined by both the significance level and the value of the standard error. Evaluating this requirement at the mean value of the standard error for those estimates for which $\hat{\beta}_1$ significantly>0, (3.3), the 10% 1-tailed significance level interval is 4.4 to 5.4, the 5% 1-tailed significance level interval is 5.7 to 6.7, and the 1% 1-tailed significance level interval 8.3 to 9.3. In this example, a completely different set of SITC sub-groups would be selected for each of these three significance levels.

Diagram 6.B.1. Probability Distribution of Estimates.



The two curves represent the probability distribution function of $\hat{\beta}_1$ under the assumption that either null hypothesis, $\beta_1=0$ or $\beta_1=1$, is true. They are based on the t-distribution with 20 df, and standard error of $\hat{\beta}_1 = 3.3$.

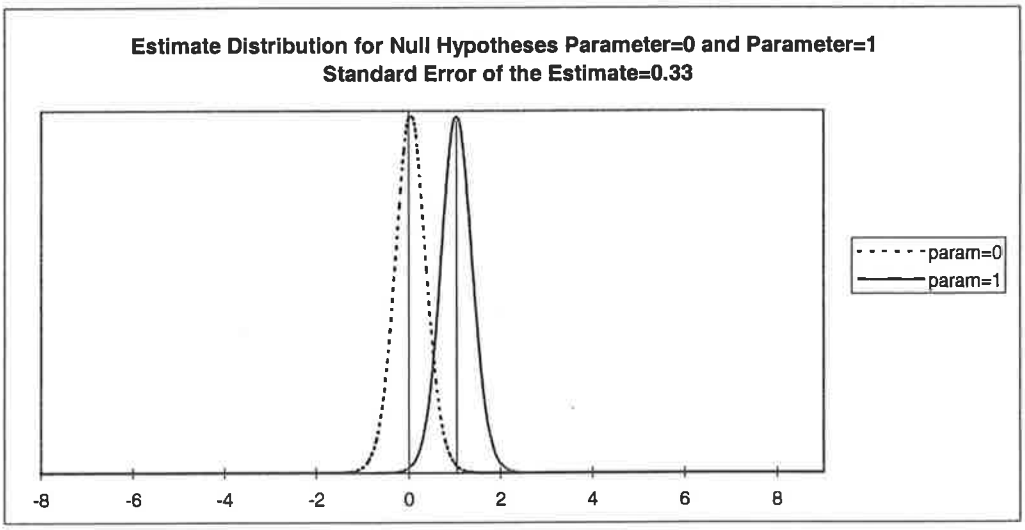
The problem arises from the overlap of the distributions of the estimates around the values of the parameter specified in the two null hypotheses, as illustrated in Diagram 6.B.1. This diagram is based on the mean value of the standard error of all estimates significantly greater than zero (10% 1-tailed). In this case, 4.4 is the minimum value of the estimate at which the null hypothesis, $\beta_1=0$, will be rejected in favour of the alternate, $\beta_1>0$, at the 10% 1-tailed level of significance. At the same time, the probability of obtaining a lower estimate than this (4.4) if the null hypothesis, $\beta_1=1$, is true, is 0.84. This means that the probability of failing the test $\beta_1>0$ and $\beta_1=1$, if $\beta_1=1$, is 0.84 plus the upper tailed probability level used to evaluate the null hypothesis $\beta_1=1$. In this case this is 0.1, meaning that the probability of failing the composite test (test ii) is 0.94, even if $\beta_1=1$. This number could be made larger by increasing the probability value used to test the null hypothesis $\beta_1=0$ and decreasing the probability value used to test the null hypothesis $\beta_1=1$, but significance levels should not be adjusted just to achieve the desired result.

Even at the minimum standard error of the estimate (0.86), a minimum estimate of 1.14 is required to reject the null hypothesis $\beta_1=0$ in favour of the alternate $\beta_1>0$ at the 10% 1-tailed level of significance and, even if the null hypothesis $\beta_1=1$ is true, the probability of obtaining an estimate less than this is 0.56, which is still unacceptably high.

This problem is not unique to this particular analysis. It will occur, to various levels of severity, whenever it is possible for an estimate to meet the "not significantly different from *x*" requirement and, at the same time, not meet the "statistically significantly different from zero" requirement. For example, repeating the above exercise with a value of the standard error of one-tenth of that used there (0.33), the corresponding intervals are 0.56-1.44, 0.57-1.57, and 0.83-1.83. At the 5% and 1% levels of significance there is still "overlap", but because the value of the standard error is smaller, the problem is less severe.

Diagram 6.B.2 shows the distributions of the estimates based on the two null hypotheses $\beta_1=0$ and $\beta_1=1$, with a standard error of the estimate of 0.33, using the same X axis scale as in Diagram 6.5.1. A comparison of the two diagrams illustrates the relevance of the magnitude of the standard error of the estimate to the problem of independently evaluating the two null hypotheses in a meaningful way.

Diagram 6.B.2. Probability Distribution of Estimates.



The two curves represent the probability distribution function of $\hat{\beta}_1$ under the assumption that either null hypothesis, $\beta_1=0$ or $\beta_1=1$, is true. They are based on the t-distribution with 20 df, and standard error of $\hat{\beta}_1 = 0.33$.

7. Innovative Goods and Growth: An Econometric Evaluation

7.1 Introduction

This chapter evaluates, with a number of econometric estimations, the proposition that the level of production of innovative goods is a factor determining a country's economic growth rate. It also evaluates the proposed underlying mechanism by which this occurs: that there will be a positive growth rate in the import to GDP ratio for such goods, that this will lead to a higher export growth rates for innovative goods and, consequently, the higher the innovative goods content of a country's exports, the higher will be that country's export growth rate. It is then argued that the higher the export growth rate, the higher the GDP growth rate; this arising either (or both) from the direct contribution of export growth to GDP growth, or through accommodating a higher GDP growth rate while maintaining balanced trade.

This chapter is in two sections. Section 7.2 analyzes import and export growth rates for individual SITC sub-groups, and section 7.3 analyzes import, export and GDP growth rate by country. The proposition that there will be an increase over time in the import to GDP ratio for innovative goods is evaluated in (7.2.1). The results are statistically significant and as expected, and support the proposition. Sub-section 7.2.2 evaluates the argument that the export growth rate will be higher for innovative goods. This argument is also supported, with the results being statistically significant and as expected. Sub-section 7.3.1 evaluates the argument that, the higher the innovative goods content of a country's exports, the higher the growth rate of those exports. The results are statistically significant and as expected, supporting that argument. Sub-section 7.3.2 evaluates the equivalent argument for imports. The results are inconclusive. Sub-section 7.3.3 examines the argument that, the higher the innovative goods content of exports and the lower for imports, the higher the GDP growth rate. The proposition is supported, with the results being statistically significant and as expected.

7.2 Import and Export Growth by SITC Sub-Group

7.2.1 Import to GDP Growth

The expectation is that over time there will be an increase in the import to GDP ratio for innovative goods - that the growth in the import to GDP ratio for such goods will be positive. The proposition to be tested is that the probability of an increase in the import to GDP ratio is higher for innovative than for non-innovative goods. The use of the various measures of intra-industry trade as proxies for innovative product groups is based on the argument that the higher the level of measured intra-industry trade for any SITC sub-group, then the higher the probability that this sub-group represents an innovative product group. The proposition to be tested, then, is that the higher the level of intra-industry trade, the greater the probability that the growth in the import to GDP ratio will be positive. This is tested by means of a logit regression using maximum likelihood, with the sign of the growth in the import to GDP ratio being the dependent variable, and the various intra-industry trade indices the explanatory variables. The criterion for positive growth is that the mean growth rate of the import to GDP ratio over all 25 countries for each SITC sub-group should be positive.

This approach, rather than an OLS regression with the growth rate being the dependent variable, is taken because it is not being argued that the higher the measured level of intra-industry trade, the higher the growth rate, but, rather, that the higher the level of intra-industry trade, the higher the probability that the growth rate will be positive. Nevertheless, an OLS regression is subsequently carried out to determine if the level of intra-industry trade has any explanatory power as to the magnitude of growth, as well as the sign.

7.2.1.1 Sign of Growth Rate in Import to GDP Ratio

The full model estimated is

$$[\text{mean growth} \left(\frac{M_{ij}}{Y_j}\right) > 0] = \beta_0 + \beta_1(GL) + \beta_2(GL)^2 + \beta_3(GL)^3 + \\ \beta_4(G_M) + \beta_5(G_M)^2 + \beta_6(G_X) + \beta_7(G_X)^2$$

Where GL, G_M, G_X refer to the Grubel-Lloyd, and Glejser import and export indices respectively. The squared and cubed terms are included to allow for any non-linearity in the effects of the indices. The expected signs of the coefficients are such that the first partial derivative of the dependent variable (y) with respect to the Grubel-Lloyd index, given by $\frac{\partial y}{\partial(\mathrm{GL})} = \beta_1 + 2\beta_2(\mathrm{GL}) + 3(\beta_3)^2$, should be positive for the range of values of the Grubel-Lloyd index; that the first partial derivative of the dependent variable with respect to the Glejser import index, given by $\frac{\partial y}{\partial(\mathrm{G_M})} = \beta_4 + 2\beta_5(\mathrm{G_M})$, should be negative over the range of values of this index; and that the first partial derivative of the dependent variable with respect to the Glejser export index, given by $\frac{\partial y}{\partial(\mathrm{G_X})} = \beta_6 + 2\beta_7(\mathrm{G_X})$, should be negative over the range of values of this index. The results are summarized in Table 7.1.

Table 7.1. Estimation of Incidence of Positive Growth in Import to GDP Ratio

	A	B	C	D	E
intercept	-0.62	2.04 ***	1.66 ***	-0.01	-0.48
	(1.5)	(0.35)	(0.32)	(2.72)	(2.64)
GL	8.75			27.0	27.1
	(11.5)			(19.5)	(19.3)
$(\mathrm{GL})^2$	-32.1			-85.0 *	-84.3 *
	(29.3)			(46.6)	(46.9)
$(\mathrm{GL})^3$	35.7			77.8 **	77.4 **
	(23.9)			(35.8)	(35.6)
$\mathrm{G_M}$		-2.84 ***		-2.60 ***	-2.69 ***
		(0.64)		(0.68)	(0.67)
$(\mathrm{G_M})^2$		0.67 ***		0.61 **	0.62 **
		(0.24)		(0.25)	(0.25)
$\mathrm{G_X}$			-0.77 ***	-0.22	
			(0.18)	(0.25)	
-2 logL	681.6	665.9	684.3	649.2	649.9
R^2	0.06	0.1	0.05	0.13	0.13
AIC	706.6	671.9	688.3	663.2	661.9
HL	5.31	3.4	3.06	5.53	6.41

N=518. GL: Grubel Lloyd IIT index. $\mathrm{G_M}$ and $\mathrm{G_X}$: The Glejser Import and Export Indices respectively. *,**,***, significant at 10%, 5% and 1% (2 tailed) respectively. Figures in parentheses are standard errors. R^2 is calculated using the method of Cox and Snell (1989) modified by the method of Nagalkerke (1991) to give a maximum value of 1. AIC: Akaike Information Criterion. HL : Hosmer and Lemeshow goodness of fit test (Hosmer and Lemeshow 1989), distributed as χ^2_8.

The squared term for the Glejser export index is not significant and, consequently, models including this term have been omitted. Models A, B and C are included to show the estimate of the coefficient of each of the intra-industry trade indices in isolation, each in the most effective functional form. Although the three coefficients in Model A are not significant, the coefficients for GL and $(\mathrm{GL})^2$ are significant in the absence of the cubed term, the addition of which greatly increases the standard errors of the estimates due to multi-collinearity. While the inclusion of the cubed term in

Model A is not quite significant at the 10% level, it is significant when included in Models D and E, and so is included in Model A to enable comparison.

Model D demonstrates the effect of combining all three indices. In this model the Glejser export index is insignificant, and is omitted in Model E. In Model E, the estimated coefficients for the Glejser import index and its square give the partial derivative of the dependent variable with respect to the Glejser import index as $(-2.69+1.24(G_M))$, meaning that the probability of positive import to GDP growth is decreasing in the value of the index, as expected, up to an index value of 2.17. With this value being above the 97th percentile the slope is effectively negative (as expected) over the entire range, ranging from -2.83 at the minimum to zero at the maximum. This effect is not surprising in view of the fact that the distribution of the Glejser import index is positively skewed, with the fourth quartile accounting for nearly 80% of the total range.

The estimated coefficients from Model E for β_1, β_2, and β_3 give the partial derivative of the dependent variable with respect to the Grubel-Lloyd index as $(27.1-168.6(GL)+232.2(GL)^2)$. Between values of the index of 0.24 and 0.49, corresponding to the 3rd and 53rd percentiles respectively, the value of the derivative lies between 0 and -3.5, effectively zero; suggesting that this index has little or no explanatory power within this range. Below this intermediate range, the value of the derivative varies from 27 to zero, and above it from zero to 33. While the Glejser export index is not significant when used in combination with the other two indices, it is significant when used on its own, and with the expected sign.

To summarize the results in Table 7.1, the coefficients for each of the three intra-industry trade indices individually are significant and have the expected sign. In combination, both the Grubel-Lloyd and Glejser indices are significant and of the expected sign, while the Glejser export index is insignificant.

The suggestion of little or no explanatory power of the Grubel-Lloyd index in the mid-range is supported by Table 7.2., which shows little or no variation of the proportion of positive growth rates in the range 0.2 to 0.6.

Table 7.2: Proportion of Positive Growth Rates in M/Y Categorized by Intra-Industry Trade Measures.

GL upper limit	0.2	0.3	0.4	0.5	0.6	1.0
N	8	32	89	161	142	86
% growth M/Y >0	37.5	50	55.0	51.6	57.0	81.4
Glejser M upper limit	0.5	1.0	1.5	2.0	2.5	-
N	136	269	78	23	7	5
% growth M/Y >0	72.8	60.6	37.2	21.7	57.1	40.0
Glejser X upper limit	1.0	1.5	2.0	2.5	-	
N	32	159	199	85	43	
% growth M/Y >0	78.1	62.3	60.8	48.2	37.2	

The Hosmer and Lemeshow goodness of fit test arranges observations into 10 groups ranging from highest to lowest predicted event probability. The range of predicted probabilities for Model E for positive growth rate in the import to GDP ratio was 0.85 to 0.3. The value of the corresponding goodness of fit statistic, distributed as χ^2_8, is 6.41, indicating a good fit between actual and predicted.

7.2.1.2 Magnitude of Growth Rate in the Import to GDP Ratio

To determine if the various proxies for innovative products have any explanatory power for the magnitude of the import to GDP growth rate, the growth rate was regressed against the three intra-industry trade indices using ordinary least squares (OLS) for all manufacturing sub-groups, and then separately for those having positive and negative growth rates.

For this and all subsequent OLS regressions at the SITC sub-group level in this chapter there was evidence of heteroscedasticity with respect to the Glejser import index. While significant, it was mild[1], and the remedy of WLS markedly increased multicollinearity. Consequently the original OLS estimates are presented.

Table 7.3 summarizes the results for all manufacturing SITC sub-groups. Individually, each explanatory variable is significant and with the expected sign, although in combination only the Glejser import index is significant. The squared and cubed terms of the various indices were not significant and consequently not included here.

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[1] The Park test was significant at less than 1 % but R^2 was approximately 0.03. The use of WLS leads to the inclusion of an additional variable, $(G_M)^{-0.5}$, which significantly increases the variance of the estimates.

Table 7.3 Estimation of Import to GDP Growth Rates, All Manufacturing

	A	B	C	D	E	F	G
intercept	-0.026 ** (0.009)	0.031 *** (0.005)	0.035 *** (0.008)	0.010 (0.013)	-0.006 (0.020)	0.036 *** 0.008)	0.007 (0.020)
GL	0.076*** (0.019)			0.037 (0.021)	0.056 ** (0.025)		0.039 (0.025)
G_M		-0.027 *** (0.005)		-0.023 *** (0.006)		-0.025 *** (0.006)	-0.023 *** (0.006)
G_X			-0.015 *** (0.004)		-0.007 (0.006)	-0.004 (0.005)	0.001 (0.006)
R^2	0.03	0.05	0.02	0.06	0.03	0.05	0.06
F	15.7 ***	27.9 ***	11.9 ***	15.5 ***	8.6 ***	14.2 ***	10.3 ***

N=518. GL: Grubel Lloyd IIT index. G_M and G_X: The Glejser Import and Export Indices respectively. *,**,***, significant at 10%, 5% and 1% (2 tailed) respectively. Figures in parentheses are standard errors.

Given that the three intra-industry trade indices are correlated, the use of two or three of them in combination can be expected to introduce multicollinearity. When all three are used, the variance inflation factors for the Grubel-Lloyd, Glejser import and export indices respectively are 1.8, 1.4 and 2.0, which is not particularly severe. The severity does increase with the addition of the squared term of any of the indices. For example, a model incorporating only the Glejser import index and its square has a variance inflation factor of between 8 and 9.

Table 7.4 summarizes the results of the same estimation, limited to those SITC sub-groups exhibiting negative growth rates in the import to GDP ratio. The results are much the same as those in Table 7.3, with the estimated coefficients generally not significantly different. The Grubel-Lloyd index in the combined model (Model G) is now significant as a result of a doubling of the estimated value of the coefficient.

Table 7.4 Estimation of Import to GDP Growth Rates, Negative Growth Rates

	A	B	C	D	E	F	G
intercept	-0.076 *** (0.010)	-0.015 *** (0.005)	-0.015 * (0.008)	-0.045 *** (0.014)	-0.082 *** (0.021)	-0.016 ** (0.008)	-0.071 *** (0.021)
GL	0.091*** (0.021)			0.055 ** (0.024)	0.097 *** (0.028)		0.078 *** (0.028)
G_M		-0.023 *** (0.005)		-0.016 *** (0.006)		-0.024 *** (0.006)	-0.020 *** (0.006)
G_X			-0.011 ** (0.004)		0.002 (0.006)	0.002 (0.005)	0.010 (0.006)
R^2	0.08	0.09	0.03	0.12	0.08	0.09	0.13
F	18.9 ***	22.2 ***	6.5 ***	13.9 ***	9.5 ***	11.1 ***	10.2 ***

N=216. GL: Grubel Lloyd IIT index. G_M and G_X: The Glejser Import and Export Indices respectively. *,**,***, significant at 10%, 5% and 1% (2 tailed) respectively. Figures in parentheses are standard errors.

The same estimation carried out for those SITC sub-groups with a positive growth in the import to GDP ratio produced no significant results. The reason for the difference in results between the two groups is not immediately apparent. The variances of the growth rates for the two groups are virtually identical. The variances of the Glejser indices are significantly less for the positive growth group, but the variance of the Grubel-Lloyd index is greater. The conclusion is that the intra-industry trade indices do have explanatory power as to whether the import to GDP growth is positive or negative but, beyond that, the evidence is mixed.

7.2.2 Export Growth

The analysis of import growth was based on the import to GDP ratio, but there is no useful equivalent ratio for export growth. Theory suggests that imports are a function of domestic GDP, and exports a function of foreign GDP. But while it is straightforward to define the entity to which domestic GDP refers, it is not so in the case of foreign GDP. This might be possible with the availability of multilateral trade data, but there could be problems with this approach. For example, changes in the set of importing countries for any given product group and country could not be assumed to be exogenous. While it would be a simple matter to measure the growth rate in the export to domestic GDP ratio, there is no theoretical foundation for so doing. Not only is export growth not a function of domestic GDP growth, it could be considered to contribute to GDP growth.

The alternative is to use a measure of export growth unqualified by any form of GDP growth. This being the case, it is possible to use total export growth for each SITC sub-group as the measure, rather than the mean (or median) of the individual growth rates for each country. There is some advantage in doing this. Export growth in any product group for any country will be influenced by any change in the value of s_{ij}, the share of expenditure on product group i on varieties produced in country j. While this also the case for imports, the elasticity of imports with respect to s_{ij} is for most countries less than 0.1, while for exports it is always one. Given the diversity of country sizes within the data set being used, it is possible for a number of smaller countries to significantly increase product share (s_{ij}) at the expense of a relatively small decrease in the share of the larger country, thereby significantly increasing exports of a number of countries while marginally reducing the exports of one. While growth in total exports is not totally insensitive to such reallocation of product group share, it will be less responsive than for individual countries. The measure of export growth in the following analysis is growth in total exports by SITC sub-group. For the import to GDP ratio the initial interest is in whether such growth is positive or negative, but there is no corresponding form of classification for export growth.

Table 7.5 summarizes the regression results of growth rate in total exports against the three intra-industry trade indices. In Models A and B the coefficients for the Grubel-Lloyd and Glejser import indices are significant and of the expected sign. The estimated coefficients for the Glejser import index, and the square of that term, give partial derivatives of the export growth rate with respect to the Glejser import index as ($-0.059+0.028(G_M)$, $-0.044+0.026(G_M)$, $-0.065+0.028(G_M)$, $-0.055+0.026(G_M)$) for Models B, D, E and G respectively, suggesting that export growth is a convex function of the Glejser import index, decreasing up to values of 2.1, 1.7, 2.3 and 2.1 respectively for that index. These values are above the 97th, 95th, 98th and 97th percentiles of the values of the Glejser import index for the manufacturing SITC sub-groups. The upper two percentiles of the Glesjer import index for all manufacturing SITC sub-groups accounts for more than one third of the total range.

Model C, utilizing the Glejser export index alone, is not significant. In Models D and G, the Grubel-Lloyd and Glejser import indices in combination are significant, and have the expected sign. The explanatory power of both Models A and B are significantly improved by combining these two indices in Model D.

Table 7.5. Estimation of Export Growth Rates - All Manufacturing

	A	B	C	D	E	F	G
intercept	-0.009 (0.010)	0.082 *** (0.009)	0.058 *** (0.008)	0.025 (0.016)	-0.067 *** (0.026)	0.074 *** (0.010)	-0.039 * (0.022)
GL	0.12 *** (0.02)			0.096 *** (0.023)	0.17 *** (0.026)		0.153 *** (0.026)
G_M		-0.059 ** (0.017)		-0.044 *** (0.017)		-0.065 *** (0.017)	-0.055 *** (0.007)
$(G_M)^2$		0.014 ** (0.006)		0.013 ** (0.006)		0.014 ** (0.006)	0.013 ** (0.006)
G_X			-0.006 (0.005)		0.019 *** (0.006)	0.007 (0.006)	0.026 *** (0.006)
R^2	0.06	0.05	0.003	0.08	0.08	0.05	0.11
F	19.1 ***	12.0 ***	1.8	14.3 ***	22.6 ***	8.6 ***	15.5 ***

N=518. GL: Grubel Lloyd IIT index. G_M and G_X: The Glejser Import and Export Indices respectively. *,**,***, significant at 10%, 5% and 1% (2 tailed) respectively. Figures in parentheses are standard errors.

The contribution of the Glejser export index is unexpected. Individually, as in Model C, and combined with the Glejser import index, it is insignificant. However in combination with the Grubel-Lloyd index, as in Models E and G, it is not only significant but the estimated coefficient is positive, the opposite sign to that which was expected. The significance level of this coefficient in both Models E and G, together with the observation that the inclusion of this variable in Models E and G significantly improves the explanatory power, makes it unlikely that this is a due to a random effect.

The results for export growth to this point can be summarized as follows. The Grubel-Lloyd and Glejser import indices are significant, jointly and individually, and with the expected sign. The Glejser export index on its own is not significant, but is significant in conjunction with the Grubel-Lloyd index, and then with the opposite sign to that which was expected. This apparently contradictory result with the Glejser export index will be discussed a little later in this section.

To further analyze the explanatory power of these variables, the above regressions were carried out separately for the SITC sub-groups having either positive or negative growth rates in the import to GDP ratio. The results are summarized in Table 7.6. None of the squared terms is significant and they are therefore omitted. In the interest of brevity only the more relevant models are included.

Table 7.6. Regression of Export Growth Rates Against Intra-Industry Trade Indices Separately for Positive and Negative Import to GDP Growth Rates

	M/Y growth	intercept	GL	G_M	G_X	R^2	F
A	+	0.041 *** (0.011)	0.06 *** (0.022)			0.02	7.2 ***
	-	-0.036 ** (0.014)	0.11 *** (0.03)			0.06	13.9 ***
B	+	0.073 *** (0.006)		-0.004 (0.007)			0.3
	-	0.027 *** (0.007)		-0.014 * (0.007)		0.02	3.8 *
C	+	0.06 *** (0.010)			0.006 (0.006)		1.2
	-	0.011 (0.012)			0.002 (0.006)		0.74
E	+	-0.028 (0.023)	0.12 *** (0.03)		0.024 *** (0.007)	0.06	9.9 ***
	-	-0.14 *** (0.03)	0.21 *** (0.04)		0.03*** (0.008)	0.12	14.7 ***
G	+	-0.027 (0.023)	0.12 *** (0.028)	-0.003 (0.008)	0.025 *** (0.007)	0.06	6.7 ***
	-	-0.13 *** (0.030)	0.19 *** (0.039)	-0.016 * (0.009)	0.037 *** (0.009)	0.13	11.0 ***

GL: Grubel Lloyd IIT index. G_M and G_X: The Glejser Import and Export Indices respectively. *,**,***, significant at 10%, 5% and 1% (2 tailed) respectively. Figures in parentheses are standard errors. Positive growth in M/Y, N=302; negative, N=216.

In this instance, significant results are obtained for both positive and negative growth rate groups. The major difference from analyzing the two groups separately is the low level of significance of the Glejser import index. It is significant jointly and individually only in the case of negative import to GDP growth, and then only at the 10% level. The Grubel-Lloyd index is significant with the expected sign as before, while the Glejser export index is again significantly positive, but only in conjunction with the Grubel-Lloyd index.

To enable comparison with the logit regression of positive/negative import to GDP growth rates summarized in Table 7.1, a similar exercise was carried out for export growth rates, with the dependent variable indicating whether the export growth rate was greater or less than the mean. The results are summarized in Table 7.7.

Table 7.7 Estimation of Export Growth Rates Greater than Mean

	A	B	C	D
intercept	-1.56 *** (0.38)	0.76 *** (0.19)	0.52 * (0.31)	-2.37 *** (0.87)
GL	3.58 *** (0.78)			4.47 *** (1.06)
G_M		-1.55 ** (0.62)		-1.47 ** (0.66)
$(G_M)^2$		0.31 (0.24)		0.30 (0.24)
G_X			-0.22 (0.17)	0.76 *** (0.26)
R^2	0.056	0.04	0.005	0.09
AIC	698.8	706.1	717.9	690.5
-2logL	694.8	700.1	713.9	680.5
HL	7.5	2.54	7.9	11.9

N=518. GL: Grubel Lloyd IIT index. G_M and G_X: The Glejser Import and Export Indices respectively. *,**,***, significant at 10%, 5% and 1% (2 tailed) respectively. Figures in parentheses are standard errors. R^2 is calculated using the method of Cox and Snell (1989) modified by the method of Nagalkerke (1991) to give a maximum value of 1. AIC: Akaike Information Criterion. HL : Hosmer and Lemeshow goodness of fit test (Hosmer and Lemeshow 1989), distributed as χ_8^2 .

The results are much the same. The Grubel-Lloyd and Glejser indices are significant, jointly and severally, with the expected sign. The Glejser export index is insignificant by itself, but significant and positive in combination with the Grubel-Lloyd index. The unexpected behaviour on the part of the Glejser export index is persistent. In all of the above analyses of export growth, it is insignificant by itself and significantly positive only in combination with the Grubel-Lloyd index. This was also observed using the mean of export growth over individual countries as the dependent variable. But with various measures of import growth as the dependent variable it was consistently significant by itself (with the expected negative sign) and insignificant in combination with the other indices.

There are two issues here. The unexpected behaviour of the Glejser export index as an explanatory variable for export growth, and its different behaviour as an explanatory variable for import growth. In an ideal situation one might expect import and export growth by trade category to be identical. However this is not an ideal situation. For example the 25 countries considered here do not make up the entire world, but it is difficult to see how the incomplete nature of the sample alone could systematically lead to this particular result.

It is tempting to interpret the positive coefficient for the Glejser export index as suggesting that production of the innovative goods for which export growth is the highest is not evenly distributed over the 25 countries included, but this does not explain why the same effect was not observed for import growth. These results do not depend on the particular growth variable used. The expected coefficients were also obtained for all three indices when total import growth was the dependent variable, and the positive estimated coefficient for the Glejser export index was also obtained with the mean export growth as the dependent variable. A satisfactory explanation awaits further analysis.

To summarize, the coefficients of the Grubel-Lloyd and Glejser import indices are significant, and of the expected sign, when analyzing both import to GDP growth and export growth. This is evidence in support of the argument that, with continuing innovation, there is an increase in the import to GDP ratio for innovative products, leading to a greater than average export growth. The results with the Glejser export index are less clear and require further explanation. The positive coefficient for this variable when used in combination with the Grubel-Lloyd index should not be interpreted as contrary evidence because it is observed only in this combination.

It could be argued that these results reflect no more than an income elasticity of demand effect, and any such argument is not easily refuted. There are suggestions that high intra-industry trade goods have high income elasticity of demand, but there is no evidence of this having been directly measured. The suggestions are based on two observations. The first is that intra-industry trade on a country basis is higher for high income countries, but this is observed only when lesser developed countries are included in the sample, and it is likely to reflect the different composition of imports and exports expected from lesser developed countries. The second observation is that measured levels of intra-industry trade are increasing over time, and so is average income. However, income is not the only thing changing over time. Product innovation occurs over time, and this observation is not inconsistent with the argument being presented concerning product innovation.

In the estimations carried out in Chapter 6 on the model

$$\log\left(\frac{M_{ij}}{Y_j}\right) = \beta_0 + \beta_1 \log(1-s_{ij}) + \beta_2 \log(I_j) + u_{ij} \text{ (from 6.3.2)}$$

β_2 is an estimate for $(\eta_j\text{-}1)$ where η_j is the income elasticity of demand for product group j. An estimate of β_2 significantly different from zero is therefore an indicator of income elasticity of demand being less than or greater than one.

A number of estimates significantly greater than that expected under the null hypothesis of unit income elasticity for all product groups was found for income elasticity less than one but not for greater than one. When a dummy variable indicating income elasticity of demand less than one was added to Model E in Table 7.1 the coefficient was not significant, and of the opposite sign to that which might have been expected. This is not conclusive, and the absence of a significant number of estimates of income elasticity of demand greater than one casts some doubt over these results.

There are several factors which may have contributed to this. One such factor is not taking into account income distribution within each country. Francois and Kaplan (1995) use several measures to make allowance for this, but time did not permit this to be done in this analysis. Another contributing factor may have been that the countries included in the data set are predominantly, if not exclusively, high income countries, and provide a relatively narrow range of average incomes. More meaningful results might have been obtained with a wider range of incomes, but then the assumption of otherwise identical economies would be less reasonable.

7.3 Import, Export and GDP Growth by Country

This section examines the relationship between the innovative goods content of both imports and exports by country, and their corresponding growth rates and growth rate in GDP.

7.3.1 Export Growth

The instantaneous growth rate of exports from country j can be expressed as

$\hat{X}_j = x_{ij}\,\hat{X}_{ij}$, where x_{ij} is the proportion of product group i in the exports of country j, and $\hat{X}_{ij}$ is the growth in exports of product group i from country j. It is argued that export growth is greater for innovative than non-innovative goods and that, consequently, the higher the innovative good content of a country's exports, the higher the rate of export growth.

The measure of innovative good content used is an export weighted average intra-industry trade index for each country, based on the intra-industry trade index by SITC sub-group determined using 1992 data. The weights (x_{ij}) are based on 1982 export values as this is the base year of the period being considered. Country level intra-industry trade indices calculated in this manner differ from the conventional country indices in that the value used for any given SITC sub-group is the same, irrespective of the country or year. Variations in any index between countries, and over time, reflect only variations in the composition of exports rather than in the level of intra-industry trade.

Using the export composition of the base year alone is sufficient only if each innovative product group (i) experiences the same export growth rate in each country - that is $\hat{X}_{ij} = \hat{X}_i \;\; \forall \; i,j$, in which case the product group share for each country (s_{ij}) remains constant. There is however no reason to expect this to be the case, and to allow for any net increase or decrease in the country share of innovative goods three additional explanatory variables will be included, these being the changes in the three export weighted indices from 1982 to 1992.

Table 7.8 summarizes the three export weighted intra-industry trade indices for both 1982 and 1992, and the changes over that period.

Table 7.8 Manufacturing Export Weighted Average Intra-Industry Trade Index by Country

Country	Grubel-Lloyd Index			Glejser Import Index			Glejser Export Index		
	1982	1992	Δ	1982	1992	Δ	1982	1992	Δ
Australia	0.472	0.499	*0.027*	0.840	0.833	*-0.007*	1.86	1.79	*-0.018*
Austria	0.528	0.539	*0.011*	0.631	0.664	*0.033*	1.57	1.63	*0.068*
Belgium	0.491	0.504	*0.014*	0.832	0.779	*-0.054*	1.85	1.83	*-0.020*
Canada	0.467	0.488	*0.021*	0.951	0.877	*-0.075*	2.00	1.97	*-0.029*
Denmark	0.548	0.558	*0.010*	0.625	0.627	*0.002*	1.49	1.51	*0.017*
Finland	0.497	0.511	*0.014*	0.830	0.710	*-0.119*	1.68	1.74	*0.065*
France	0.510	0.519	*0.010*	0.703	0.691	*-0.012*	1.75	1.78	*0.027*
Germany	0.508	0.525	*0.017*	0.661	0.640	*-0.022*	1.69	1.70	*0.005*
Greece	0.477	0.491	*0.014*	0.753	0.648	*-0.105*	1.67	1.69	*0.018*
Hong Kong	0.458	0.502	*0.043*	0.523	0.554	*0.031*	1.60	1.62	*0.017*
Iceland	0.428	0.435	*0.007*	1.01	1.03	*0.024*	2.00	2.00	*-0.005*
Ireland	0.522	0.535	*0.012*	0.622	0.600	*-0.022*	1.80	1.75	*-0.051*
Italy	0.507	0.522	*0.016*	0.638	0.634	*-0.004*	1.59	1.62	*0.025*
Japan	0.487	0.501	*0.014*	0.697	0.656	*-0.042*	1.76	1.82	*0.055*
Korea	0.487	0.501	*0.012*	0.761	0.713	*-0.048*	1.60	1.76	*0.156*
Netherlands	0.508	0.524	*0.017*	0.712	0.663	*-0.049*	1.69	1.65	*-0.039*
New Zealand	0.510	0.520	*0.010*	0.767	0.729	*-0.038*	1.67	1.65	*-0.021*
Norway	0.493	0.517	*0.025*	0.974	0.912	*-0.062*	1.75	1.73	*-0.023*
Portugal	0.462	0.475	*0.014*	0.666	0.603	*-0.063*	1.79	1.72	*-0.071*
Singapore	0.497	0.487	*-0.010*	0.725	0.701	*-0.024*	1.71	1.83	*0.119*
Spain	0.509	0.506	*-0.003*	0.736	0.665	*-0.071*	1.66	1.79	*0.132*
Sweden	0.519	0.531	*0.012*	0.727	0.691	*-0.037*	1.68	1.69	*0.016*
Switzerland	0.509	0.516	*0.007*	0.701	0.674	*-0.027*	1.77	1.74	*-0.027*
UK	0.525	0.536	*0.009*	0.746	0.691	*-0.055*	1.71	1.71	*0.009*
US	0.531	0.523	*-0.008*	0.708	0.713	*0.005*	1.64	1.80	*0.159*
mean	0.498	0.511	*0.013*	0.745	0.708	*-0.034*	1.72	1.74	*0.021*
std dev	0.027	0.025	*0.011*	0.114	0.106	*0.039*	0.121	0.106	*0.066*

Indices for both 1982 and 1992 are weighted averages of the component intra-industry trade indices calculated at the SITC sub-group level from 1992 data. Weightings are from export data for the year indicated. Note: The Grubel-Lloyd index is increasing in the level of intra-industry trade, the Glejser indices decreasing. Δ is the change from 1982 to 1992.

The Glejser indices show greater variation amongst countries than does the Grubel-Lloyd index (relative to the mean value). The change in the mean values of the Grubel-Lloyd and Glejser import indices is consistent with a greater export share for innovative goods over time. Using the paired difference test both of these changes are statistically significant[2]. The change in the Glejser export index is in the opposite direction, but not statistically significant.

Two dummy variables are used. NonOECD for the non OECD countries, and Iberian for Spain and Portugal, to cater for the admission of these two countries into the EC during the first half of the period for which growth is being analyzed. Both are statistically significant.

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[2] Significant at the 0.1% level, using both parametric and non-parametric tests.

Foreign GDP growth, as measured by the aggregate GDP growth of the remaining 24 countries, was not significant. When the changes in the three intra-industry trade indices over the measurement period were included, only the change in the export weighted Glejser export index was found to be significant. The results are summarized in Table 7.9.

Table 7.9 Estimation of Manufacturing Export Growth Rates by Country

	A	B	C	D	E	F	G
Intercept	0.05 ***	-0.08 ***	0.13 ***	0.088 ***	0.034	-0.20	-0.22 *
	(0.004)	(0.072)	(0.02)	(0.058)	(0.040)	(0.12)	(0.11)
GL		0.27 *				0.30 **	0.38 **
		(0.14)				(0.14)	(0.14)
G_M			-0.11 ***		-0.17 ***	-0.16 ***	-0.13 ***
			(0.027)		(0.031)	(0.030)	(0.031)
G_X				-0.02	0.084 ***	0.13 ***	0.10 ***
				(0.03)	(0.029)	(0.033)	(0.034)
ΔG_X							-0.091 *
							(0.048)
Iberian	0.053 ***	0.057 ***	0.047 ***	0.053 ***	0.044 ***	0.050 ***	0.054 ***
	(0.014)	(0.014)	(0.011)	(0.014)	(0.010)	(0.009)	(0.009)
Non OECD	0.058 ***	0.064 ***	0.049 ***	0.056 ***	0.052 ***	0.063 ***	0.073 ***
	(0.012)	(0.012)	(0.009)	(0.012)	(0.008)	(0.009)	(0.010)
R^2	0.61	0.67	0.78	0.62	0.84	0.87	0.89
F	17.4 ***	14.1 ***	24.7 ***	11.4 ***	26.8 ***	26.1 ***	25.3 ***

N=25. GL: Grubel Lloyd IIT index. G_M and G_X: The Glejser Import and Export Indices respectively. ΔG_X: Change in G_X from 1982 to 1992. *,**,***, significant at 10%, 5% and 1% (2-tailed) respectively. Figures in parentheses are standard errors. There is no evidence of heteroscedasticity or of specification error.

Model A is the "base case" with only the two dummy variables, included for the sake of comparison. In Models B and C, the Grubel-Lloyd and Glejser import indices are individually significant and of the expected sign. In Model D, the Glejser export index has the expected sign but is not significant. In Model E, with the two Glejser indices in combination, the Glejser export index is significant but with the sign opposite to that which is expected. Model F includes the Grubel-Lloyd index, still significant and with the expected sign. In Model G the change in the Glejser export index is included, and this is significant with the expected sign. The addition of the Grubel-Lloyd index to Model E to form Model F improves the explanatory power significantly but only at the 10% level, and similarly the addition of the ΔG_X variable to Model F to form Model G.

Again, there is no apparent explanation for the role of the Glejser export index. Used in isolation it is not significant but has the expected sign; in combination with the Glejser import index it is significant and significantly increases the explanatory power, but the sign is the opposite to that expected. The one change variable which was significant was that for the Glejser export index, and that does have the expected sign. While most of the explanatory power comes from the two dummy variables, the other explanatory variables do explain 70% of the variation not explained by the dummy variables. Model G without the dummy variables gives an R^2 in excess of 0.5, but with evidence of model specification error.

7.3.2 Import Growth

Attempts to estimate a similar model for growth in the import to GDP ratio, or import growth, were not successful. The variances of the import weighted intra-industry trade indices were approximately one quarter of the export weighted equivalents, and were highly correlated with each other. The variable with the highest explanatory power was the log of the population, with a positive coefficient, but this variable was highly correlated with each of the intra-industry trade indices. The population variable was not significant in the case of export growth.

The mean and standard deviation of the import weighted intra-industry trade indices are shown in Table 7.10. These values are directly comparable with those shown for the export weighted indices in Table 7.8.

Table 7.10. Summary of Manufacturing Import Weighted Intra-Industry Trade Indices by Country

	Grubel-Lloyd Index			Glejser Import Index			Glejser Export Index		
	1982	1992	Δ	1982	1992	Δ	1982	1992	Δ
mean	0.505	0.515	0.010	0.709	0.67	-0.039	1.71	1.71	0.00
std deviation	0.014	0.014	0.001	0.060	0.043	0.032	0.092	0.077	0.041

Indices for both 1982 and 1992 are weighted averages of the component intra-industry trade indices calculated at the SITC sub-group level from 1992 data. Weightings are from export data for the year indicated. Note: The Grubel-Lloyd index is increasing in the level of intra-industry trade, the Glejser indices decreasing. Δ is the change from 1982 to 1992.

Again the changes in the weighted Grubel-Lloyd and Glejser import indices are statistically significant[3] and in the direction consistent with a greater import content of innovative goods.

The inability to explain variations in import growth rates on the basis of intra-industry trade indices is not unexpected, given the expectation that the pattern of import of innovative goods will be similar across countries. This is the basis for the use of the

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[3] Using the paired difference test. Using both parametric and non-parametric tests the difference was significant at the 0.01% level.

Glejser import index as a proxy for innovative goods, and it is for this reason that the focus in this thesis is on the contribution of innovative goods to export growth.

7.3.3 GDP Growth

This section examines the proposition that that the innovative good content of exports and imports have some bearing on the GDP growth rate. The basis for this proposition is the following expression derived in Chapter 3.

$$\hat{Y} = \frac{\hat{X}|_{Y^*} - \hat{M}|_Y + \eta_X \hat{Y}^*}{\eta_M}$$ (from 3.7.5) where

$\hat{Y}$ is GDP growth

$\hat{Y}^*$ is growth in foreign GDP

$\hat{X}|_{Y^*}$ is export growth at constant foreign GDP

$\hat{M}|_Y$ is import growth at constant GDP

η_X is income elasticity of export demand at constant export composition

η_M is income elasticity of import demand at constant import composition

$\hat{Y}^*$ is included as a contributory factor to export growth. However, the available measures of this variable were not found to be significant in the previous analysis of export growth, and will not be included here.

It has been argued that the greater the innovative good content, the higher the value of $\hat{X}|_{Y^*}$ and, to a lesser extent, $\hat{M}|_Y$. Using the various measures of intra-industry trade as measures of the innovative goods content of both imports and exports, it is expected that GDP growth rate would be decreasing in the import weighed intra-industry trade indices, and increasing in the export weighed intra-industry trade indices. There are consequently six potential explanatory variables, with changes in each of them over the measurement period providing another six.

Estimated coefficients of the import and export weighted Glejser export indices, the import weighted Grubel-Lloyd index, and the changes in all six indices over the measurement period, were not significant. Results obtained from the other three indices and an additional variable, the difference between the export and import weighted Grubel-Lloyd indices, are summarized in Table 7.11. Results obtained with other combinations of these variables are presented and discussed in Appendix A to this chapter.

There are various measures of GDP growth which can be used. The results using growth in GDP in $US at constant prices are summarized in Table 7.11. Results obtained with other measures of GDP growth are discussed subsequent to the discussion of Table 7.11.

Table 7.11 GDP Growth ($US) as a Function of Import and Export Weighted Intra-Industry Trade Indices

	A	B	C	D	E	F
Intercept	0.054 *** (0.005)	0.049 *** (0.004)	0.031 (0.048)	0.037 (0.042)	-0.31 (0.19)	-0.26 (0.18)
export wtd GL					0.68 ** (0.33)	0.57 * (0.33)
import wtd G_M			0.133 ** (0.062)	0.096 * (0.054)	0.19 *** (0.059)	0.16 ** (0.061)
export wtd G_M			-0.096 *** (0.032)	-0.074 ** (0.029)	-0.16 *** (0.033)	-0.13 *** (0.040)
DXMGL					-0.82 *** (0.27)	-0.63 ** (0.30)
Iberian	0.036 *** (0.016)	0.041 *** (0.013)	0.031 ** (0.013)	0.036 *** (0.012)	0.030 ** (0.011)	0.034 *** (0.011)
NonOECD		0.039 *** (0.011)		0.029 *** (0.010)		0.017 (0.012)
R^2	0.18	0.49	0.49	0.64	0.68	0.71
F	5.02 **	10.4 ***	6.73 ***	8.91 ***	8.18 ***	7.51 ***

N=25. GL: Grubel Lloyd IIT index. G_M: The Glejser Import Index , weighted as indicated. DXMGL, the difference between the export and imported weighted GL indices. GDP growth calculated on the basis of GDP in domestic currency for years 1982 and 1992 converted to $US at prevailing exchange rates and deflated with the US implicit GDP deflator. Source: *International Financial Statistics*, various volumes. *,**,***, significant at 10%, 5% and 1% (2 tailed) respectively. Figures in parentheses are standard errors. There is no evidence of model specification error or heteroscedasticity.

In Models C, D, E and F, the estimated coefficients for both the import and export weighted Glejser import indices are significant and of the expected sign; and in Models E and F the estimated coefficient of the export weighted Grubel-Lloyd index is significant and of the expected sign. The estimated coefficient of the export weighted Grubel-Lloyd index is not significant in the absence of the variable DXGML, which is the difference between the export and import weighted Grubel-Lloyd indices. The estimated coefficient of this variable is significant but of the opposite sign to that expected. These two variables are highly correlated (r = 0.91) producing a variance inflation factor in the range of 8 to 9 for both variables in Models E and F.

In Model F the NonOECD variable is not significant, and Model E shows the effect of deleting this variable. Comparing Models A and E, it can be seen that Model E explains 60% of the variation in GDP growth not explained by the dummy variable for the two Iberian countries. Model E without the Iberian dummy variable has R^2=0.57. Comparing Models A and C, it can be seen that the import and export weighted Glesjer import indices, in combination, explain 38% of the variation in GDP growth not explained by Iberian dummy variable. Model C without this dummy variable has R^2=0.36.

The signs and statistical significance of the estimated coefficients of the import and export weighted Glejser import indices, and of the export weighted Grubel-Lloyd index, support the proposition that GDP growth rate is increasing in the innovative goods content of exports and decreasing in the innovative goods content of imports. The interpretation of the sign of the estimated coefficient for the variable DXMGL, in combination with the export weighted Grubel-Lloyd index, is not straightforward. It suggests that, while GDP growth is increasing in the innovative goods content of exports, it is decreasing in the degree to which the innovative goods content of imports, as measured by the import weighted Grubel-Lloyd index, is not correspondingly increasing.

These results, and the results for export growth, show that both the export growth rate and GDP growth rate are increasing in the innovative goods content of exports. It remains to establish whether the effect of export composition on GDP growth rate is through the export growth rate. A regression of GDP growth rate using export growth rate as the only explanatory variable gave R^2=0.48, establishing the expected correlation between the two, but not necessarily causality . The explanatory power was not improved either by the addition of the dummy variable nor by any other explanatory variable from Model E, other than the import weighted Glejser import index. The addition of the export growth variable to the list of explanatory variables used in Model E had no statistically significant effect. These results support the proposition that the effect of the innovative goods content of exports on GDP growth rate is through the export growth rate.

To determine if the explanatory power of the various intra-industry trade indices for GDP growth was specific to growth based on GDP in \$US, the same models were estimated using both the growth in GDP in domestic currency at constant price, and the growth in the GDP measure RGDPTT from the Penn World Table. This latter variable measures domestic absorption at constant prices and net foreign balance at current prices (Summers and Heston 1991, p346). In both cases, the NonOECD dummy was significant and the Iberian dummy not significant, which makes a strict comparison more difficult, but the R^2 values obtained in the absence of both dummy variables were 0.49 and 0.57 respectively, and in both cases the estimated coefficients were of the same sign and within one standard error of those obtained in Model E in Table 7.11. The conclusion is that the explanatory power of this model is not limited to growth in GDP expressed in \$US.

7.4 Conclusions

At the individual SITC sub-group level, the various intra-industry trade indices, particularly the Grubel-Lloyd and Glejser import indices, are shown to have some explanatory power in the growth of the import to GDP ratio and the growth of exports. The estimated coefficients are consistent with the argument that growth in trade is greater for innovative than for non-innovative goods. At the country level, export growth is shown to be increasing in the aggregate weighted intra-industry trade index for a country's exports. Again this is consistent with the argument that, the higher the innovative goods content of a country's exports, then, all else being equal, the greater the rate of export growth. It is also shown that the import and export weighted intra-industry trade indices can explain a large proportion of the variation in GDP growth rate, in a manner consistent with the argument that the production of innovative goods can be expected to influence GDP growth rate, through the effect on import and export growth rates.

7.5 Appendix A

Tables 7A.1, 7A.2, 7A.3 and 7A.4 show models with further combinations of the explanatory variables used in the models shown in Table 7.11, with all four possible combinations of the two dummy variables. Table 7A.5 summarizes the statistical significance of additional variables in the form of intra-industry trade indices, and Table 7A.6 the statistical significance of adding the dummy variables.

Table 7A.1. GDP Growth ($US) as Function of Import and Export Weighted Intra-Industry Trade Indices, in the Absence of Dummy Variables

	A	B	C	D	E	F
Intercept	0.131 *** (0.028) *10^{-4}*	-0.032 (0.055) *0.57*	0.035 (0.053) *0.51*	0.098 (0.090) 0.29	0.219 * (0.120) *0.082*	-0.216 (0.209) *0.313*
export wtd GL				-0.081 (0.181) *0.65*	-0.282 (0.167) *0.106*	0.534 (0.368) *0.162*
import wtd G_M		0.126 (0.078) *0.119*	0.140 ** (0.067) *0.0495*		0.110 (0.067) *0.114*	0.184 ** (0.067) *0.013*
export wtd G_M	-0.099 ** (0.037) *0.014*		-0.104 *** (0.035) *0.0068*		-0.134 *** (0.038) *0.0019*	-0.173 *** (0.038) *0.0002*
DXMGL						0.753 ** (0.310) *0.024*
R^2	0.24	0.10	0.36	0.01	0.44	0.57
Adjusted R^2	0.20	0.06	0.30	-0.03	0.36	0.48
F	7. 09**	2.62	6.22 ***	0.205	5.45 ***	6.52 ***

N=25. GL: Grubel Lloyd IIT index. G_M: The Glejser Import Index , weighted as indicated. DXMGL, the difference between the export and imported weighted GL indices. GDP growth calculated on the basis of GDP in domestic currency for years 1982 and 1992 converted to $US at prevailing exchange rates and deflated with the US implicit GDP deflator. Source: *International Financial Statistics*, various volumes. *,**,***, significant at 10%, 5% and 1% (2 tailed) respectively. Figures in parentheses are standard errors. Figures in *italics* are P values, based on the t-distribution.

Table 7A.2. GDP Growth ($US) as Function of Import and Export Weighted Intra-Industry Trade Indices. Iberian Dummy Variable Only.

	A	B	C	D	E	F
Intercept	0.122 *** (0.026) *0.0001*	-0.031 (0.051) *0.55*	0.031 (0.048) *0.53*	0.069 (0.085) *0.42*	0.171 (0.114) 0.15	-0.309 (0.186) *0.114*
export wtd GL				-0.030 (0.170) *0.86*	-0.214 (0.160) *0.196*	0.683 * (0.327) *0.051*
import wtd G_M		0.121 (0.072) *0.106*	0.133 ** (0.062) *0.041*		0.112 * (0.063) *0.087*	0.193 *** (0.059) *0.0042*
export wtd G_M	-0.091 ** (0.035) *0.0154*		-0.096 *** (0.032) *0.007*		-0.120 *** (0.036) *0.003*	-0.160 *** (0.033) *0.0001*
DXMGL						0.820 (0.273) *0.0073*
Iberian	0.032 ** (0.014) *0.037*	0.035 ** (0.015) *0.033*	0.031 ** (0.013) *0.031*	0.035 ** (0.016) *0.043*	0.027 * (0.013) *0.058*	0.030 ** (0.011) *0.016*
R^2	0.38	0.27	0.49	0.18	0.53	0.68
Adjusted R^2	0.32	0.21	0.42	0.11	0.44	0.60
F	6.60 ***	4.13 **	6.73 ***	2.42	5.69 ***	8.18 ***

N=25. GL: Grubel Lloyd IIT index. G_M: The Glejser Import Index , weighted as indicated. DXMGL, the difference between the export and imported weighted GL indices. GDP growth calculated on the basis of GDP in domestic currency for years 1982 and 1992 converted to $US at prevailing exchange rates and deflated with the US implicit GDP deflator. Source: *International Financial Statistics*, various volumes. *,**,***, significant at 10%, 5% and 1% (2 tailed) respectively. Figures in parentheses are standard errors. Figures in *italics* are P values, based on the t-distribution

Table 7A.3. GDP Growth ($US) as Function of Import and Export Weighted Intra-Industry Trade Indices. NonOECD Dummy Variable Only

	A	B	C	D	E	F
Intercept	0.112** (0.027 *0.0003*	-0.010 (0.072) *0.85*	0.041 (0.049) *0.42*	0.040 (0.083) *0.64*	0.159 (0.12) *0.209*	-0.185 (0.22) *0.41*
export wtd GL				0.026 (0.17) *0.88*	-0.18 (0.17) *0.305*	0.47 (0.39) *0.24*
import wtd G_M		0.089 (0.072) *0.23*	0.109 (0.064) *0.105*		0.096 (0.065) *0.16*	0.168 ** (0.073) *0.033*
export wtd G_M	-0.079 ** (0.035) *0.033*		-0.087 ** (0.034) *0.018*		-0.109 ** (0.040) *0.013*	-0.157 *** (0.046) *0.003*
DXMGL						-0.66 * (0.35) *0.079*
NonOECD	0.029 ** (0.012) *0.024*	0.032 ** (0.013) *0.020*	0.025 * (0.012) *0.051*	0.036 ** (0.013) *0.013*	0.020 (0.013) *0.14*	0.008 (0.013) *0.55*
R^2	0.40	0.30	0.47	0.26	0.50	0.57
Adjusted R^2	0.34	0.24	0.39	0.19	0.40	0.46
F	7.23 ***	4.78 **	6.18 ***	3.77 **	4.94 ***	5.12 ***

N=25. GL: Grubel Lloyd IIT index. G_M: The Glejser Import Index , weighted as indicated. DXMGL, the difference between the export and imported weighted GL indices. GDP growth calculated on the basis of GDP in domestic currency for years 1982 and 1992 converted to $US at prevailing exchange rates and deflated with the US implicit GDP deflator. Source: *International Financial Statistics*, various volumes. *,**,***, significant at 10%, 5% and 1% (2 tailed) respectively. Figures in parentheses are standard errors. Figures in *italics* are P values, based on the t-distribution

Table 7A.4. GDP Growth ($US) as Function of Import and Export Weighted Intra-Industry Trade Indices. Both Iberian and NonOECD Dummy Variables

	A	B	C	D	E	F
Intercept	0.100 ***	-0.006	0.037	-0.003	0.072	-0.028
	(0.023)	(0.043)	(0.042)	(0.071)	(0.110)	(0.19)
	0.0003	*0.90*	*0.39*	*0.96*	*0.53*	*0.18*
export wtd GL				0.105	-0.054	0.573 *
				(0.14)	(0.16)	(0.33)
				0.47	*0.74*	*0.098*
import wtd GM		0.078	0.096 *		0.093	0.163 **
		(0.061)	(0.054)		(0.057)	(0.061)
		0.21	*0.092*		*0.117*	*0.016*
export wtd GM	-0.067 **		-0.074 **		-0.080 **	-0.128 ***
	(0.030)		(0.029)		(0.036)	(0.040)
	0.037		*0.019*		*0.038*	*0.0049*
DXMGL						-0.632 **
						(0.30)
						0.048
Iberian	0.037 ***	0.040 ***	0.036 ***	0.043 ***	0.034 **	0.034 ***
	(0.012)	(0.013)	(0.012)	(0.013)	(0.012)	(0.011)
	0.0057	*0.0053*	*0.0058*	*0.0044*	*0.012*	*0.0081*
NonOECD	0.034 ***	0.036 ***	0.029 ***	0.042 ***	0.028 **	0.017
	(0.010)	(0.011)	(0.010)	(0.011)	(0.011)	(0.012)
	0.0038	*0.0033*	*0.0090*	*0.0015*	*0.025*	*0.175*
R^2	0.58	0.52	0.64	0.50	0.64	0.71
Adjusted R^2	0.53	0.45	0.57	0.43	0.55	0.62
F	9.84 ***	7.68 ***	8.91 ***	6.97 ***	6.84 ***	7.51 ***

N=25. GL: Grubel Lloyd IIT index. G_M: The Glejser Import Index , weighted as indicated. DXMGL, the difference between the export and imported weighted GL indices. GDP growth calculated on the basis of GDP in domestic currency for years 1982 and 1992 converted to $US at prevailing exchange rates and deflated with the US implicit GDP deflator. Source: *International Financial Statistics*, various volumes. *,**,***, significant at 10%, 5% and 1% (2 tailed) respectively. Figures in parentheses are standard errors. Figures in *italics* are P values, based on the t-distribution

Table 7A.5 Statistical Significance of Additional Explanatory Variables in Form of Intra-Industry Trade Indices

Dummy Variable	Model A to C	Model C to E	Model E to F	Model C to F
None	4.33 ** *0.049*	2.84 *0.107*	5.93 ** *0.024*	4.72 ** *0.021*
Iberian	4.73 ** *0.041*	1.79 *0.196*	9.02 *** *0.007*	5.76 ** *0.011*
NonOECD	2.86 *0.106*	1.12 *0.303*	3.43 * *0.080*	2.34 *0.123*
Both	3.14 * *0.092*	0.12 *0.731*	4.51 ** *0.048*	2.33 *0.126*

The figures in normal font are the values of the F statistic, calculated as $\frac{(ESS_{new} - ESS_{old})/df_1}{RSS_{new}/df_2}$, distributed as $F_{df_2}^{df_1}$, where df_1 is the number of additional variables, and df_2 = (N-k-1) where N is the number of observations, and k is the number of explanatory variables in the new model. Figures in *italics* are the P values based on the null hypothesis that the coefficients of the additional variables are jointly zero. ***,**,* signifies the P value <0.01, 0.05, 0.1 (1 tailed) respectively.

The estimated coefficient of the export weighted Glejser import index is significant, and of the expected sign, for all models where it is included (A, C, E, F), and for all four combinations of the two dummy variables. The estimated coefficient of the import weighted Glejser import index, although of the expected sign, is not significant at the 10% level when used as the only intra-industry trade index, although in the absence of the NonOECD dummy variable, in Tables 7A.1 and 7A.2, the P value is less than 0.12.

When the import weighted Glejser import index is combined with the export weighted Glejser import index, in Model C, the estimated coefficient of the import weighted Glejser import index still has the expected sign. In the absence of the NonOECD variable, in Tables 7A.1 and 7A.2, the estimated coefficient is significant at the 5% level. In the presence of the two dummy variables, in Table 7A.4, it is significant at the 10% level, and is close to being significant at the 10% level in the presence of the NonOECD dummy variable alone, with a P value of 0.106, in Table 7A.3. The statistical significance of the import weighted Glejser import index as an additional explanatory variable, as shown in Table 7A, corresponds to the statistical significance of the estimated coefficient of that variable. In all four cases, the addition of the import weighted Glejser import index to Model A to form Model C increases the adjusted R^2 value. Model C gives values for R^2 ranging from 0.36 to 0.64, depending on the combination of dummy variables being used.

The estimated coefficient of the export weighted Grubel-Lloyd index, when used as the sole intra-industry trade index, in Model D, is not significant. The sign varies according to the dummy variables being used, but the P values are so high that no significance can be attached to this. When the export weighted Grubel-Lloyd index is added to Model C to form Model D, the estimated coefficient is consistently negative, the opposite to that expected. In no case is the estimated coefficient statistically significant, although it is close to being significant at the 10% level in the absence of both dummy variables, in Table 7A.1. Table 7A.5 shows that the addition of this variable does not significantly increase the explanatory power of the model, although it does come close to it at the 10% significance level in the absence of both dummy variables, as shown in Table 7A.5. The addition of the export weighted Grubel-Lloyd index to Model C to form Model E increases the adjusted R^2 in Tables 7A.1, 7A.2 and 7A.3, although only slightly in Table 7A.2 and less again in Table 7A.3. The value of the adjusted R^2 is reduced in Table 7A.4, in the presence of both dummy variables.

The addition of the variable DXMGL (the difference between the export and import weighted Grubel-Lloyd indices) gives estimated coefficients of the expected sign for the export weighted Grubel-Lloyd index, although the sign of the estimated coefficient of the variable DXMGL is the opposite to that expected. There is a high positive correlation between these two variables (r=0.91), inflating the estimated variance of the estimated coefficients by a factor of eight or more. The effect of this can be seen by comparing the standard errors of the estimates of the coefficient of the export weighted Grubel-Lloyd index in Model F with those in Model E, with those of Model F being approximately double those of Model E. This results in a lower significance level for the estimated coefficient of this variable. Nevertheless, the estimated coefficient is statistically significant at the 10% level in the presence of the Iberian dummy, in Tables 7A.2 and 7A.4. In the absence of the NonOECD dummy variable, in Table 7.2B, the estimated coefficient is close to being significant at the 5% level. The NonOECD dummy variable is not significant for Model F in Table 7A.4, in the presence of the Iberian dummy variable. There is no statistically significant correlation between the NonOECD dummy variable and the export weighted Grubel-Lloyd index. Table 7A.5 shows that the addition of the DXMGL variable to Model E to form Model F is statistically significant in all four cases. The addition of both the DXMGL variable and the export weighted Grubel-Lloyd index to Model C to form Model F is statistically significant only in the absence of the NonOECD dummy variable, as in Tables 7A.1 and 7A.2, but the values of the adjusted R^2 are increased in all four cases.

Table 7A.6 Statistical Significance of Addition of Dummy Variables

		Models			
Addition of	To	A	C	E	F
Iberian	-	4.90 ** *0.037*	5.30 ** *0.032*	4.03 * *0.058*	6.97 ** *0.016*
NonOECD	-	5.86 ** *0.024*	4.24 * *0.052*	2.36 *0.140*	0.43 *0.567*
Iberian	NonOECD	9.58 *** 0.006	9.58 *** *0.006*	7.78 ** *0.012*	8.88 *** *0.008*
NonOECD	Iberian	10.6 *** *0.004*	8.34 *** *0.009*	5.92 ** *0.025*	2.02 *0.173*

The figures in normal font are the values of the F statistic, calculated as $\frac{(\mathrm{ESS}_{\mathrm{new}} - \mathrm{ESS}_{\mathrm{old}}) / \mathrm{df}_1}{\mathrm{RSS}_{\mathrm{new}} / \mathrm{df}_2}$, distributed as $F^{df_1}_{df_2}$, where df_1 is the number of additional variables, and df_2 = (N-k-1) where N is the number of observations, and k is the number of explanatory variables in the new model. Figures in *italics* are the P values based on the null hypothesis that the coefficients of the additional variables are jointly zero. ***,**,* signifies the P value <0.01, 0.05, 0.1(1 tailed) respectively.

Table 7A.6 summarizes the statistical significance of the increased explanatory power arising from the addition of the dummy variables to the various models. The addition of either dummy variable significantly increases the explanatory power of both Models A and C. The addition of the NonOECD dummy variable to Model E is significant only in the presence of the Iberian dummy variable, while in Model F the addition of the NonOECD dummy variable is not significant in either the absence or presence of the Iberian dummy variable, although in the presence of the Iberian dummy variable the value of the adjusted R^2 is marginally increased.

The effect of jointly adding the variable DXMGL and the export weighted Grubel-Lloyd index could be seen as making the NonOECD variable redundant. Comparing Model F in Table 7A.1 with Model C in Table 7A.3 it can be seen that replacing the NonOECD variable (7A.3, C) with these two variables (7A.1, F) increases both R^2 (from 0.47 to 0.57) and adjusted R^2 (from 0.39 to 0.48). Similarly, the addition of the NonOECD variable to Model F is not significant in either the presence or absence of the Iberian dummy variable (Table 7A.6), although in the presence of the Iberian dummy variable the adjusted R^2 is increased from 0.60 (7A.2, F) to 0.62 (7A.4, F).

There is no single criterion for determining whether Model C in Table 7A.4 or Model F in Table 7A.4 is preferred. It could be argued that being able to replace a dummy variable, albeit one with a sound basis, with one or more variables more connected to the study being undertaken, is a positive development. The negative aspect of so doing is that the estimated coefficient of the variable DXMGL is the opposite to that which would be expected.

8. Implications

8.1 Introduction

The preceding chapter has shown that, all else being equal, the higher the innovative goods content of a country's exports the higher the export growth rate. A country with a low (high) innovative goods composition of exports relative to that of imports might therefore be expected over time to develop a trade deficit (surplus). The solution for a trade deficit country with a low share of innovative goods output is to increase its output of innovative goods, by increasing its country share. In a free market economy, this will occur only as a result of decisions made by profit maximizing firms. This chapter considers the forces which might bring this about, and some possible obstacles.

Lancaster (1980) considered this question in the context of increased expenditure on differentiated goods arising from two countries opening to trade. It was argued that the only condition giving stable trade balance was one where the two countries had the same resource allocation between differentiated and undifferentiated goods, this equilibrium condition being brought about by currency depreciation in the deficit country, and a consequent reallocation of resources into the differentiated sector.

This provides the starting point for this chapter - to discuss some specific aspects of differentiated goods which might have some bearing on the adjustment of imports and exports of innovative goods following a currency depreciation. Section 8.2 discusses the potential effects of exchange rate fluctuations on imports and exports of innovative goods. The effect on prices of exchange rate fluctuations, under conditions of imperfect competition, is discussed in (8.2.1). The effect of exchange rate fluctuations on the consumption of imported varieties of an innovative product group is considered in (8.2.2); and on the production and export of innovative goods in (8.2.3). The conclusion is that the production and export of innovative goods are potentially more responsive to exchange rate fluctuations than are imports. The next three sections discuss some issues relevant to the expansion of the innovative goods sector.

Section 8.3 briefly discusses the role of factors of production in determining the contribution of the innovative goods sector to a country's exports. Section 8.4

discusses possible barriers to entry into the innovative goods sector, with particular attention to the difficulty of obtaining finance for innovation and marketing. Sections 8.5 and 8.6 discuss the potential of licensing and foreign direct investment as a means of a country increasing its production of innovative goods without the need for product innovation. Section 8.7 discusses some policy implications that arise from the conclusions of Chapter 7 and the points discussed in this chapter.

8.2 Exchange Rate Adjustment

8.2.1 Exchange Rate Pass-through to Prices

There are a number of empirical studies[1] showing that, for manufactured goods, the price elasticity with respect to exchange rate is less than one, the average being in the vicinity of 0.5.

Krugman (1987) proposes several possible explanations for this, one being monopolistic price discrimination. This is commonly referred to in the literature as "pricing to market". Krugman (*op. cit.*) does express some reservations about this explanation, pointing out that decreasing elasticity with decreasing price depends on the shape of the demand curve. However, as pointed out by, amongst others, Knetter (1993), this is not particularly restrictive, requiring only that the demand curve be less convex than the constant elasticity demand curve. Lee (1997) argues that imperfect competition is an important determinant of exchange-rate pass-through elasticity, while Knetter (1993) finds that there is greater variation in pass-through elasticities between industries than between either source or destination countries. Menon (1992) finds significant differences in exchange rate pass-through for Australian exports over a number of industrial categories[2].

If monopolistic price discrimination is the explanation of exchange rate pass through being less than one, then it would be expected that individual varieties of innovative product groups, with downward sloping demand curves, would demonstrate an exchange rate pass through of less than one. Theory predicts this where there is a

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[1] Amongst others, Fukuda and Cong(1994), Knetter(1993), Lee(1997), Marston(1990), Mertens and Ginsburgh(1985), Tongzon and Menon(1994),Yang (1997).

[2] The author does suggest that domination by foreign firms in several categories may influence these results.

downwards sloping demand curve. It is therefore relevant to consider how this affects the adjustment in the consumption and production of innovative goods following an exchange rate depreciation. In the following discussion it will be shown that the potential effects will be greater for production than consumption.

8.2.2 The Effect on Consumption

An exchange rate pass through of less than one for innovative goods means a smaller increase in the price of imported varieties following an exchange rate depreciation than would be expected in the case of complete pass through. The affect of any price increase on the consumption of imported varieties will depend on, *inter alia*, the elasticity of substitution between imported and domestic varieties within the one product group. This is decreasing in the proportion of varieties within a group which is imported, and, in the limiting case where all varieties are imported, equal to zero. Evidence in support of this comes from Yang (1997), who concluded from a study of US imports that elasticity of substitution with respect to exchange rate decreases with increasing import share. Using GDP share as an estimator for innovative product group share, it would be expected that, for all but two of the countries studied here, imports would represent more than 90% of their expenditure on any innovative product group, and for ten countries more than 99%. Consequently, a low elasticity of substitution between imported and domestic varieties can be anticipated.

8.2.3 The Effect on Production and Export

Production decisions are made not on price but on potential profits. Currency depreciation will increase the export price of domestic varieties in domestic currency, but by less than the full extent of the depreciation. This means that the price in foreign currency will decrease and hence the quantity demanded increase. With an increase in quantity demanded, and in the difference between price and marginal cost in domestic currency, the profitability of the innovative goods sector will increase. In the case of an exchange rate appreciation it follows, by similar reasoning, that profits in the production of innovative goods will decrease. One possible response to this is foreign direct investment (FDI), in either the importing or some other country. FDI will be discussed later in this chapter.

It seems, therefore, reasonable to expect that, following exchange rate depreciation, there will be minimal adjustment in the consumption of innovative goods; but that the increased profitability in the innovative goods sector will be an incentive for the expansion of that sector. This is the motivation suggested by Lancaster (1980) for the expansion of the innovative goods sector in the deficit country. The degree to which this expansion does occur will occur will depend on factor mobility, and on the existence of any barriers to entry into the innovative goods sector. These two issues are discussed next.

8.3 Factors of Production

The production factors most commonly considered to be relevant to the production of innovative goods are human capital and labour, with human capital used more intensively in the innovative goods sector. Grossman and Helpman (1991c) have three sectors - innovation, production of innovative goods, and production of undifferentiated goods - in descending sequence of human capital factor intensity.

Given this arrangement of factor intensities, any increase in innovation and/or the production of innovative goods could be expected to increase the cost of human capital. If factor intensities are taken as given, and fixed by country, this will reduce the profitability of the innovative goods sector and impede its expansion. If, however, human capital formation is endogenized, as for example by Grossman and Helpman (1991c, 5.2), this will increase the rate of human capital formation and the country intensity of that factor - assuming factor immobility between countries.

The model of human capital as an endogenous rather than exogenous factor seems better suited to the developed economies, This being the case, the availability of factors of production would not, other than possibly for a short period, present an impediment to the expansion of the innovative goods sector within the developed economies.

8.4 Barriers to Entry

The required investment in both innovation and marketing can present barriers to entry into the innovative goods sector. There is a level of risk attached to the innovation process. If the innovation process is unsuccessful, there will be no return on the investment, and no tangible asset. Even if successful, the return on investment requires a further investment in marketing, without which potential consumers will have no information on the characteristics of the new good and there will be no revenue. The marketing investment is also risky: success is not guaranteed and failure leaves no tangible asset. Because of the risks associated there may be difficulties in obtaining finance for these investments.

Inability to obtain finance for the investment in innovation or marketing would represent a barrier to entry. In the model of Grossman and Helpman (1991c, p48) freedom of entry is achieved by means of two assumptions. It is a perfect foresight model, and consequently investment in innovation is riskless. Households are indifferent between investment in bonds and investment in innovation. Perfect information on the part of consumers is assumed, avoiding the need for marketing. Without either of these assumptions there would not be freedom of entry.

There are three potential sources of finance; internal, debt and equity. Schumpeter (1942, Chapter 8), in a defence of monopolies, points out the attraction of internal financing of risky investments. Arrow (1962, p 612) attributes the predominance of internal financing over external equity financing to uncertainty, while Kamien and Schwartz (1978) claim that it is a "virtual necessity" that industrial research and development be funded internally.

Himmelberg and Petersen (1994) attribute the failure to detect this effect in econometric studies to the range of firm sizes included, arguing that larger firms may not be similarly constrained. The argument is tested by restricting the analysis to small firms[3]. The results support the argument, showing an elasticity of R&D expenditure with respect to cash flow of 0.67. Hao and Jaffe (1993) obtain similar results, and find that liquidity ratio is also a contributor. When the sample is broken down into groups based on firm size only, the smallest third of firms gave significant results, with the elasticity of R&D expenditure to permanent change in liquidity being 0.5.

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[3] The firms are limited to those having a capital replacement in the range $US(1-10)M.

Venture capital[4] is a form of external financing which has developed in response to the need to finance high risk activities such as product innovation. Kortum and Lerner (1998) find a positive correlation between the receipt of venture capital and innovation, as measured by patents. On the basis of their sample of US firms, they conclude that 15% of innovation in the previous decade resulted from venture capital. Their data also suggest that venture capital is more likely to be used by larger than by smaller firms (*op. cit.*, Table A-4). The direction of causality between firm size and venture capital, if it exists, is not clear. If, however, smaller firms find it more difficult to obtain venture capital, then this might explain the greater dependence of small firms on internal financing cited above.

Firm location may be a factor in the availability of venture capital. Lorenz (1989, p52) points out that while risks are independent of market size, potential rewards are not. All else being equal, firms in small countries are more likely to be reliant on export markets, and the asociated costs and uncertainties, to justify venture capital than are firms in larger countries. Mason and Harrison (1991) note that, given the "hands on" approach of venture capitalists, proximity of the venture capitalist and potential recipient is likely to be important.

This discussion suggests that requirement for finance can constitute a barrier to entry into both innovation and the production of innovative goods. Small firms find it more difficult to obtain venture capital and instead are more reliant on internal financing. Entrants are likely to be small firms but a new firm has no revenue from which to internally finance innovation. Location can influence finance availability in several ways. There is evidence that the proximity of the firm and the venture capitalist is significant, and that the size of the country can be relevant. A firm starting up in a large country is less likely to be dependent on the development of export markets to recover the cost of innovation than is a firm in a small country.

One way around these barriers is to use the results of innovation undertaken elsewhere. There are two avenues for doing this; licensing and foreign direct investment (FDI).

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[4] Venture capital has several characteristics. It is equity capital, with the venture capitalist having some involvement in the running of the firm (in distinction to, for example share capital). The investment is considered to be long term, risky, and any reward in the form of capital gain, rather than dividend or interest. It is not a liquid investment. (Lorenz 1989).

8.5 Licensing

Licensing is a mechanism by which a firm can use another firm's innovation for the production of innovative goods. Caves *et al* (1983) discuss a number of difficulties associated with technology licensing, some of which are specific examples of imperfections in the market for information. It is of interest that in one third of the cases studied there were restrictions on the licensee's market, usually to the domestic market. There were also production location restrictions for one third of the cases constituting, the author suggests, a functional substitute for market restrictions.

These findings suggest that many, or possibly most, instances of technology licensing are effectively no more than import substitution, and as such will have no impact on exports. Given that small countries are expected to import over 90% of their expenditure on differentiated goods, only import substitution on a large scale could be expected to materially affect the trade balance. However, Caves *et al* (1983) do find that licensing can be a means of lowering the barrier to entry for a firm into carrying out its own innovation.

8.6 Foreign Direct Investment

Firm ownership of a product variety, and the imperfect market for information, provide both the ownership and internalization components of Dunning's (1979) ownership-locality-internalization based theory of foreign direct investment.

Dunning (*op. cit.*), reviewing the literature, argues that outwards FDI for manufacturing industry is mainly in "technology intensive industries" and those "producing differentiated high income consumer goods". These conclusions are supported by Grubaugh (1987)[5], Martin (1991) and Blonigen and Feenstra (1996). Barry and Bradley (1997) cite a study by O'Malley (1992) showing that 63% of employment in Ireland in foreign owned manufacturing firms was in industrial sectors characterized by increasing returns to scale (consistent with differentiated products) at the firm level, compared to 23% for indigenous manufacturing firms.

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[5] In a logit model estimated with ML, both R&D and advertising expenditures are shown to be statistically significant and positive determinants of foreign direct investment in a cross-industry analysis.

The motivations for FDI appear to be varied. Costs seem to play a part, but do not appear to dominate. Hines (1996) shows that taxation levels in potential host countries are a significant determinant of inwards FDI originating in the US. Dunning (1996) cites[6] an analysis indicating that the costs of both labour and capital are significant, but for the most part only when countries are grouped by geographic location[7], not when they are grouped by income level. In the studies of country specific determinants of host FDI reviewed by Dunning (1998), market size was the most consistent explanatory variable. However, there is evidence which suggests that, while some FDI is for the primary purpose of servicing the market in which it is located, other cases appear to be more for the purpose of export to other countries, in which case the market size of the host country might not be as important.

Several other determinants seem specific to FDI servicing the one market. Blonigen and Feenstra (1996) show that US inward FDI from Japan reduces the probability of protection, and that the probability of protection is a determinant of FDI[8]. In this same study, the depreciation of the $US against the Yen is also a significant and positive factor in explaining FDI from Japan into the US. Hood and Taggart (1997), in a comparison of German FDI into Ireland and the UK, conclude that FDI into the UK is more aimed at the local market[9] than is the case for Ireland. This suggests that the size of the home market[10] influences not only the quantity of inwards FDI but also the purpose. The same study shows that, in the case of FDI into Ireland, only 4% of the sample was by way of acquisition of a domestic firm, compared with 36% for FDI into the UK.

FDI into Ireland is of some interest. Barry and Bradley (1997) show that locally owned Irish firms export 35% of output, 44% of which to the UK, and Irish subsidiaries of UK firms export 39% of output, 60% of which to the UK. In contrast, Irish subsidiaries of firms located in other countries export 86-96% of output, of which only

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[6] The reference given is Srinivasan and Mody (1996) forthcoming in the *Canadian Journal of Economics*, but no such reference could be found.

[7] The three locations are EEC, Latin America, and East Asia. When grouped by income level (low, middle, high) these factors are not significant.

[8] The authors distinguish non-acquisition from acquisition FDI and find the former much more sensitive to the probability of protection.

[9] 80% of Irish subsidiaries have domestic sales accounting for <20% of total, compared to 8% for the UK. 4% of Irish subsidiaries have domestic sales accounting for >80% of total, compared to 53% for the UK.

10-20% is exported to the UK. Subsidiaries of UK firms, which account for only 10% of total output from all foreign subsidiaries, behave, as a group, more like Irish firms than subsidiaries of other countries.

Walsh (1996) shows that the share of "non-traditional, high technology"[11] sectors in Irish exports increased from 18% in 1979 to 49% in 1995. These sectors all fit the concept of innovative goods. This is reflected in the export weighted intra-industry trade indices by country shown in Table 7.6 from Chapter 7, where the innovative goods content of exports places Ireland in the top two or three countries, depending on the measure of intra-industry trade used.

From Walsh (1996), exports increased from 43% of GDP in 1979 to 70% in 1995. As might be expected of export growth driven by FDI, there was a concurrent increase in gross profit remittances, royalty payments and the like, from 2.8% of GDP in 1979 to 14.6% in 1995. Correcting for such payments, the current account balance has shifted from a deficit of 15% of GDP in the early 1980's to a surplus of 3-5% in the early to mid 1990's. Ireland can therefore be seen as an example of high export growth arising from a high export component of innovative goods. It might be argued that this is no more than an increase in output arising from increased levels of investment. Any such argument would need to explain why this investment was concentrated over a narrow range of industrial sectors, and why the dependence on investment was from outside rather than within the country.

A similar issue was raised by Romer (1992) in a discussion of Hong Kong originating FDI in Mauritius in the textile industry. The author points out that a substantial proportion of the physical investment was financed by domestic savings, and that the significance of the FDI was knowledge of textile manufacturing and exporting. Similarly, the significance of the FDI into Ireland is its knowledge content.

8.7 Policy Implications

The above discussion suggests some avenues by which intervention might be expected to have a tendency to increase a country's innovative product share. One is to increase

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[10] On the basis of relative GDPs ($US,1992), the UK domestic market is 20 times that of Ireland.

the rate of innovation, usually implemented by assistance to R&D. This can come in two forms - either through publicly funded R&D, for example the university sector or, in Australia, the CSIRO[12]; or by some form of assistance to R&D carried out by private firms, for example tax concessions. Because private R&D is likely to be directed towards areas for which manufacturing expertise exists, and this is not necessarily the case for public R&D[13], private R&D is more likely to lead to a greater country share in innovative goods than is publicly funded R&D. Policies designed to facilitate the marketing activity are less evident, but the Export Marketing Development Grants scheme is one such example.

Assistance to the provision of venture capital can come from the legislative framework. For example, a change to the US Employee Retirement Income Security Act in 1979, permitting pension funds to invest in venture capital, resulted in a significant increase in investment in the form of venture capital. And, because the return to venture capital is predominantly in the form of capital gains, the attractiveness of such investment is sensitive to the tax treatment given to capital gains. The expressed objective of changes to the Capital Gains Tax in Australia is to increase the availability of venture capital.

Inwards FDI by firms already active in innovation, and with well developed marketing operations, offers an alternative means by which a country's share in the production of innovative products might be increased. While the intrinsic properties of innovative goods provide the ownership and internalization components of FDI, the determinants of location are less clear. Dunning (1998) suggests that, across a number of studies, market size was the most consistent determinant. In such cases, it is likely that the major effect of inwards FDI would be import replacing rather than export increasing, although the two are not mutually exclusive. In any event, expanding the domestic market size is not an available policy instrument, other than in the very long run.

Ireland has pursued a policy of attracting inwards FDI by means such as low corporate tax rates, subsidies and tax concessions (O'Sullivan 1993, Barry and Bradley 1997) - a

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[11] SITC rev 3 categories: 75, Office and ADP machines; 51, Organic chemicals; 77, Electrical machinery; 09, Miscellaneous foods; 54 Medical and pharmaceutical products.

[12] Commonwealth Scientific and Industrial Research Organization.

[13] A point made in the Industry Commission report on Research and Development (1995) vol 2 p 614-5

policy which appears to have met with some success. However, it does not necessarily follow that the same policies would be successful for other countries. Ireland may have some specific attributes, such as being English speaking and a part of the EC, which are not readily replicated for all countries, and the policies adopted by Ireland would not necessarily be as effective in other countries. The end result of a number of countries competing with concessions and subsidies for inwards FDI could be a zero, or even negative, sum game for the countries concerned.

9. Concluding Comments

9.1 Introduction

This chapter provides the concluding remarks for this thesis. Section 9.2 summarizes the overall conclusions which can be drawn. The limitations of the research carried out are discussed in Section 9.3, and Section 9.4 suggests some directions for further research.

9.2 Conclusions

The thesis has set out to examine a particular aspect of the contribution of product innovation to economic growth. Rather than considering the role of product innovation in global economic growth, the aspect considered has been the contribution of the production of innovative goods to the economic growth rate of individual countries. The proposal examined is that, all else being equal, the higher the innovative goods content of a country's exports, the higher that country's export growth rate and, therefore, the higher the GDP growth rate, with balanced trade, which that country can sustain.

There are two threads to this argument. One is that innovative goods conform to the definition of differentiated goods within the theory of trade driven by product differentiation. From this it follows that, within a simplifying set of assumptions, all varieties of innovative goods produced within a country will be exported and all other varieties of innovative goods imported. The other thread is that, with continuing product innovation, the expenditure share on innovative goods will increase and this, combined with the pattern of trade in such goods described above, will lead to an increase in the average import to GDP ratio for such goods, all else remaining constant. Accordingly, the export growth rate will, on average, be higher for innovative than for non-innovative goods. If this is the case, then the higher the innovative goods content of a country's exports, the higher will be the expected export growth rate, and the higher the GDP growth rate which is consistent with balanced trade.

This argument gives rise to four testable hypotheses:
(a) The growth rate in the import to GDP ratio is higher for innovative goods.
(b) On average, export growth rates are higher for innovative goods.
(c) The higher the innovative goods content of a country's exports, the higher the export growth rate.
(d) The higher the innovative goods content of a country's exports, and the lower for imports, the higher the GDP growth rate.

These four propositions have been tested with econometric estimations, using the Grubel-Lloyd and Glejser intra-industry trade indices as proxies for innovative goods. The sample used was selected to prevent, as far as possible, the results being influenced by other factors. To prevent the results being influenced by the division between manufactured and non-manufactured goods, only manufactured goods (SITCs 5-8) have been included. For the analysis by individual country, the effect of the level of economic development has been minimized by using a sample composed of 22 OECD countries, augmented by three high growth East Asian economies.

Using the Grubel-Lloyd and Glejser indices as proxies for innovative goods at the individual SITC sub-group level, the probability of the growth in the import to GDP ratio being positive has been shown to be statistically significantly greater for innovative goods. Similarly, the export growth rate has been shown to be statistically significantly greater for innovative than for non-innovative manufactured goods. Using weighted average export indices as proxies for the innovative goods content of exports, the export growth rate by country has been shown to be increasing in the innovative goods content of exports. Finally, the GDP growth rate by country has been shown to be both increasing in the innovative goods content of exports, and decreasing in the innovative goods content of imports.

This analysis required some method of identifying innovative goods, and the Grubel-Lloyd and Glejser intra-industry trade indices were used for this purpose. A considerable part of this thesis has been devoted to establishing the validity of so doing. The theory of trade driven by product differentiation predicts the existence of intra-industry trade for differentiated goods, and it can be reasoned that innovative goods conform with the definition of differentiated goods within this theory, but the use of the intra-industry trade indices as proxies for innovative goods does not rely on this alone.

Chapter 4 examined the argument that observed intra-industry trade is a random result of an inappropriate aggregation of goods into the one trade category. While some intra-industry trade from such a source cannot be eliminated, the conclusion is that such two-way trade would be random in nature, and therefore unlikely to produce a consistently high level of intra-industry trade across the 22 countries on which the intra-industry trade measure by SITC sub-group is based. This argument is supported by the empirical analysis of Chapter 5, which examines the contribution of the degree of aggregation to intra-industry trade, as measured by the Grubel-Lloyd index. There is a statistically significant positive correlation between the number of sub-categories per trade category and the value of the Grubel-Lloyd index. However, the contribution of this variable to the value of the index is little more than marginal, and there is some doubt as to the direction of causality.

It was suggested, in Chapter 3, that trade driven by product differentiation would exhibit both intra-industry trade, as measured by the Grubel-Lloyd index, and a degree of uniformity in contribution to total imports by country, as measured by the Glejser import index. The finding, that the explanatory power of models employing two or three of these indices in combination was frequently greater than with a single index, supports this approach, and suggests that future empirical work on intra-industry trade might benefit from the use of the two types of index in combination. The empirical analysis in Chapter 6 shows that the intra-industry trade indices have some ability to predict those SITC sub-groups for which the pattern of trade is consistent with the expectations of trade driven by product differentiation.

While it could still be argued that none of this proves conclusively that the intra-industry trade indices are valid proxies for innovative goods, any such argument would need to take into account the observation that, for a number of dependent variables, models using the indices as explanatory variables produce significant estimates, with estimated coefficients mostly significant and with the expected sign. This suggests that the values of these indices are not predominantly the result of random effects and, if the intra-industry trade indices are not indicating innovative products, the question remains as to what they might be measuring that would lead to these results.

If it is accepted that the intra-industry trade indices are valid proxies for differentiated goods, then the interpretation of the results in Chapter 7, concerning the contribution of the production of innovative goods to country specific economic growth, depends on the nexus between differentiated and innovative goods. This was discussed in Section 3.4. It was argued that innovative goods will be differentiated because firms will not invest in product innovation unless they can retain exclusive ownership of the result of the innovation, which is the innovative good. This is a sufficient condition for a good to be a differentiated one. It was also argued that the concept of costless differentiation, while a convenient one for some analytical purposes, is, at best, barely plausible implying, as it does, either perfect information, or some haphazard process involving trying anything as long as it is different, to see if it works.

The concept of innovative goods is not introduced just to add another layer of complexity. The prediction of the overall result reported in Chapter 7 is premised upon the argument that, with continuing product innovation, the share of expenditure on innovative goods will increase. This premise, as argued in Section 3.5.1, relates to the expectation which motivates a profit maximizing firm to incur the cost of product innovation. Product differentiation, on the other hand, is essentially a static concept, and does not provide any basis for this premise. Without this premise, the results reported in Chapter 7 remain as interesting observations, but lacking an explanation. It should be noted that the argument, that expenditure share on innovative goods will increase with product innovation, is not an *ex post* explanation of these results. As discussed in Section 3.7, any explanation based on apparently high income elasticities of demand for differentiated goods, measured longitudinally, is unsatisfactory unless it can be demonstrated, *inter alia*, that the constituent products of differentiated product groups have not changed over time. Nevertheless, the interpretation of these results would be strengthened if the relationship between innovative goods and the intra-industry trade indices could be more strongly established. This is further discussed in Section 9.4.

The policy implications are briefly surveyed in Chapter 8. Having established that the production and consequent export of innovative goods contribute positively towards a country's economic growth, policies designed to increase the production of innovative goods can be regarded as being in the national interests. Such policies can be of two types - encouraging the innovation process itself, or encouraging the production of existing innovative goods. The two are not mutually exclusive - the location of innovation may influence, but not necessarily determine, the country of production. Intervention can be justified by barriers to entry, arising largely from the uncertainty with which any innovation can be expected to be associated. It has not been possible to do full justice to policy aspects within this thesis, but the topic has been included because one of the motivations for this thesis was to establish that policies designed to increase the export of innovative goods can be seen as being in the national interest.

9.3 Limitations of this Research

It has been assumed that all trade in innovative goods is reflected in the value of trade in the actual goods. This is often not the case for industries where replication is easy, and economies of scale in production not significant. This is particularly relevant to industries where copyright law is applicable; such as computer software, recorded music, video tape/cinematographic film and publishing. For these industries, replication frequently occurs within the country of sale rather than the country of origin, either through FDI or licensing. In such cases the value of trade is reflected in the value of royalties paid or repatriated profits. Such transactions are not included in the data set used here and, consequently, this trade has not been included in this analysis. There are data available for repatriated profits and royalties, but not at a level of disaggregation, or frequency, comparable to that for the trade data in physical goods used in this analysis. With trade in information, as opposed to physical goods, widely forecast to increase in the future, the lack of data describing such trade at a level of detail comparable with that for physical goods will take on an increasing significance.

The analysis has, to some extent, been limited by the use of multi-lateral rather than bilateral data. This has been done not to simplify the analysis but to reduce the cost of the data. The use of bilateral data would add an additional dimension to the measurement of intra-industry trade and other measures of product differentiation, and enable a more rigorous assessment of the degree to which trade in any one product group was consistent with the model. The analysis could be improved also with the use of less aggregated data, at the five digit SITC level. Again, the reason this was not done was one of cost.

9.4 Directions for Further Research

The concept of innovative goods used in this thesis has been intentionally broad. The innovation process itself has not been considered, and neither has the means by which the innovating firm retains ownership of the innovated product. Within the set of all innovative goods, two groups of goods - not mutually exclusive - can potentially be identified. These are R&D intensive goods, and those goods for which intellectual property rights are applicable.

Legler (1987), amongst others, has produced a classification, by trade category, of goods considered to have high and medium levels of R&D intensity. Although this identifies only a sub-set of innovative goods, it is a measure of product innovation that is independent of that used in this thesis, and provides an opportunity to evaluate the use of intra-industry trade indices as proxies for innovative goods. An analysis of trade growth and other characteristics would enable a comparison with the broad class of innovative goods, and a better informed evaluation of the potential benefits of policies aimed at increasing levels of R&D.

The group of goods for which intellectual property rights law is applicable is more difficult to identify. Maskus and Penubarti (1995) use a category of "patent intensive" industrial sectors, and Maskus (1990) uses a list of trade categories for which copyright, trade mark or design law would be applicable. A separate analysis of these groups would provide input into any evaluation of the distribution of potential benefits of TRIPs, and again enable a comparison with the broad group of innovative goods. Because both of these groups represent specific types of innovative goods, it is expected that they would demonstrate the same characteristics as the broader class of innovative goods and, in particular, that they would demonstrate higher than average export growth rates.

Because product innovation is not easily measured, the link between the intra-industry trade indices and innovative products, and indeed that between differentiated products and innovative goods, cannot readily be demonstrated. If product innovation were easily measurable, there would be no need of a proxy for innovative goods. However, the two categories of goods discussed above could reasonably be expected to be constituted of innovative goods, and this does offer some opportunity to analyze the relationship between the intra-industry trade indices and innovative goods. The demonstration of the expected relationship between the two, for these two categories, would not be incontrovertible evidence of the theorized relationship encompassing all innovative goods but, nevertheless, would be consistent with the accepted practice of testing a theory by developing a prediction based upon it, and testing the prediction. Incontrovertible evidence would require some independent means of identifying all innovative goods, and, as pointed out above, were this available there would be no need for a proxy to identify innovative goods.

10. References

Abd-el-Rahman K. (1991) "Firms' Competitive and National Comparative Advantages as Joint Determinants of Trade Composition" *Weltwirtschaftliches Archiv* **127** 83-97

Aghion, P. and Howitt, P. (1992) "A Model of Growth Through Creative Destruction" *Econometrica* **60** (2) 323-351

Aquino A. (1978) "Intra-industry Trade and Inter-Industry Specialization as Concurrent Sources of International Trade in Manufactures" *Weltwirtschaftliches Archiv* **114** (2) 275-96

Aquino A. (1981) "The Measurement of Intra-Industry Trade When Overall Trade is Imbalanced" *Weltwirtschaftliches Archiv* **117** (4) 763-6

Arrow K. (1962) "Economic Welfare and the Allocation of Resources for Invention" in R.R.Nelson (ed) *The Rate and Direction of of Inventive Activity: Economic and Social Factors* Princeton University Press Princeton 609-26

Balassa B. (1966) "Tariff Reductions in Manufactures among the Industrial Countries" *American Economic Review* **56** 466-73

Balassa B. (1986a) "Intra-Industry Specialization: A Cross Country Analysis" *European Economic Review* **30** 27-42

Balassa B. (1986b) "The Determinants of Intra-Industry Specialization in United States Trade" *Oxford Economic Papers* **38** 220-33.

Balassa B. and Bauwens L. (1987) "Intra-Industry Specialisation in a Multi-Country and Multi-Industry Framework" *Economic Journal* **97** 923-939

Baldwin R. (1979) "Determinants of Trade and Foreign Investment: Further Evidence" *Review of Economics and Statistics* **61** 40-48

Ballance R., Forstner H. and Sawyer W. (1992) "An Empirical Examination of the Role of Vertical Product Differentiation in North-South Trade" *Weltwirtschaftliches Archiv* **128** (2) 331-338

Barry F. and Bradley J. (1997) "FDI and Trade: The Irish Host-Country Experience" *The Economic Journal* **107** 1798-1811

Beath J. (1990) "Innovation, Intellectual Property Rights and the Uruguay Round" *The World Economy* **13** (4) 411-426

Bergstrand J. (1983) "Measurement and Determinants of Intra-Industry International Trade" in Tharakan P.K.M. (1983)

Bergstrand J. (1990) "The Heckscher-Ohlin-Samuelson Model, The Linder Hypothesis and the Determinants of Bilateral Intra-industry Trade" *Economic Journal* **100** 1216-1229

Bhagwati J. (1972) "The Heckscher-Ohlin Theorem in the Multi-Commodity Case" *Journal of Political Economy* **80** 1052-55

Blonigen B. and Feenstra R. (1996) "Protectionist Threats and Foreign Direct Investment" *NBER Working Paper 5475* National Bureau of Economic Research Cambridge Ma

Brulhart M. (1994) "Marginal Intra-Industry Trade: Measurement and Relevance for the Pattern of Industrial Adjustment" *Weltwirtschaftliches Archiv* **130** (3) 600-613

Caves R. (1981) "Intra-Industry Trade and Market Structure in the Industrial Countries" *Oxford Economic Papers* **33** (2) 203-23

Caves R. and Greene D. (1996) "Brands' Quality Levels, Prices, and Advertising Outlays: Empirical Evidence on Signals and Information Costs" *International Journal of Industrial Organization* **14** (1) 29-52

Caves R., Crookell H. and Killing J. (1983) "The Imperfect Market for Technology Licenses" *Oxford Bulletin of Economics and Statistics* **45** 249-67

Chamberlin E. (1962) *The Theory of Monopolistic Competition* 8th Edition Harvard University Press Cambridge Ma

Clark D.P. (1993) "Recent Evidence on Determinants of Intra-Industry Trade" *Weltwirtschaftliches Archiv* **129** (2) 332-343

Cook R. (1977) "Detection of Influential Observation in Linear Regression" *Technometrics* **19** (1) 15-18

Cook R. (1979) "Influential Observations in Linear Regression" *Journal of the American Statistical Association* **74** (365) 169-74

Cox D.R. and Snell E.J. *The Analysis of Binary Data* Second Edition. Chapman and Hall, London

Culem C. and Lundberg L. (1986) "The Product Pattern of Intra-Industry Trade: Stability among Countries and over Time" *Weltwirtschaftliches Archiv* **122** (1) 113-129

Deardorff A. (1982) "The General Validity of the Heckscher-Ohlin Theorem" *The American Economic Review* **72** (4) 683-94

Dixit A. and Stiglitz J. (1977) "Monopolistic Competition and Optimum Product Diversity" *American Economic Review* **67** 297-308

Dunning J. (1979) "Explaining Changing Patterns of International Production: in Defence of the Eclectic Theory *Oxford Bulletin of Economics and Statistics* **41** (4) 269-295

________ (1998) "The European Internal Market Program" in Dunning J. (ed) *Globalization, Trade and Foreign Direct Investment* Elsevier Amsterdam

Ethier W. (1982) "National and International Returns to Scale in the Modern Theory of International Trade" *The American Economic Review* **72** 389-405

_______ (1979) "Internationally Decreasing Costs and World Trade" *Journal of International Economics* **9** 1-24

Falvey R. (1981) "Commercial Policy and International Trade" *Journal of International Economics* **11** 495-511

Falvey R. and Kierzkowski H. (1987) "Product Quality, Intra-Industry Trade and (Im)perfect Competition" in *Protection and Competitionin International Trade: Essays in Honour of W.M. Corden* Blackwell Oxford

Finger J. (1975) "Trade Overlap and Intra-Industry Trade" *Economic Inquiry* **13** (4) 581-589

Fukuda S. and Cong J. (1994) "On the Choice of Invoice Currency by Japanese Exporters: The PTM Approach" *Journal of the Japanese and International Economies* **8** 511-29

Gavelin L. and Lundberg L. (1983) "Determinants of Intra-Industry Trade: Testing Some Hypotheses on Swedish Trade Data" in Tharakan P.K.M. (1983)

Glejser H. (1983) "Intra-Industry and Inter-Industry Trade Specialization: Trend and Cycle in the EEC (1973-1979)" in Tharakan P.K.M. (1983)

Glejser H., Goosens K. and Vanden Eede M. (1979) "Interindustry and Intra-Industry Specialization Do Occur in World Trade" *Economics Letters* **3** (3) 261-5

Glejser H., Goosens K. and Vanden Eede M. (1982) "Inter-Industry versus Intra-Industry Specialization in Exports and Imports (1959-1970-1973)" *Journal of International Economics* **12** 363-9

Globerman S. (1992) "North American Trade Liberalization and Intra-Industry Trade" *Weltwirtschaftliches Archiv* **128** (3) 487-97

Gray H. and Martin J. (1980) "The Meaning and Measurement of Product Differentiation in International Trade" *Weltwirtschaftliches Archiv* **116** (2) 322-9

Greenaway D. (1983) "Patterns of Intra-Industry Trade in the United Kingdom" in Tharakan P.K.M. (1983)

Greenaway D. (1984) "The Measurement of Product Differentiation in Empirical Studies of Trade Flows" in Kierskowski H. (1984)

Greenaway D., Hine R. and Milner C. (1995) "Vertical and Horizontal Intra-Industry Trade" *Economic Journal* **105** 1505-18

____________ (1994a) "Country Specific Factors and the Pattern of Horizontal and Vertical Intra-Industry Trade in the UK" *Weltwirtschaftliches Archiv* **130** 77-100

____________ and Elliott R. (1994b) "Adjustment and the Measurement of Marginal Intra-Industry Trade" *Weltwirtschaftliches Archiv* **130** (2) 418-27

Greenaway and Milner (1981) "Trade Imbalance Effects in the Measurement of Intra-Industry Trade" *Weltwirtschaftliches Archiv* **117** (4) 756-62

Greenaway and Milner (1983) "On the Measurement of Intra-Industry Trade" *Economic Journal* **93** 900-908

Greenaway and Milner (1986) *The Economics of Intra-Industry Trade* Blackwell Oxford UK

Greenwald, D. (1983) *The McGraw-Hill Dictionary of Modern Economics* McGraw-Hill Book Co. Sydney

Greenwood, D. (1995) *Antimicrobial Chemotherapy* Oxford University Press

Grossman G. and Helpman E. (1989) "Product Development and International Trade" *Journal of Political Economy* **97** (6) 1261-1283

____________ (1991a) "Quality Ladders in the Theory of Growth" *Review of Economic Studies* **58** 43-61

____________ (1991b) "Endogenous Product Cycles" *Economic Journal* **101** 1214-1229

____________ (1991c) *Innovation and Growth in the Global Economy* MIT

____________ (1991d) "Quality Ladders and Product Cycles" *Review of Economic Studies* **58** 43-61

____________ (1993) "Innovation, Imitation, and Intellectual Property Rights" *Econometrica* **61** (6) 1247-80

Grubaugh S. (1987) "Determinants of Direct Foreign Investment" *Review of Economics and Statistics* **69** (1) 149-52

Grubel H. (1967) "Intra-Industry Specialization and the Pattern of Trade" *Canadian Journal of Economics and Political Science* **33** 374-88

Grubel and Lloyd (1971) "The Empirical Measurement of Intra-Industry Trade" *Economic Record* **47** (120) 494-517

Grubel and Lloyd (1975) *Intra-Industry Trade: The Theory and Measurement of International Trade in Differentiated Products* MacMillan London

Grupp H. (1991) "Innovation Dynamics in OECD Countries: Towards a correlated Network of R&D Intensity, Trade, Patent and Technometric Indicators" in *The Technology Economy Programme* (1991) OECD Paris

Hamilton C. and Kniest P.(1991) "Trade Liberalisation, Structural Adjustment and Intra-Industry Trade: A Note" *Weltwirtschaftliches Archiv* **127** (2) 356-367

Hao K. and Jaffe A. (1993) "Effect of Liquidity on Firms' R&D Spending" *Economics of Innovation and New Technology* **2** (4) 275-82

Harrigan J. (1995) "The Volume of Trade in Differentiated Intermediate Goods: Theory and Evidence" *Review of Economics and Statistics* **77** (2) 283-93

Havrylyshyn O. and Civan E. (1983) "Intra-Industry Trade and Stage of Development" in *Intra-Industry Trade* ed P. Tharakan North Holland

Helpman E. (1981) "International Trade in the Presence of Product Differentiation, Economies of Scale and Monopolistic Competition" *Journal of International Economics* **11** 305-40

__________ (1984) "A Simple theory of International Trade with Multinational Corporations" *Journal of Political Economy* **92** (31) 451-471

__________ (1987) "Imperfect Competition and International Trade: Evidence from Fourteen Industrial Countries" *Journal of the Japanese and International Economies* **1** 62-81

Helpman E. and Krugman P. (1985) *Market Structure and Foreign Trade* MIT Press Cambridge Ma

Himmelberg C. and Petersen B. (1994) "R&D and Internal Finance: A Panel Study of Small Firms in High Tech Industries" *Review of Economics and Statistics* **76** (1) 38-51

Hines (1996) "Tax Policy and the Activities of Multinational Corporations" *NBER Working Paper 5589* National Bureau of Economic Research Cambridge Ma

Hobby, G.L. (1985) *Penicillin: Meeting the Challenge* Yale University Press, New Haven

Hood N. And Taggart J. (1997) "German Foreign Direct Investment in the UK and Ireland: Survey Evidence" *Regional Studies* **31** 139-150

Horiba V. (1974) "A Note on the Factor Proportions Theory in the N-Factor Case" *Kyklos* **24** 339-343

Hosmer D.W. and Lemeshow S. (1989) *Applied Logistic Regression* John Wiley and Sons Inc., New York.

Hufbaeur G. (1970) "The Impact of National Characteristics and Technology on the Commodity Composition of Trade in Manufactured Goods" in *The Technology Factor in International Trade* ed Vernon R. National Bureau of Economic Research New York 145-231

Hufbaeur G. and Chilas J. (1974) "Specialization by Industrial countries: Extent and Consequences" in *The International Division of Labour Problems and Perspectives* Edited by H.Giersch JCB Mohr Tubingen

Hufbaeur G. and O'Neill J. (1972) "Unit Values of U.S. Machinery Exports" *Journal of International Economics* **2** (3) 265-75

Hughes K.S. (1993) "Intra-Industry Trade in the 1980's: A Panel Study" *Weltwirtschaftliches Archiv* **129** (3) 561-572

Hummels D. and Levinsohn J. (1995) "Monopolistic Competition and International Trade: Reconsidering the Evidence" *Quarterly Journal of Economics* **110** (3) 799-836

Industry Commission (1995) *Research and Development* AGPS Canberra

Jones R.W. (1956) "Factor Proportions and the Heckscher-Ohlin Theorem" *Review of Economic Studies* **24** 1-10

Kamien M. and Schwarz N. (1978) "Self-Financing of an R&D Project" *American Economic Review* **68** (3) 252-61

Kennedy C. and Thirlwall A. (1979) "Import Penetration, Export Performance and Harrod's Trade Multiplier" *Oxford Economic Papers* **31** 303-323

Kingston, W. (2000) "Antibiotics, Invention and Innovation" *Research Policy* **29** (6) 679-710

Kojima K. (1964) "The Pattern of International Trade Among Advanced Countries" *Hitotsubashi Journal of Economics* **5** 16-36

Knetter M. (1993) "International Comparisons of Pricing-to-Market Behaviour" *American Economic Review* **83** (3) 473-86

Kortum S. and Lerner J. (1998) "Does Venture Capital Spur Innovation" NBER Working Paper 6846, National Bureau of Economic Research Cambridge Ma

Kravis I. and Lipsey R. (1971) *Price Competitiveness in World Trade* National Bureau of Economic Research, Columbia University Press, New York

Kravis I. and Lipsey R. (1978) "Price Behaviour in the Light of Balance of Payment Theories" *Journal of International Economics* **8** (2) 193-246

Krugman P. (1979a) "Increasing Returns, Monopolistic Competition, and International Trade" *Journal of International Economics* **9** 469-479

________ (1979b) "A Model of Innovation, Technology Transfer, and the World Distribution of Income" *Journal of Political Economy* **87** 253-266

________ (1980) "Scale Economies, Product Differentiation, Pattern of Trade" *American Economic Review* **70** 950-959

________ (1987) "Pricing to Market When the Exchange Rate Changes" in Arndt S. and Richardson J (eds) *Real Financial Linkages among Open Economies* Cambridge MA MIT Press

________ (1989) "Differences in Income Elasticities and Trends in Real Exchange Rates" *European Economic Review* **33** 1031-54

Lancaster K. (1980) "Intra-Industry Trade Under Perfect Monopolistic Competition" *Journal of International Economics* **10** 151-175

________ (1966a) "A New Approach to Consumer Theory" *Journal of Political Economy* **74** 132-57

________ (1966b) "Allocation and Distribution Theory: Technological Innovation and Progress" *The American Economic Review* Papers and Proceedings **???** 14-23

Leamer E. (1993) "Factor Supply Differences as a Source of Comparative Advantage" *American Economic Review* **83** (2) 436-39

_______ (1980) "The Leontief Paradox, Reconsidered" *Journal of Political Economy* **88** (31) 495-503

Lee H. And Lee Y. (1993) "Intra-Industry Trade in Manufactures: The Case of Korea" *Weltwirtschaftliches Archiv* **129** (1) 159-171

Lee J. (1997) "The Response to Exchange Rate Pass-Through to Market Concentration in a Small Economy: The Evidence From Korea" Review *of Economics and Statistics* **79** (1) 142-5

Legler H. (1987) "German Competitiveness of Technology-Intensive Products" in Grupp H. (ed) *Problems of Measuring Technological Change* TUEV Rheinland Cologne, cited by Grupp H.

Lipsey R. (1976) A Review of Grubel and Lloyd (1975) *Journal of International Economics* **6** 312-4

Loertscher R. and Wolter F. (1980) "Determinants of Intra-Industry Trade: Among Countries and Across Industries" *Weltwirtschaftliches Archiv* **116** (2) 280-93

Long, P.H. and Bliss, E.A. (1939) *The Clinical and Experimental Use of Sulfanilamide, Sulfapyridine and Allied Compounds* The MacMillan Company, New York

Lorenz T.(1989) *Venture Capital Today* Woodhead-Faulkner New York

Lundberg L. (1982) "Intra-Industry Trade: The Case of Sweden" *Weltwirtschaftliches Archiv* **118** (2) 302-16

Mansfield, M., Schwartz, M. and Wagner S. (1981) "Imitation Costs and Patents: An Empirical Study" *The Economic Journal* **91** (December) 907-918

Marston R. (1990) "Pricing to Market in Japanese Manufacturing" *Journal of International Economics* **29** 217-36

May and Baker (1955) *Sulphonamide Therapy* (5th edition) May and Baker Ltd, Dagenham England

Martin S. (1991) "Direct Foreign Investment in the United States" *Journal of Economic Behaviour and Organization* **16** 283-293

Marvel H. and Ray E. (1987) "Intraindustry Trade: Sources and Effects on Protection" *Journal of Political Economy* **95** (6) 1278-91

Maskus K. (1990) "Normative Concerns in the International Protection of Intellectual Property Rights" *The World Economy* **13** (4) 509-521

Maskus K. and Penubarti M. (1995) "How Trade Related are Intellectual Property Rights" *Journal of International Economics* **39** 227-48

Mason C. and Harrison R. (1991) "Venture Capital, the equity gap and the 'north-south divide' in the United Kingdom" in *Venture Capital* ed M.B.Green Routledge London

Melvin J.(1968) "Production and Trade With Two Factors and Three Goods" *American Economic Review* **58** 1249-68

_______ (1971) "Production Indeterminacy with Three Goods and Two Factors: Reply" *American Economic Review* **61** (1) 245-46

Menon J. (1992) "Exchange Rates and Prices of Australian Manufactured Exports" *Weltwirtschaftliches Archiv* **128** (4) 695-709

Mertens Y. and Ginsburgh V. (1985) "Product Differentiation and Price Discrimination in the European Community: The Case of Automobiles" *The Journal of Industrial Economics* **34** 151-166

Michaely M. (1962) *Concentration in International Trade* Contributions to Economic Analysis **28** North-Holland Amsterdam

Nagalkerke N.J.D. (1991) "A Note on a General Definition of the Coefficient of Determination" *Biometrika* **78** 691-2

O'Malley E. (1992) "Industrial structure and economics of scale in the context of 1992" in *The role of the Structural Funds: Analysis of Consequences for Ireland in the Context of 1992, 203-49*. Policy Research Series Paper no 13. Dublin: The Economic and Social Research Institute

Pagoulatos E. And Sorensen R. (1975) "Two-Way International Trade: An Econometric Analysis" *Weltwirtschaftliches Archiv* **111** (3) 454-65

Pearce, D. (ed) (1992) *The MIT Dictionary of Modern Economics* The MIT Press Cambridge Ma

Pomfret R. (1979) "Intra-Industry Trade in Intraregional and International Trade" in *On the Economics of Intra-Industry Trade* (ed. H. Giersch). Tubingen: J.C.B.Mohr.

_________ (1985) "Categorical Aggregation and International Trade" *Economic Journal* **95** 483-85

_________ (1986) "On the Division of Labour and International Trade: or, Adam Smith's Explanation of International Trade" *Journal of Economic Studies* **13** (4) 56-63

_________ (2001) Private Communication, March 2001

Posner M. (1961) "International Trade and Technical Change" *Oxford Economic Papers* **13** 323-341

Rajan R. (1996) "Measures of Intra-industry Trade Reconsidered with Reference to Singapore's Bilateral Trade with Japan and the United States" *Weltwirtschaftliches Archiv* **132** (2) 378-89

Rivera-Batiz and Romer (1991a) "Economic Integration and Endogenous Growth" *Quarterly Journal of Economics* **106** (2) 530-555

____________ (1991b) "International Trade with Endogenous Technological Change" *European Economic Review* **35** 971-1004

Rodgers J. (1988) "Intra-industry Trade: Aggregation and the HOS Model" *Journal of Economic Studies* **15** (5) 5-23

Romer, Paul M. (1986) "Increasing Returns and Long-Run Growth" *Journal of Political Economy* **94** (5) 1002-1037

______(1987) "Growth Based on Increasing Returns Due to Specialization" *American Economic Review P&P* **77** (2) 56-62

_____ (1990a) "Endogenous Technological Change". *Journal of Political Economy* **98** (5) S71-s102

______ (1990b) "Are Convexities Important for Understanding Growth" *The American Economic Review, Papers and Proceedings* **80** (2) 97-103

______ (1992) "Two Strategies for Economic Development: Using Ideas and Producing Ideas" *Proceedings of the World Bank Annual Conference on Development Economics* 1992 63-91 World Bank

Rutherford, D. (1992) *Dictionary of Economics* Routledge London

Salop, Steven C. (1979) "Monopolistic Competition with Outside Goods" *Bell Journal of Economics* **10** (1) 141-56

Schmookler, J. (1966) *Invention and Economic Growth.* Harvard University Press Cambridge

Schumpeter, J. (1942) *Capitalism, Socialism and Democracy* Allen and Unwin London

Schwartzman, D. (1976) *Innovation in the Pharmaceutical Industry* The Johns Hopkins University Press Baltimore

Segerstrom, Anant and Dinopolous (1990) "A Schumpertarian Model of the Product Life Cycle" *The American Economic Review* **80** (5) 1077-1091

Segerstrom, Paul S. "Innovation, Imitation and Economic Growth" *Journal of Political Economy* **99** (4) (1991) 807-27

Sheehan, J. (1982) T*he Enchanted Ring* The MIT Press Cambridge Ma

Shelburne, R.C. (1993) "Changing Trade Patterns and the Intra-Industry Trade Index: A Note" *Weltwirtschaftliches Archiv* **129** (4) 829-36

Smulders and van der Klundert (1995) "Imperfect Competition, Concentration and Growth with Firm Specific R&D" *European Economic Review* **39** 139-160

Somma E. (1994) "Intra-Industry Trade in the European Computers Industry" *Weltwirtschaftliches Archiv* **130** (4) 784-789

Spink, W.W. (1942) *Sulfonamide Therapy* The Year Book Publishers Inc. Chicago, Illinois

Stanton, R. and Launder, B. (1998) *The Essential Dictionary of Economics* McGraw-Hill Australia

Stewart D.D. (1971) "Production Indeterminacy with Three Goods and Two Factors: A Comment on the Pattern of Trade" *American Economic Review* **61** (21) 241-44

Stewart, G.T. (1965) *The Penicillin Group of Drugs* Elsevier Publishing Co., Amsterdam

Stokey, Nancy (1988) "Learning by Doing and the Introduction of New Goods" *Journal of Political Economy* **96** (4) 701-717

___________ (1995) "R&D and Economic Growth" *Review of Economic Studies* **62** 469-489

Stone J.A. and Lee H. (1995) "Determinants of Intra-Industry Trade" *Weltwirtschaftliches Archiv* **131** (1) 67-85

Subramanian A. (1990) "TRIPs and he Paradigm of GATT: a Tropical, Temperate View" *The World Economy* **13** (4) 509-521

Summers and Heston (1991) "The Penn World Table (Mark 5): An Expanded Set of International Comparisons, 195-1988" *Quarterly Journal of Economics* **106** (2) 327-368

Taylor, C. and Silbertson, Z. (1973) *The Economic Impact of the Patent System* Cambridge University Press

Tharakan P.K.M. (1984) "Intra-Industry Trade Between the Industrial Countries and the Developing World" *European Economic Review* **26** 213-27

Tharakan P. And Kerstens B. (1995) "Does North-South Horizontal Intra-Industry Trade Really Exist? An Analysis of the Toy Industry" *Weltwirtschaftliches Archiv* **131** (1) 86-105

Toh K. (1982) "Intra-Industry Trade in US Manufacturing Industries" *Weltwirtschaftliches Archiv* **118** (2) 281-301

Tongzon J. and Menon J. (1994) Exchange Rates and Export Pricing in a Small Open NIC: the Singaporean Experience" *Singapore Economic Review* **39** (2) 201-11

Torstensson J. (1996) "Can Factor Proportions Explain Vertical Intra-Industry Trade" *Applied Economics Letters* **3** 307-9

___________ (1991) "Quality Differentiation and Factor Proportions in International Trade: An Empirical Test of the Swedish Case" *Weltwirtschaftliches Archiv* **127** (1) 183-94

Vanek J. (1968) "The Factor Proportions Theory: The N-Factor Case" *Kyklos* **21** (4) 749-56

Verdoorn P.J. (1960) "The Intra-Bloc Trade of Benelux" in *Economic Consequences of the Size of Nations* ed E.A.G. Robinson Macmillan London

Vernon R. (1966) "International Investment and International Trade in the Product Cycle" *Quarterly Journal of Economics* **80** 190-207

Waksman, S.A. (1949) (ed) *Streptomycin* The Williams and Wilkins Co. Baltimore

Walsh B. (1996) "Stabilization and Adjustment in a Small Open Economy" *Oxford Review of Economic Policy* **12** (3) 74-86

Weder R. (1995) "Linking Absolute and Comparative Advantage to Intra-Industry Trade Theory" *Review of International Economics* **3**(3) 342-54

Weiss (1972) "The Geographic Size of Markets in Manufacturing" *The Review of Economics and Statistics* **54** 245-57

Wills R. and Mueller W. (1989) "Brand Pricing and Advertising" *Southern Economic Journal* **56** (2) 383-95

Vona S. (1991) "On the Measurement of Intra-Industry Trade: Some Further Thoughts" *Weltwirtschaftliches Archiv* **127** (4) 678-700

Wolter F. (1979)(Comment on Pomfret 1979) in *On the Economics of Intra-Industry Trade* (ed. H. Giersch). Tubingen: J.C.B.Mohr.

Yang J. (1997) "Exchange Rate Pass-Through in US Manufacturing Industries" *Review of Economics and Statistics* **79** (1) 95-104

You J. (1979) Appendix to R.E. Baldwin (1979).