GROWTH, ALLOCATION AND TRADE IN SWEDEN

An empirical application of the Heckscher–Ohlin theory

Harry Flam

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PREFACE

The seed that eventually grew into this dissertation was probably planted by my former teacher in trade theory at Berkeley, Ernest Nadel, when he asked on an examination why small countries have larger trade shares than big countries. One or two years later, when playing with a two-factor, three-good trade model, I found the somewhat unexpected answer that a growing country which devotes a larger share of its resources to its non-traded sector may find its trade share to be increasing. This result provided the actual starting point - and is now a mere footnote on page 134. Another more general factor that initiated the work on this dissertation is my interest in problems of growth, allocation and trade, which was stimulated by my teachers and thesis advisers, Karl G. Jungenfelt and Karl-Göran Mäler.

Students of international trade theory will recognize that models used in chapters 1, 6, 7 and 8 draw on work by Ronald W. Jones, particularly his 1965 article "The Structure of Simple General Equilibrium Models" in *Journal of Political Economy* and his 1974 article "The Small Country in a Many-Commodity World" in *Australian Economic Papers*.

The first two thirds of my work was carried out at the Stockholm School of Economics, the last third at the Institute for International Economic Studies. I regard it as a privilege to have worked at both institutions. Many colleagues have contributed generously in various ways. Lennart Ohlsson gave

constructive comments on an early version of chapters 2-5. Others whose help is easy to pinpoint are mentioned at the beginning of the chapter to which they contributed. However, the most important contributors are only mentioned in this preface, although they improved on all chapters. I am very grateful to Karl G. Jungenfelt, Karl-Göran Mäler and Lars E.O. Svensson for long discussions and many corrections and useful suggestions.

Less specific but important moral and intellectual encouragement was given by Lars Bergman, Ronald Findlay, Assar Lindbeck and Staffan Viotti.

My manuscripts were typewritten by Margareta Blomberg, Edda Liljenroth, Kerstin Niklasson, Monica Peijne and Ann-Marie Soler with care, patience and much-needed speed. The main burden fell on Kerstin Niklasson and Monica Peijne, who shouldered it with characteristic graciousness. Birgitta Eliason took care of the printing arrangements very efficiently. All the figures (except figure 5.1 and 7.1) have been expertly drawn by my mother, Frymeta Flam.

Financial support from Jacob Wallenbergs Fond and from Bertil Ohlins Fond is gratefully acknowledged.

To Eva, my wife, I want to express my gratitude for understanding and enduring.

Stockholm in May, 1981

Harry Flam

CONTENTS

CHAPTER 1 INTRODUCTION AND SUMMARY

1.1 THE QUESTIONS

- Are the standard Heckcher-Ohlin model and its accompanying theorems useful tools for empirical studies?
- What hypotheses about Swedish post-war growth, allocation and trade are generated by a standard Heckscher-Ohlin model with two factors and three goods, one of which is non-traded?
- Are the model's predictions borne out by simulations with a particular and widely used many-sector, quantitative, general equilibrium model of the Swedish economy?

These are the main questions asked in the study. They will be specified and explained further in section 1.3, which is an outline of the study and where the main results are reported. The relation of the study to the literature is briefly discussed in section 1.4. But first, in section 1.2, it is necessary to outline the theoretical framework.

1.2 THE HECKSCHER-OHLIN MODEL

The standard Heckscher-Ohlin model with two countries, two goods and two factors is a particular kind of general equilibrium model. One feature which sets it apart from more general models is the assumption that each country faces given prices on the world market. World market prices are determined by equating supply and demand of the two countries. Another particular feature is the focus on factor endowments and factor proportions. The assumption of given prices makes production independent of domestic demand, while trade depends on home demand also. Hence, the Heckscher-Ohlin model is sometimes labelled "production model". It is differences in factor endowments between countries and differences in factor proportions between goods which is the basis for three of the four basic theorems of the Heckscher-Ohlin theory, and which has earned it the alternative name "factor proportions theory". The three theorems are the *Heckscher-Ohlin* [1919][1933] *theorem*, the *Rybczynski* [1955] *theorem* and the *Stolper-Samuelson* [1941] *theorem*. The fourth basic theorem is the *factor-price equalization theorem* (Samuelson [1949]).

1.2.1 *The basic model*

The Heckscher-Ohlin model which we will outline here differs from the standard two-factor, two-good, two-country model in that the number of produced and tradable goods is not restricted to two. Another difference is that we introduce a non-traded good, i.e. a good which is produced and consumed domestically in the same quantity.[1] [2]

Assume that capital, K, and labor, L, are the two factors of production, that they are perfectly mobile between sectors but cannot move across the border, and that there are constant returns to scale in production and no joint production. Goods can be ranked by capital intensities in the way shown in

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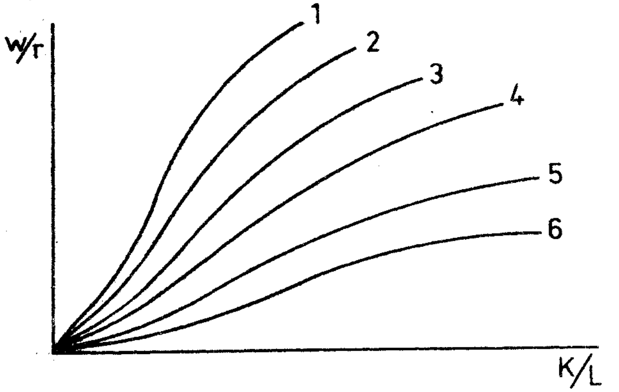
[1] The terms "tradable" and "non-traded" will be used throughout the study. In the theoretical models of this chapter and chapter 6 and 8 they imply some inherent difference between goods in the degree to which they can be traded internationally and which we do not specify. In the empirical context of chapters 3-5 "tradable" simply means that the good is being exported and/or imported and "non-traded" that it is not.

[2] The presentation draws much on Jones [1974]. A difference is that we assume the same technology in the small country and the rest of the world as the rule. Also, Jones does not consider the case of more tradable goods than factors being produced at any one time.

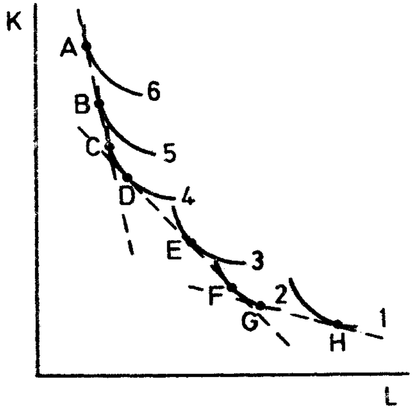
figure 1.1. Note that we assume that the ranking is independent of the wage-rental rate w/r, i.e. there are no factor intensity reversals.

Figure 1.1



Which goods a country will produce depends on the set of technologies, world market prices, and the country's factor endowments. (It will also depend on the extent of demand for and production of non-traded goods, but for the moment we abstract from the existence of non-traded goods.) To see this, consider *figure 1.2*, which shows the position of the unit-*value* isoquants in the K-L space.

Figure 1.2



As we have drawn the unit-value isoquants, there are combinations of prices and technologies such that three goods can be produced at the same time: goods 2, 3 and 4, or goods 4, 5 and 6. It is common to argue that with given prices and technology there will be a tendency to produce as many goods as there are factors, i.e. two in this case. It would be accidental to have the wage-rental ratio in *figure 1.2* tangent to more than two unit-value isoquants.

This argument is based on the observation that the system of cost functions will be over-determined, and fails to consider that the given prices are *equilibrium* prices for trading countries. Assume for a moment that the world economy is integrated, with goods and factors perfectly mobile. The number of goods produced in such an integrated economy will be determined by demand, and may well exceed the number of factors. The difference between a world economy and a small country is that prices adjust in the former, so that costs may equal prices for a larger number of goods than factors. Now, drop the assumption of complete integration and let the world be divided into regions, with factors of production immobile across regional boundaries. It is fully possible that many regions will produce more goods than factors, if technology is the same. This possibility is greater the more equal are the factor endowments between regions. The argument that in a trading world the given prices are equilibrium prices, and that therefore the situation of having more goods produced than the number of factors is not merely accidental, is made by Dixit and Norman [1980]. In what follows we will assume that there is a certain degree of specialization among regions or countries. In terms of *figure 1.2* some countries will only produce good 1 and 2, some only good 2, 3 and 4, and some only good 4, 5 and 6. Consequently, factor prices are not equalized between all countries, but only between those which produce the same goods.

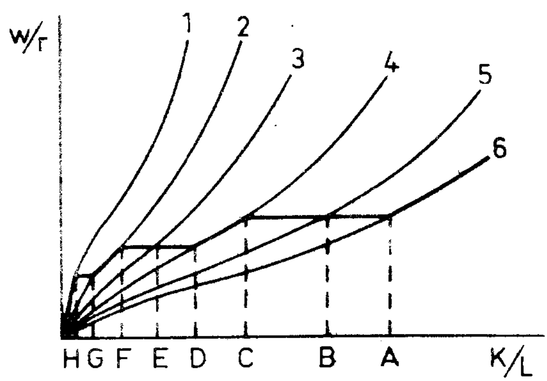
Given a situation as pictured by *figure 1.2*, it is the small country's factor endowments which determine which goods may be produced. If the endowment capital-labor ratio lies between D and F, goods 2, 3 and 4 may be produced. When the number of goods is greater than two the allocation between the goods is *indeterminate*; there exists a great number of allocations which keep the factors fully employed. But if only two goods are produced, say 2 and 3, then the allocation is determinate. In this case it is still necessary that the endowment capital-labor ratio lies between the goods capital-labor ratios, i.e. between E and F.

We note that domestic demand is without influence on the allocation. The range of possible outputs is determined by given output prices, technologies and factor endowments. In the case where more goods are produced than the number of factors the allocation is indeterminate. It is determinate when only one or two goods are produced. The possibility and necessity of complete specialization arises when the factor endowment capital-labor ratio is northwest of A, between C and D, between F and G and southeast of H in *figure 1.2*.

World prices of tradable goods, technology and factor endowments also determine factor prices. It is clear from *figure 1.2* that, at given goods prices and technology, there exists a monotonic relation between the factor endowment capital-labor ratio and the wage-rental ratio. As the endowment ratio moves from a low value at H to a high value at A the wage-rental ratio rises. In the intervals GH, DF and AC the relation is not strictly monotonic. It is only when there is complete specialization in production, in the intervals FG and CD, that the wage-rental ratio rises continuously as the endowment capital-labor ratio increases.

An alternative way of depicting the relationship between the endowment capital-labor ratio and the wage-rental ratio, when goods prices and technology are given, is shown in *figure 1.3*. Numbers and letters correspond to those in *figure 1.2*.

Figure 1.3



As we move from left to right along the K/L axis we see that the wage-rental ratio w/r increases in steps, as depicted by the heavy line. When there is incomplete specialization, as between H and G, F and D, and C and A, the factor prices are tied to the world market prices for goods. Otherwise the wage-rental ratio rises continuously when the capital-labor ratio is increased.

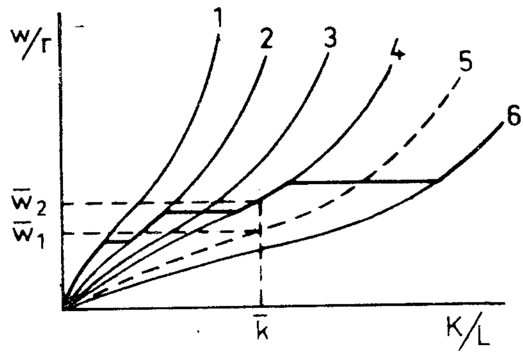
Note the implications for resource allocation as the endowment capital-labor ratio is increased. Between the origin and H there is complete specialization in the least capital intensive good 1. The increased capital abundance is absorbed by substitution of capital for labor in production. But as soon as point H is passed and some of good 2 is produced as well, the wage-rental ratio is constant and there is no substitution of capital for labor in production of any *single* good. Increases in the endowment capital-labor ratio are absorbed by increased production of the relatively capital intensive good 1. This is known as the Rybczynski [1955] effect. Eventually production of good 1 ceases altogether, at point G, and there is complete specialization in good 2. The wage-rental ratio rises until it permits production of good 3 and 4, in addition to good 2. As we move from point F to point D along the K/L-axis it is no longer possible to say precisely how the outputs of 2, 3 and 4 will be affected. However, to the right of E output of good 4 must be increased to absorb increases in the endowment capital-labor ratio. In an average and tautological sense it is of course true that the combination of outputs must become more capital intensive as we move from F to D.

1.2.2 *Introduction of a non-traded good*

Next, we modify the model to include a commodity which is not exported or imported. We let good 5 in the previous figures become a non-traded good. The modification has two important effects. One effect is on the factor prices. Now these are also determined by the demand for the non-traded good, in addition to the endowment, technology and world market prices on tradable goods. The other effect is on the extent of tradable goods production and on the allocation within the sector producing tradables. In particular, the capital intensity of the non-traded good becomes important. (However, we could have chosen any good as being non-traded; the argument would not change in principle.)

Figure 1.4 helps to illustrate the effects on factor prices and allocation of letting good 5 be non-traded.

Figure 1.4

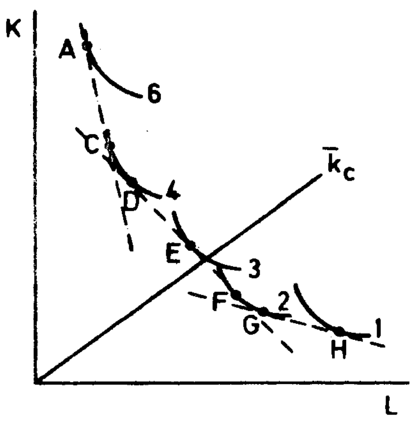


The heavy line now depicts the production of *tradables* at different wage-rental and endowment capital-labor ratios. Assume that the given endowment capital-labor ratio is $\bar{k}$. If only the non-traded good is produced the wage-rental ratio is at $\bar{w}_1$. The production of the non-traded good uses capital and labor in exactly the proportions given by $\bar{k}$ (cf. also *figure 1.3*). If now demand for the non-traded good is decreased, some resources are released for production of tradables, and there will be excess supply of capital and excess demand for labor, since at the wage-rental ratio $\bar{w}_1$ only tradables which are less capital intensive than the non-traded good can be produced. The wage-rental ratio will therefore rise, so that substitution in production of capital for labor makes both factors fully employed. Initially only one tradable is produced, good 2. As more resources are shifted from the non-traded to the tradable sector, the wage-rental ratio eventually permits production of goods 3 and 4, in addition to good 2. Now the excess supply of capital released by the non-traded sector is absorbed by reallocation, instead of by substitution. The composite tradable commodity becomes increasingly capital intensive, until only good 4 is produced. At the wage-rental ratio $\bar{w}_2$ the endowment capital-labor ratio exactly matches that of good 4, and no production of the non-traded good takes place. (This corresponds to a point between C and D in *figure 1.2*.)

1.2.3 *Trade*

We have now outlined a Heckscher-Ohlin model of production, but have said nothing about trade. To do so, it is necessary to introduce domestic demand for the goods. We make the assumption that it is homothetic and identical with that of the home country's trading partners. This assumption is made to assure that demand does not reverse the trade pattern predicted by the Heckscher-Ohlin theorem. At the given prices on tradables the bundle of consumption goods is assumed to have the factor proportions shown by the ray from the origin $\bar{k}_c$ in *figure 1.5*.[1] The figure is a replica of *figure 1.2*, except that good 5 is eliminated as it no longer is a tradable good.

Figure 1.5



[1] This is not strictly true for all countries. Since factor prices are not equalized, the same good may be produced with different factor proportions in different countries, as for example good 2 and 4 in *figure 1.5*. The ray $\bar{k}_c$ is therefore not well defined; one should consider $\bar{k}_c$ to be a narrow band rather than a line.

The country is defined to be *capital (labor) abundant* if its endowment capital-labor ratio is higher (lower) than that of the rest of the world. *The Heckscher-Ohlin theorem states that a capital abundant country will export capital intensive goods and import labor intensive goods.*[1] In terms of *figure 1.5* this means that the *bundle* of produced goods is more capital intensive than the consumption *bundle*. But note that we may not be able to say which goods will be exported and imported, and in what quantities. The total number of produced and consumed goods in the world economy as a whole is five, i.e. it is higher than the number of factors. Given preferences and the level of income we know the composition of the consumption bundle, as well as the quantities consumed. But the endowment ratio may be such that three tradables are produced, good 2, 3 and 4. Production then is indeterminate, and, thus, so is the trade pattern.

The standard 2 × 2 × 2 model, on the other hand, gives a determinate solution for production and trade. Assume that only goods 1 and 2 are produced and consumed in the world economy. A capital abundant country will then export good 2 and import good 1.

In this case there will also be *factor price equalization* among the trading countries (assuming incomplete specialization). In contrast, factor prices are not equalized in the situation depicted by *figure 1.5*. A capital abundant small country will produce good 4 and 6 at a higher wage-rental ratio than a labor abundant country which produces good 1 and 2.

1.2.4 *Changes in exogenous variables*

This completes the description of the Heckscher-Ohlin model which is the basis of the present study. But to better

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[1] We make the assumptions that (i) goods are freely mobile internationally, (ii) factors are perfectly immobile internationally, (iii) all individuals have identical homothetic preferences, (iv) production functions are the same in all countries and exhibit constant returns to scale and no joint production, and (v) there is perfect competition in the goods and factor markets.

understand the design of the study, which is presented in the next section, we must summarize the exogenous and the endogenous variables of the model, and complete the analysis of how the exogenous variables affect the endogenous variables.

Exogenous variables are: (i) *factor endowments*, (ii) *technology*, (iii) *preferences*, and (iv) *prices on tradables*. As endogenous variables we have: (i) *allocation in the tradable sector*, (ii) *relative size and pattern of trade*, and (iii) *factor prices*.

We have already indicated the effects of changes in factor endowments and in the demand for the non-traded good. It therefore remains to briefly analyze how changes in technology and prices on tradables may influence the endogenous variables in the model. For simplicity we hold demand (and output) of the non-traded good constant in the analysis. The consequences of subsequent changes in demand are commented on at the end of the discussion. We will consider technical progress in good 4 in all countries such that the amount of capital and labor required to produce one unit of output is reduced. In terms of the unit-value isoquants in *figure 1.5* this means that the good 4 isoquant is shifted towards the origin. Note that such a shift also can be interpreted as a rise in the price of good 4. Such a price rise could also result from a rise in a domestic *tariff* on good 4. Hence, in effect we consider the effects of a price change, a tariff change and a change in technology simultaneously.[1] Because of the inward shift of the unit-value isoquant of good 4, the segment AC becomes steeper, i.e. the wage-rental ratio rises in this interval, and the segment DF becomes flatter, i.e. there is a fall in the wage-rental ratio in this interval. As a result of the change in factor prices, good 3 becomes too

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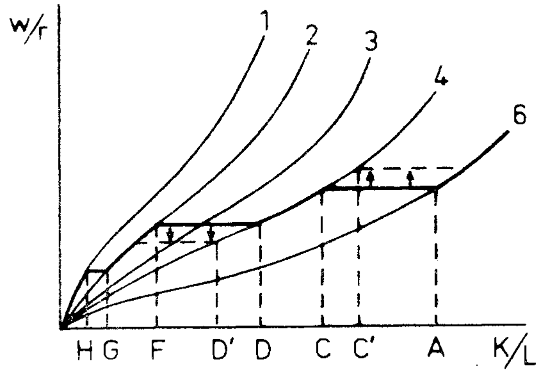
[1] This is not strictly true for a tariff change, since no consideration is taken of the change in tariff income and its consequences.

costly to produce (the wage-rental ratio now lies below good 3's unit-value isoquant). (Presumably, if good 3 is considered essential in demand, prices on the world market will move in such a way as to permit production of good 3 again.)

The effects can also be studied in *figure 1.6* below.

Figure 1.6



The fall of the wage-rental ratio in the FD interval and the rise of the ratio in the CA interval increase the scope for complete specialization in good 4; the interval DC is expanded to D'C'. At the same time there is less scope for incomplete specialization in good 2 and 4 (good 3 is dropped) or in good 4 and 6.

If the endowment capital-labor ratio initially lies between D and C on the K/L-axis, there will be no change in factor prices. Assume that the ratio initially lies in the C'A interval instead, and that the country is capital abundant so that it exports good 6 and imports good 4. Let the inward shift of the unit-value isoquant of good 4 depend on a price rise. We see that the consequence is a rise in the price of labor, which is the intensive factor in the importable good. This is the *Stolper-Samuelson* [1941] *effect*. Although it is not shown in the figure, a rise in the wage-rental ratio will also make the output of the exportable good contract. The reason is that the change in factor prices sets off substitution in production of capital for labor. In order for both factors to be fully employed there must be increased production of the labor intensive good and decreased production of the capital intensive good.

Throughout the analysis of changes in factor endowments, technology and prices on tradables we have disregarded "secondary" effects through changes in the demand for the non-traded good. As mentioned earlier, changes in the amount of resources allocated to the non-traded good will affect the endowment capital-labor ratio in the tradable sector and, therefore, they will change allocation in the tradable sector, if there is incomplete specialization, or factor prices, if specialization is complete.

1.3 AN OUTLINE OF THE STUDY AND A SUMMARY OF THE MAIN RESULTS

The study consists of three parts. The first part, chapters 2-5, attempts to establish the empirical content of the Heckscher-Ohlin model outlined above. Changes in Sweden in the post-war period in exogenous variables, such as factor endowments, technology and preferences, are recorded and estimated, and some changes in endogenous variables, such as the pattern of allocation and trade, are also described. The second part, chapter 6, is a comparative static analysis within the Heckscher--Ohlin model of the observed changes in exogenous variables. The particular version of the Heckscher-Ohlin model in chapter 6 has the same number of produced and tradable goods as factors, i.e. allocation is determinate in the model. The analysis generates hypotheses about what effects changes in factor endowments, preferences, technology and tariffs have had on allocation, trade specialization and domestic prices. The third part, chapter 7, repeats the comparative static experiments of chapter 6 in the form of simulations with a many-sector, quantitative, general equilibrium model of the Swedish economy. The purpose is to see if the predictions generated by the Heckscher-Ohlin model are borne out in a standard quantitative general equilibrium model, which has other properties than the Heckscher--Ohlin model. Finally, the study contains a generalization of the Rybczynski theorem, in chapter 8. Chapter 8 should be seen as an extension of chapter 6.

Chapter 2 describes changes in factor endowments and factor prices. Three factors are taken into account: raw labor, physical capital and human capital. During the period 1950-74 the flow of labor services, measured in man-hours, is more or less constant, while the physical capital stock and, presumably, its services increase at 4 per cent per year. The change in the aggregate rate of flow of human capital services is estimated using a national accounting identity and an assumed wage rate for raw labor. The estimated rate of change is 7.6 per cent which is quite high compared to estimates in growth accounting studies. Changes in relative factor prices roughly reflect changes in relative factor scarcities: the price of labor is increased substantially in relation to the prices of human and physical capital.

Chapter 3 deals with differences in factor proportions and technical change between 24 sectors of the Swedish economy as well as between the aggregated tradable and non-traded sectors. Human and physical capital are aggregated and capital-labor ratios calculated for the 24 sectors as well as for aggregates of tradable and non-traded sectors respectively. It is found that the non-traded sector is substantially more capital intensive than the tradable sector. The big difference is due to the extreme capital intensity of the non-traded housing sector and the sector producing electricity. However, even the public sector, which also is non-traded, is more capital intensive than the aggregate tradable sector. Correlations of capital intensity rankings of the 24 sectors between different points in time are high, and, hence, factor intensity reversals seem to be less frequent. The second half of chapter 3 attempts to estimate rates of change in total factor productivity. The method used does not give accurate estimates of levels, but is thought to yield the correct ranking of sectors according to rates of total factor productivity change. The tradable sector has a significantly higher rate during the period 1950-74 than the non-traded sector.

Chapter 4 describes changes in allocation among the 24 sectors of the economy, and in particular the allocation between the tradable and non-traded sectors. On the basis of the recorded changes in allocation and the change in the relative price of non-traded goods, we conclude that the income elasticity of demand for non-traded goods is higher than unity and/or that there has been a shift in taste towards non-traded goods.

Chapter 5 considers various aspects of Swedish foreign trade in the post-war period. It describes changes in the aggregate export-output ratio as well as in sectoral export- and import-output ratios, i.e. in the degree of *intra*-industry trade on the sector level. The considerable intra-industry trade found to exist is not explained by the Heckscher-Ohlin model, but can be explained by other theories of trade, which are briefly outlined in the chapter. An attempt is made to determine the factor content of Swedish exports and imports, on the assumption that Sweden is a capital abundant country. The results of the test of the Heckscher-Ohlin theorem indicate that exports are relatively capital intensive, as expected, but they are far from conclusive. However, a survey of other tests for Sweden finds that the evidence confirms our results. Finally, the chapter describes changes in terms-of-trade and changes in tariffs between 1959 and 1974. It is found that the terms-of-trade have been more or less constant and that tariff rates, which generally are quite low, around 5 per cent, have been reduced quite little in percentage terms.

In *chapter 6* the empirical findings in chapters 2-5 are first collected and presented as "stylized facts" of Swedish post-war economic development. The stylized facts are both changes in exogenous variables in the Heckscher-Ohlin model, in factor endowments, technology, preferences and prices on tradable goods, and what can be seen as parameters, namely the ranking of sectors according to capital intensity and the endowment position of Sweden relative to the rest of the world.

Next, a Heckscher-Ohlin model with two factors and three goods, an exportable, an importable and a non-traded good, is constructed. The model is a special case of the model presented in section 1.2, namely the case when two tradables and one non-traded good are produced, and where the non-traded good is more capital intensive than both tradables. In other words, the cases of complete specialization and of more tradables than factors are ruled out.

The comparative static experiments which are carried out for the observed changes in exogenous variables imply comparisons of one state of the economy with another, where only one exogenous variable is changed at a time. It is found that an increase in the capital stock will increase the output of the exportable good and decrease the output of the importable good, and thereby increase specialization in production and trade. Factor prices and the price of the non-traded good are constant. A shift in taste towards the non-traded good also leaves domestic prices constant but has exactly the opposite effects on the tradable outputs.

The stylized fact of increased efficiency of the tradable sector relative to the non-traded sector results in increased production of both the exportable and the importable good, but it is likely that the rate of increase is higher for the latter. Hence, we expect decreased specialization in production and a lower export-output ratio. Factor prices and the price of the non-traded good are constant also in this experiment.

The experiment of reducing an import tariff, finally, produces ambiguous results for allocation. As expected, the relative price of labor, the intensive factor in the importable good, is reduced.

In principle, the same experiments are then repeated in *chapter 7* by simulations with a fairly standard multi-sector growth (MSG-) model for the Swedish economy. None of the effects which can be expected from chapter 6 appear in the simulations however. There are probably several reasons for this. One reason is that exact predictions of output and factor price changes due to Rybczynski and Stolper-Samuelson effects no longer are possible in a many-sector, two-factor model (although production and trade are determinate in the simulation model). A second reason is that the simulation model provides for an alternative mechanism to absorb excess supply and demand of factors than reallocation of resources between different production activities (i.e. Rybczynski effects), namely substitution in production, since factor prices change in the simulations. The extent to which capital is substituted for labor and *vice versa* as the wage-rental ratio changes is substantial; the elasticity of substitution is by assumption unity. A third reason is the dominance of intra-industry trade. A large part of trade and the increase in trade cannot be explained by factor proportions differences.

In summary, we find that our attempt to gain more knowledge about changes in Swedish post-war allocation and trade patterns by using the Heckscher-Ohlin theory as a tool have met with very little success.

Chapter 8 studies the application of the generalized Rybczynski theorem by Jones [1965] to a model with non-traded goods and indecomposable inter-industry flows. The introduction of inter-industry flows makes necessary a distinction between *net* and *gross* Rybczynski output effects and also between direct and total factor intensities. It is found that a sufficient condition for the movements of the gross and net tradable outputs to bound the movements of the factors, net output movements being greater than gross output movements, is that the net output change of the non-traded good is bounded by the factor movements. This result is compared with earlier findings and the meaning of the sufficient condition is discussed in terms of basic demand parameters.

1.4 THE RELATION TO THE LITERATURE

The present study is an application of the Heckscher-Ohlin theory to empirical problems of growth, allocation and trade. As such it is most directly related to two quite separate bodies of literature. One body is the use of the Heckscher-Ohlin theory, and, more specifically, the Heckscher-Ohlin theorem to determine the factor abundance of a country or the factor content of a country's trade flows. The other body is the use of quantitative, many-sector, general equilibrium models to simulate effects of economic policy, exogenous disturbances of various kinds, increases in resources, etc.

The literature which in some way uses Heckscher-Ohlin theory for empirical research is quite large, and the bulk of this literature stems from Leontief's [1953] determination of the factor content of United States exports and imports. Leontief's study can be interpreted either as a test of the Heckscher-Ohlin theorem assuming that the United States is capital rich relative to the rest of the world (and this seems to be his own interpretation) or as a determination of the factor abundance of the United States assuming that the Heckscher--Ohlin theorem is true. We will not try to review the Leontief--based literature here, but give some references in chapter 5.

As indicated, not all of the empirical literature deals with the factor content of trade flows. Another area where the factor proportions theory has been applied is in finding the determinants of tariff structures. A Swedish example is in Lundberg's [1976] study of how trade liberalization has affected trade during the 1960's. Lundberg attempts to explain the tariff structure, both of nominal and effective tariffs, in 1959 and 1972 by multiple regression analysis, where the labor cost share, the proportion of educated labor and the natural resource content enter as explanatory variables. Another example is the attempt by Postner [1975] to determine the structure of Canadian tariffs. Postner first establishes the factor content of Canadian industries using input-output tables and then correlates factor intensities with tariff rates.

However, to our knowledge there exists no other study than the present which in addition to the Heckscher-Ohlin theorem also makes use of the Stolper-Samuelson and the Rybczynski theorem in analyzing empirical problems. The reason for this apparent gap in the literature is quite simple; the Stolper-Samuelson and the Rybczynski theorem do not easily generalize to models with more tradable and produced goods than factors, and, hence, there are only very restrictive or weak generalized propositions to test or to apply. The literature on theorems of trade in neoclassical models of production with many goods and factors is briefly surveyed in a recent article by Chang [1979].

The real world which we study has, we assume, more goods than factors, and this gives rise to indeterminacy in production, which renders the Stolper-Samuelson and Rybczynski theorem practically powerless as analytical tools. We have solved or circumvented this fundamental problem in two ways. In chapter 6 we "translate" the empirical facts in a many-sector, three--factor world into a model with the same number of produced and tradable goods as factors. In this way we obtain hypotheses about the relations between changes in endowments, preferences, technology and tradable goods prices on one hand, and allocation, factor prices and trade on the other, which are strictly true only in such a model. We then, in chapter 7, ask the question if these relations carry through in a many-sector, two-factor model of the Swedish economy, although there are no theorems to base presumptions on. (Chapter 7 contains a discussion of how various factors may work for or against the kind of results obtained in chapter 6 in the many-sector, two-factor simulation model.)

Quite separate from the empirical Heckscher-Ohlin literature is a literature which uses quantitative, many-sector, general equilibrium models to simulate effects on resource allocation, trade and prices of economic policy, various exogenous disturbances, changes in resources, etc. An early example in this tradition is Werin's [1965] study of production, trade and allocation in Sweden within a linear general equilibrium model of the economy. Werin conducts comparative statics experiments with changes in factor endowments, technology, world market prices, and tariffs and taxes, i.e. in the same variables as in chapter 7. Another example is Bergman's [1978] analysis of the future economic consequences of Swedish energy policy within the model used in chapter 7. An example more directly related to trade problems is the study by Taylor and Black [1974]. They apply a MSG-model of the Chilean economy to determine the output and employment effects (capital is fixed in each sector) of changes in tariffs.

An important difference in our view between the simulation study in chapter 7 and other studies which use the same general approach, such as those referred to above, is that we attempt to establish some *a priori* assumptions about the effects, whereas such presumptions are largely absent in other studies. At least, they are usually not based on analytical results within a general equilibrium framework. Without a consistent view of the mechanisms at work in large-scale models, the results become hard to interpret. However, as has been concluded above, it does not seem that the Heckscher-Ohlin theory is a very useful tool in our particular application.

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CHAPTER 2 CHANGES IN FACTOR ENDOWMENTS AND FACTOR PRICES*

2.1 INTRODUCTION

Factor endowments and changes in factor endowments play a crucial role in the theoretical framework presented in chapter 1. Together with technology, world market prices, and demand for non-traded goods they determine the small country's pattern of production and international specialization, as well as its factor prices. It is clear that Sweden's endowments of factors of production have undergone considerable change in the post--war period. If everything else is held constant this should have had a significant impact on the economy.

This chapter presents available data on factor endowment and factor price changes. This is done in section 2.3. As information on human capital is unavailable, the main part of section 2.3 is an account of the method by which estimates of the rate of change of the quantity and price of human capital are obtained. Section 2.4 contains a brief survey of similar estimates in other studies, as a check on the results. Section 2.5 provides a short summary of the findings. But first, in section 2.2, it is necessary to briefly discuss what and how many factors of production should be considered.

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2.2 WHICH AND HOW MANY FACTORS?

Within the framework of standard production theory factors are differentiated by being less than perfect substitutes. Factors which are perfect substitutes are effectively one and the same factor. By casual observation perfect substitutes seem to be few and, thus, the number of factors very large.

However, understanding of economic phenomena requires simplification. Empirical work often only recognizes two production factors, labor and physical capital. This is sometimes a relevant and fruitful simplification of reality. But there are at least two areas where original findings, which at first only took account of labor and capital, were considered unsatisfactory, and where subsequent research has added more production factors to arrive at more satisfactory results. One area is so-called growth accounting. Solow's [1956] original finding that only a very small part of long-term U.S. economic growth could be explained by the contribution of labor and capital inspired Denison [1963] and others to search for other factors and to reduce the residual in the growth accounting identity, what Solow called "the measure of our ignorance".

The second area is the testing of the Heckscher-Ohlin theorem. Leontief's [1953] paradox, that the U.S. is exporting labor intensive and importing capital intensive goods, prompted Kenen [1965] and others to bring in more factors to show that U.S. exports are, after all, relatively capital intensive.

Both the literature on growth accounting and on the empirical validity of the Heckscher-Ohlin theorem present strong evidence in support of adding at least a third factor, *human capital*, to the two traditional, labor and physical capital. Below is a compact summary in table format of Denison's [1963] accounting for U.S. economic growth to substantiate the argument:

Table 2.1 Sources of U.S. economic growth 1929-57

Sources of growth	*Weighted annual percentage growth rates*	*Explanatory share of GNP growth rate*
Labor	0.80	0.27
Capital	0.43	0.15
Education and experience	0.77	0.26
Economies of scale	0.34	0.12
Advance of knowledge	0.59	0.20
TOTAL	2.93	1.00

Source: Based on Denison [1963], table 32.

Several other growth accounting studies, e.g. by Christensen and Jorgensen [1969] [1970], Jorgensen and Griliches [1967] (all for the U.S.) and Nishimizu and Hulten [1978] (for Japan), confirm the significant contribution of human capital to economic growth.

Early attempts to explain U.S. trade flows by including human capital, such as those of Keesing [1965] [1968], are fairly successful, and subsequent studies include human capital variables as a rule. See e.g. the studies by Waehrer [1968], Baldwin [1971], Fareed [1972] and Branson and Monoyios [1977].

The contribution of human capital to economic growth, as demonstrated in growth accounting studies, provides a strong argument for recognizing it as a factor of production in the present context. Another argument is given by the results of studies which attempt to determine the comparative advantage of Sweden based on the factor proportions theory. All such studies indicate that Sweden is a net exporter of human capital through her commodity trade, see the survey in chapter 5. In fact, it seems that human capital is the most important determinant of Swedish trade, and that the influence of other factors, such as labor and physical capital, is less certain.

We conclude that the arguments in favor of adding human capital to labor and physical capital are convincing. What other factors of production, if any, should be taken into account? In a recent theoretical and empirical study of the Heckscher--Ohlin theorem Harkness [1979] explains U.S. net trade flows in 1957 by her endowments of some 17 factors. In addition to different kinds of labor and physical capital he includes a variety of natural resources including land. The variation in and pattern of proportionate net exports (net exports over output) is explained remarkably well by the almost exhaustive set of factors of production. However, when these factors are aggregated into four broader categories, capital, human capital, land, and natural resources, they are unable to explain significantly the variation in proportionate net exports across U.S. industries. Harkness' conclusion is that aggregation of imperfectly substitutable factors neglects many individual factor complementarities, which are shown to be important in determining net commodity exports.

Harkness' finding is a strong reason for including an exhaustive set of factors when one wants to test the Heckscher--Ohlin theorem. That, however, is not the primary aim of the present study. We wish to analyse the effects of growth, which takes the form of factor accumulation and technical progress, on allocation and trade. To make the task analytically manageable it is judged necessary to limit the number of factors. When we take account of labor, physical capital and human capital we adhere to the conventional view of a suitable level of aggregation and choice of the most important factors of production.

2.3 CHANGES IN FACTOR ENDOWMENTS AND FACTOR PRICES

We now wish to determine the rates of change in the economy's endowments of labor, physical capital, and human capital. Also, we want to establish at what rates factor prices have changed. The movements in the quantity and price of labor and physical capital are already known. It remains to estimate the rate of change in the endowment and the price of human capital. Most of the present section deals with this problem.

2.3.1 *Methodological considerations*

Consider the national accounting identity

$$(2.1) \qquad p_V V = p_L L + p_K K + p_H H$$

where V is aggregate value-added (output) or aggregate income, and L, K and H are the aggregate flows of raw labor, physical capital and human capital services respectively. The prices of output and of inputs are p_V, p_L, p_K and p_H. Since output here is national output, the price p_V can be viewed as the general price level.

Differentiate (2.1) logarithmically to obtain

$$(2.2) \qquad \hat{p}_V + \hat{V} = \theta_L(\hat{p}_L+\hat{L}) + \theta_K(\hat{p}_K+\hat{K}) + \theta_H(\hat{p}_H+\hat{H})$$

where the weights θ_i (i=L,K,H) are national income shares and a circumflex "^" denotes rate of change.

We can rewrite (2.2) as

$$(2.3) \qquad \hat{p}_V - \theta_L\hat{p}_L - \theta_K\hat{p}_K - \theta_H\hat{p}_H = -\hat{V} + \theta_L\hat{L} + \theta_K\hat{K} + \theta_H\hat{H}$$

Set the left- and right-hand-side of (2.3) equal to $-\hat{T}$ to obtain

$$(2.4) \qquad \hat{p}_V = \theta_L\hat{p}_L + \theta_K\hat{p}_K + \theta_H\hat{p}_H - \hat{T}$$

and

$$(2.5) \qquad \hat{V} = \theta_L\hat{L} + \theta_K\hat{K} + \theta_H\hat{H} + \hat{T}$$

$\hat{T}$ may be defined as the rate of change in total factor productivity (cf. chapter 3 for a more detailed derivation and a theoretical interpretation of (2.4) and (2.5)).

Expressions (2.4) and (2.5) are indices of the change in the general price level and in total output respectively. We will use (2.4) and (2.5) to solve for unknown changes in the price and quantity of human capital as given by

$$(2.6) \qquad \hat{H} = \frac{1}{\theta_H}(\hat{V}-\theta_L\hat{L}-\theta_K\hat{K}-\hat{T})$$

and

$$(2.7) \qquad \hat{p}_H = \frac{1}{\theta_H}(\hat{p}_V-\theta_L\hat{p}_L-\theta_K\hat{p}_K-\hat{T})$$

The rate of change in total factor productivity, $\hat{T}$, is unknown. In the estimation we set $\hat{T} = 0$. The change in total facto productivity will therefore be picked up by the estimates of $\hat{H}$ and $\hat{p}_H$.

How reasonable is the proposed approach for estimating movements in human capital and its price? Changes in total factor productivity are, according to Abramovitz [1962], commonly viewed as "... the effect of 'costless' advances in applied technology, managerial efficiency, and industrial organization (cost - the employment of scarce resources with alternative uses - is, after all, the touchstone of an 'input') ..." Human capital, on the other hand, is in most growth account ing studies estimated on the basis of earnings differentials between individuals with different amounts of formal schooling. Schooling is associated with investments, so clearly human capital, when measured in this way, is not costless. In the same way it is clear that raw labor and physical capital constitute "scarce resources with alternative uses".

It should be kept in mind that the measurement of human capital is a major difficulty in growth accounting studies. It is hard to find measures of the costs associated with various forms of human capital, and even to know what these costs actually are. The number of years of formal schooling is perhaps the most obvious proxy for investment in human capital, and the earnings differentials between individuals with different amounts of schooling a self-evident measure of returns to human capital. At the same time it is hard to believe that "advances in applied technology, managerial efficiency, and industrial organization" really are totally costless. It may be more correct to say that much of knowledge and skills in individuals acquired by learning-by-doing and other experience has a cost, but that the cost is hard to define and to measure. The production units pay all their income to factor owners, none of whom are owners of a factor labelled "total factor productivity". By our method of estimation it is the owners of human capital who receive all of the reward to what conventionally is measured as total factor productivity.

To estimate changes in the price and quantity of human capital in the way proposed above may be quite unreasonable. However, our aim is not to obtain estimates with a high degree of precision, only to determine the *ranking* of rates of change in factor endowments and factor prices. Compared to conventional estimates ours will have a strong upward bias. The magnitude of the potential bias is discussed below, in section 2.4.

2.3.2 *Data sources*

A brief account of how data were found or imputed is necessary. The rates of change of total output and its price are simply taken from national accounts data on GNP in constant and current prices.[1] The rate of change of physical capital services is the rate of change of physical capital *stocks* according to the national accounts. In other words, an assumption is made about constant proportions between the flow of services and the stock. The national accounts give separate data for physical capital in the form of "buildings" and "machinery". The two kinds of physical capital have simply been added. To obtain the rate of change of the price of physical capital, the stock rate of change was subtracted from the aggregate income to capital rate of change in nominal terms. Again, an assumption of constant proportions between stocks and service flows is employed.

As a measure of the change in labor service input we use man-hour data in the national accounts. The price of labor services presents a problem. Labor services are defined as the services of labor exclusive of human capital. Somewhat arbitrarily we choose to let the services of dish-washers in the restaurant and hotel industry (SNR 6300) represent raw labor services, and take the negotiated hourly wage of such labor as its price.[2]

Once the raw labor wage is determined we can divide the wage sum of national income into returns to raw labor, by multiplying total man-hours by the wage rate, and to human capital, by subtracting the returns to raw labor from the total wage sum. We thus obtain the shares of national income of the three factors for 1950, 1958, 1966 and 1974. As weights θ_i (i = L, K, H) in the expressions (2.6) and (2.7) we use the

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[1] All national accounts data referred to are from SM N 1975:98.

[2] Wage rates were provided by Hotell- och restauranganställdas förbund (the union of hotel and restaurant employees).

unweighted average shares for the starting and end years for each subperiod. Rates of change are estimated for each subperiod and are then averaged to obtain rates for the change in price and quantity of human capital for the whole period 1950-74. In this way some of the effects of changing relative factor prices and endowments on the weights are neutralized.

2.3.3 *Results*

Estimates of rates of change for the price and quantity of human capital are presented in *table 2.2* for the periods 1950-58, 1958-66 and 1966-74. The last column in the table records the unweighted averages of the subperiod rates. Rates of change in prices and quantities of labor and physical capital and of aggregate output are also shown.

During the 24-year period 1950-74 real income or output increased at an average rate of 3.7 per cent per year. At the same time the general price level increased at a yearly average rate of 4.9 per cent.

Table 2.2 Rates of change of input and output prices and quantities

	1950-58		*1958-66*		*1966-74*		*Average*	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Labor								
volume	-0.1	0.0	0.5	0.2	-0.9	-0.3	-0.2	0.0
price	9.7	3.2	7.7	2.5	10.5	3.5	9.3	3.1
Physical capital								
volume	3.8	1.7	4.0	1.5	4.1	1.3	4.0	1.5
price	3.2	1.4	0.3	0.1	3.3	1.1	2.3	0.9
Human capital								
volume[1]	6.3	1.4	9.4	2.6	7.2	2.5	7.6	2.2
price[1]	3.1	0.7	5.0	1.4	2.1	0.7	3.4	0.9
Aggregate income								
volume	3.1		4.3		3.7		3.7	
price	5.3		4.1		5.3		4.9	

[1] Estimated rates.

Note: Rates in columns (1), (3) and (5) are not weighted by income shares [illegible]$_i$, rates in columns (2), (4) and (6) are weighted. Column (7) gives unweighted rates, and column (8) gives unweighted averages of weighted rates. Factor rates do not always sum to aggregate rates because of rounding errors.

Sources: SM N 1975:98, Appendix 2, 4 and 5, Hotell- och restauranganställdas förbund.

Consider first column (8), which gives the contributions to aggregate growth and price level changes of factor accumulation and factor price changes. Some 60 per cent of aggregate growth at 3.7 per cent per year is due to human capital accumulation, and the rest to accumulation of physical capital. There is no change in the input of labor, weighted by income shares, and thus no contribution to growth. On the other hand, the main cause of aggregate price increases at 4.9 per cent per year is a high weighted rate of increase in the raw labor wage. It contributed some 63 per cent of the increase in the general price level. The rest, 37 per cent, is shared equally between the price changes of physical and human capital.

From column (7) it is evident that Sweden's factor endowments changed substantially during the period, in a capital abundant direction. Human capital is estimated to grow at a ver high rate, 7.6 per cent. Physical capital accumulated at a lowe but still high rate, 4.0 per cent, while the supply of man--hours actually decreased slightly.

The changes in relative factor prices roughly reflect the changes in relative factor supplies, see column (7). The rate of change in the raw labor wage, 9.3 per cent, may seem very high. However, the real rate is only 9.3-4.9 = 4.4 per cent, which is not much higher than the total per-hour real income rate of change, 3.7+0.2 = 3.9 per cent.

We may speculate that there has been a downward pressure on the human capital price in Sweden during the postwar period due to non-market forces, and specifically to the way wages and salaries are determined in Sweden. The degree of unionization is very high and wage negotiations are highly centralized. Since the early 1960's an objective of the unions has been to diminish wage differentials within their membership through negotiated settlements. The policy has been quite successful. It is possible that high-wage earners, with relatively much human capital, have had to "subsidize" low-wage earners, with relatively much raw labor. In other words, the rate of return to raw labor may have increased less relative to the return to human capital, if wages had been wholly determined under competitive conditions in the labor market.

2.4 COMPARISON WITH RESULTS IN OTHER STUDIES

As expected, the growth rate for human capital services seems high, especially when it is compared to estimates of *efficient labor input per man-hour* in some selected growth accounting studies. Denison [1963] calculates an index of labor input for the U.S. for the period 1929-1957, taking account of a variety of factors: growth of employment, number of hours per work week, effect of shorter hours on quality of a man-hour's work, education, increased experience and better utilization of women workers, and changes in age-sex composition of the labor force. By subtracting the annual growth rate of total hours of work from the annual growth rate of this index we can obtain a growth rate for the *effective* labor input per hour. This we interpret as a rough approximation of the human capital services rate of change estimate made in section 2.3 above. The figure for the human capital services per man-hour growth rate calculated in this way is 1.57 per cent. Jorgenson and Griliches [1967] estimate indexes of efficient labor input per man-hour for U.S. males for shorter periods within the period 1940-1965. They only adjust for changing composition of the labor force with respect to years of schooling, and come up with an unweighted average growth rate for six subperiods of 0.78 per cent. Christensen and Jorgenson [1969] calculate a growth rate of efficient labor input per man-hour for the U.S. and the period 1929-1967 of 1.06 per cent per year, taking account of changes in the composition of the labor force by educational attainment. In trying to establish the sources of Japanese economic growth 1955-1971 Nishimizu and Hulten [1978] estimate that change in the composition of the labor force with respect to education has raised efficient labor input by a mere 0.16 per cent annually in the period 1958-1971 (private sector except agriculture and services).

In view of these results we suspect that our own estimate has a strong upward bias, which is due to the inclusion of what traditionally is measured separately as total factor productivity change. The estimated annual rate of change in total factor productivity is generally substantial in other studies, see *table 2.3* below.

Table 2.3 Estimates of total factor productivity (TFP) and human capital (HC) rate of change in selected growth accounting studies

	Annual rate of change		*Explanatory share for TFP of output growth rate*
	HC	TFP	
Christensen-Jorgenson [1969][1]	1.06	1.13	0.36
Denison [1963][2]	1.57	0.93	0.32
Jorgenson-Griliches [1967][3]	0.78	1.60	0.46
Nashimizu-Hulten [1978][4]	0.16	2.88	0.25
Star [1974][5]	– [6]	0.87	0.27
AVERAGE		*1.48*	*0.33*
Our adjusted estimate	*2.6*	*1.48*	

1 U.S. 1929-67.

2 U.S. 1921-57.

3 U.S. private domestic economy 1945-65, before adjustments for aggregation errors of various kinds, errors in investment goods prices and in capacity utilization.

4 Japan 1955-71.

5 17 U.S. manufacturing industries 1950-60.

6 Not available.

To see how our estimate of human capital accumulation compares with those in other studies, we have reestimated the rate of change in human capital, but instead of setting $\hat{T} = 0$ in equation (2.6) we set $\hat{T} = 1.48$, i.e. equal to the unweighted average in five growth accounting studies. The adjusted estimate of human capital growth is 2.6 per cent, which is considerably lower than the original 7.6 per cent. It is still high compared to the rates in other studies as shown in *table 2.3*.

We have also calculated the effect on the rate of change of the human capital price of positive total factor productivity growth. A rate of 1.48 per cent in total factor productivity change gives a negative rate of -2.4 in the nominal human capital price. In other words, the relative price of human capital falls substantially in this example.

2.5 SUMMARY

In this chapter movements of factor endowments and factor prices in Sweden during the period 1950-74 are described. Three factors of production are taken into account: raw labor, physical and human capital.

National accounts statistics show a more or less constant supply of raw labor services, measured in terms of man-hours, and a yearly average increase of 4 per cent in the physical capital stock. Using an accounting identity we estimated a rate of increase in human capital services of 7.6 per cent. Hence, per man-hour there is 2.5 times as much physical capital stock at the end of the period as at the beginning, and, presumably, nearly 6 times as much human capital services.

If instead of zero growth in total factor productivity we assume rates consistent with results in selected growth accounting studies for other countries, the estimated rate of growth in human capital is brought down to 2.6 per cent. This figure is still high compared to rates common in the literature.

Despite the crude methods used to estimate human capital services it seems certain that human and physical capital have increased very substantially relative to raw labor during the period under study.

Changes in relative factor prices roughly reflect changes in relative factor scarcities. The return to raw labor services increased at a rate of 9.3 per cent, while the return to physical capital only increased at 2.3 and to human capital at 3.4

per cent annually. The price level at the same time increased at a rate of almost 5 per cent. Hence, there was a fall in the relative prices of both forms of capital and a rise in the price of raw labor.

It should be commented, in relation to the Heckscher-Ohlin world of chapter 1, that changes in factor prices caused by changes in relative factor scarcities are possible if the economy changes specialization by dropping some product or taking up production of some other, or when there is complete specialization in the tradable sector. However, when the economy is producing on a flat section of its transformation surface, changes in factor endowments cannot influence factor prices.

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CHAPTER 3 FACTOR PROPORTIONS AND TECHNICAL CHANGE*

3.1 INTRODUCTION

The double aim of this chapter is to describe factor proportions and to estimate technical change in different sectors of the economy. By technical change we mean the rate of change in total factor productivity.

Both factor proportions and technical change are exogenous in the Heckscher-Ohlin model in chapter 1. At given factor endowments, world market prices and demand for non-traded goods differences between productive activities in their proportionate use of factors determine which goods are produced and which are not. Factor proportions in the non-traded sector are of particular interest, because any change in the output of non-traded goods will change the factor endowment available to the tradable sector and, therefore, the allocation of resources within that sector and the trade pattern. Changes in relative efficiency between sectors brought about by different rates of technical change alter relative costs and prices. This will in turn also change allocation and trade.

The plan of the chapter is as follows. In section 3.2 we briefly discuss the principles and the level of disaggregation. Section 3.3 contains a derivation of different capital

* Urban Bäckström and Parameswar Nandakumar provided research assistance.

intensity measures. Sectoral capital-labor ratios are presented in section 3.4. Special interest is accorded the difference in capital intensity between the tradable and the non-traded sectors of the economy. In section 3.5 a theoretical framework for total factor productivity measurement is presented. Estimated rates of total factor productivity change are in section 3.6. Again the interest is focused on the difference between the tradable and the non-traded sectors. Section 3.7, finally, is a short summary of the main findings in the chapter.

3.2 LEVEL AND TYPE OF DISAGGREGATION

The particular disaggregation introduced here is used also in the descriptive chapters 4 and 5 and in the simulations in chapter 7. It was chosen, firstly, because it is a familiar sector classification based on international and Swedish industry classifications, and, secondly, because it is the disaggregation applied in the medium-term forecasting model of the Ministry of Economic Affairs (Ekonomidepartementet) and also in a simulation model developed by Bergman and Por [1980], which is the basis for our own simulation model in chapter 7. Hence, relatively much time series and other data are readily available, and results can potentially be compared with those in other studies.

There are at least two different kinds of principles behind the disaggregation. One principle is to group activities which use the same types of input, as for example agriculture and the steel industry. Another principle of disaggregation is according to output characteristics from the consumer's viewpoint: transportation services, clothes, various private services, etc. Often both and possibly other principles are applied for the same sector. A more correct disaggregation principle in our context, one which is based on the theoretical model, is to group activities according to factor proportions. In applying such a principle one might find e.g. steel-making and shipping services in the same sector, or agriculture and commerce. All principles entail problems: some disregard the central role played by factor proportions in the theoretical framework used here, and the factor proportions principle takes little notice of how consumers may structure their demands. However, the principles are not mutually exclusive. The particular disaggregation made takes some consideration of production characteristics and thus of differences in factor proportions between different sectors.

The *level* of aggregation is to some degree dependent on the principle applied. In our case we have 23 private and 1 public sector.[1] Some of the sectors are rather small and one, the engineering sector, is rather big measured in terms of shares of total output. Further disaggregation would provide a firmer basis for statistical tests, but it was judged that it would cost too much in the form of missing data and redesign of an existing simulation model.

3.3 CAPITAL INTENSITY MEASURES

Following the discussion in chapter 2 we take account of three factors of production: raw labor, physical capital and human capital. Each production activity combines these factors to produce some commodity. Typically, the proportions in which they are combined vary from sector to sector, and we now wish to measure the proportions. But first we have to define factor proportions measures which are based on the theoretical concept of a production function and which can be applied with available statistical data. It will be seen that to arrive at such measures a number of strong assumptions have to be made.

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[1] There are 7 public sectors in the simulation model used in chapter 7.

Consider a production function on the general form

$$(3.1) \qquad Q_i = f_i(L_i, K_i, H_i, Z_i)$$

for sector i, where Q_i is sector i's gross output, and L_i, K_i, H_i and the vector Z_i are the inputs of raw labor, physical capital, human capital and intermediate goods respectively.

Profits Π_i are given by

$$(3.2) \qquad \Pi_i = p_i Q_i - q_i Z_i - w_i L_i - R_i^K K_i - R_i^H H_i,$$

where p_i and the vector q_i are prices, w_i is the wage rate, and R_i^K and R_i^H are gross rentals for physical and human capital respectively.

Gross rentals are defined as

$$(3.3) \qquad R_i^K = (r_i + \delta_i) p^K$$

and

$$(3.4) \qquad R_i^H = (\rho_i + \gamma_i) p^H.$$

Net rental rates are denoted by r_i and ρ_i, rates of depreciation by δ_i and γ_i, and capital prices by p^K and p^H.

Value-added, V_i, is defined as

$$(3.5) \qquad V_i = p_i Q_i - q_i Z_i =$$

$$= \Pi_i + w_i L_i + r_i p^K K_i + \delta_i p^K K_i + \rho_i p^H H_i + \gamma_i p^H H_i.$$

Value-added is the sum of profits, factor returns and depreciation charges. It corresponds to *value added in factor values* (förädlingsvärde till faktorpris) in the Swedish national accounts statistics. More specifically, the components are called

$(\Pi_i + r_i p^K K_i)$	= operating surplus (driftsöverskott),
$\delta_i p^K K_i$	= consumption of capital (kapitalförslitning),

and

$(w_i L_i + \rho_i p^H H_i + \gamma_i p^H H_i)$	= compensation of employees (löner inklusive kollektiva avgifter).

We will now use the components of value-added shown above to define two different capital-labor ratios. First we define

$$(3.6) \qquad \kappa_1 = \frac{\Pi_i + R_i^K K_i + R_i^H H_i}{w_i L_i} .$$

We will assume that $r_i = r$, $\delta_i = \delta$, $\rho_i = \rho$, $\gamma_i = \gamma$, $w_i = w$, $\forall i$. Also, we assume that $\Pi_i = 0$, $\forall i$. Then the ratio can be rewritten as

$$(3.7) \qquad \kappa_1 = \frac{R^K K_i + R^H H_i}{wL_i} .$$

A second capital-labor ratio is defined by the ratio between returns to physical capital and returns to labor. We assume that $r_i = r$, $\delta_i = \delta$, $w_i = w$, and $\Pi_i = \Pi$, $\forall i$. The ratio is

$$(3.8) \qquad \kappa_2 = \frac{R^K K_i}{wL_i} .$$

We note that simply

$$\kappa_1 = \kappa_2 + \frac{R^H H_i}{wL_i} .$$

Clearly, the assumptions about equal rates of net returns and depreciation for both types of capital, equal wage rates and zero profits across sectors, which are made to arrive at the ratios (3.7) and (3.8), are quite strong. A more direct approach to obtain the corresponding ratios is to use data on factor quantities instead of service flows. Such data are less influenced by business cycle variations, market imperfections, etc., which may result in differences in factor rewards and profits between sectors. The national accounts contain data on physical capital stocks and the supply of man-hours. There are no quantitative data on human capital; instead we must use the service flows which were obtained from value-added data in the way described in chapter 2. We have imputed stock values by capitalizing the flow values. As discount rate we used the observed gross rental rate for physical capital in the national accounts.[1]

We now define the capital-labor ratios

$$(3.9) \qquad \kappa_3 = \frac{p^K K_i + p^H H_i}{L_i}$$

and

$$(3.10) \qquad \kappa_4 = \frac{p^K K_i}{L_i} ,$$

which correspond to (3.7) and (3.8) respectively in that κ_1 and κ_3 have human and physical capital in the denominator whereas κ_2 and κ_4 only have physical capital in the denominator.

3.4 CAPITAL-LABOR RATIOS

In this section we present measurements of sectoral capital-labor ratios according to (3.7) - (3.10). This is done in subsection 3.4.2. In addition we discuss the capital intensity difference between the tradable and non-traded sectors in somewhat more detail in subsection 3.4.3. To check for capital intensity reversals we have correlated rankings according to capital intensity at different points in time. The results are in subsection 3.4.4. But first, in subsection 3.4.1, we want to theck the reliability of our measures of capital intensity.

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1 All data are from the national accounts, SM N 1975:98, Appendix 2, 4, and 5.

3.4.1 *Correlation between different rankings*

We expect the rank correlation between the rank order according to κ_1 and κ_3 to be high, since both κ_1 and κ_3 are composite capital-labor ratios, with physical and human capital in the denominator. For similar reasons the rank correlation between the orderings according to κ_2 and κ_4 should also be high. Consider *table 3.1* which contains the Spearman correlation coefficients:

Table 3.1 Rank correlation between the four different rankings according to capital-labor ratios

	κ_1	κ_2	κ_3	κ_4
κ_1	-	0.855**	0.521*	0.436*
κ_2	0.855**	-	0.222	0.355
κ_3	0.521*	0.222	-	0.857**
κ_4	0.436*	0.355	0.857**	-

* Significant at the 5 per cent level.

** Significant at the 1 per cent level.

Source: Based on *table 3.2*

As expected there is a significant correlation between κ_1 and κ_3. On the other hand, no significant correlation is found between κ_2 and κ_4.

It is interesting to note that the correlations between κ_1 and κ_2 on one hand, and between κ_3 and κ_4 on the other, are highly significant. In other words, rankings according to capital-labor ratios with physical and human capital in the denominator and with only physical capital in the denominator are very similar.

The results lead us to conclude that the assumptions underlying especially κ_1 and κ_2 are very strong. Remember that we have assumed equal rates of return and depreciation, and zero profits in all sectors. In is clear, for example, that the part of value-added in the national accounts statistics which is labelled operating surplus and of which profits may have a sizable share fluctuates much across sectors in different years and also for the same sector over time. The role of market imperfections and business cycles is probably not negligible, as we have assumed.

It is likely that the value-added measures κ_1 and κ_2 are more aversely affected by strong assumptions than are the stock measures κ_3 and κ_4. With these observations in mind we next turn to the results of the capital intensity measurements.

3.4.2 *Capital-labor ratios*

Consider *table 3.2* which contains capital-labor ratios according to (3.7) - (3.10) for 24 sectors of the economy:

Table 3.2 Capital-labor ratios
Averages for 1950, 1958, 1966 and 1974

Sector		Capital-labor ratio			
		K_1	K_2	K_3	K_4
1	Agriculture	2.69[1]	2.69[1]	52.69	52.69
2	Forestry	3.74	2.66	85.68	23.17
3	Mining	7.43	5.52	213.71	84.21
4	Import-sheltered food mfg	3.76	2.67	105.98	36.25
5	Import-competing food mfg	3.42	2.12	152.56	62.25
6	Beverage and tobacco	4.32	2.66	165.96	63.67
7	Textiles and clothing	1.72	0.82	84.17	24.04
8	Wood and wood products	2.87	1.69	138.33	55.39
9	Printing and publishing	3.28	1.44	155.00	39.19
10	Rubber	3.59	2.06	156.79	51.25
11	Chemicals				
12	Petroleum	6.82	5.12	261.56	145.90
13	Non-metallic minerals	2.50	1.09	150.19	57.74
14	Iron and steel	2.70	0.81	207.99	84.57
15	Engineering	2.39	0.97	110.96	23.82
16	Ships	2.44	0.59	152.44	30.02
17	Other manufacturing	1.65	0.69	79.87	15.42
18	Electricity, gas and water	8.83	7.23	730.88	640.10
19	Construction	3.66	1.63	115.31	10.53
20	Commerce	1.85	0.78	82.45	17.10
21	Transport	1.64	0.24	177.64	100.60
22	Housing	66.39	65.01	6116.02	6024.00
23	Private services	2.86	2.06	75.35	18.29
24	Public sector	2.73	0.24[2]	210.09	66.79

[1] It is likely that a substantial part of what is reported as capital income in the agricultural sector in fact is a return to labor. The recorded hourly wage is below that of raw labor, hence the zero share in value-added for human capital and the equality of the two capital-labor ratios.

[2] The low value is due to the national accounting convention of not imputing net returns to capital in the public sector, only depreciation charges.

Source: SM N 1975:98, Appendix, 2, 4, and 5.

The results in the table are broadly consistent with common views about capital intensities in different sectors. Columns κ_2 and κ_4 contain the standard physical capital-labor ratios. As expected, Housing, Electricity, Iron and steel, Petroleum, and Mining are shown to be relatively capital intensive in this sense, while Forestry, Textiles, Construction, Commerce and Private services appear as labor intensive. Somewhat more surprising is the relative labor intensity of Engineering, a weighty sector in terms of output and in trade. It is interesting to note that food manufacturing which is sheltered from foreign competition is significantly less capital intensive than food manufacturing which competes with imports.

When human capital is taken into account, see columns κ_1 and κ_3, Forestry, Import-sheltered food manufacturing, Textiles, Commerce and Private services still rank as relatively labor intensive sectors. Sectors which appear intensive in human capital are Mining, Printing and publishing, Iron and steel, Ships, Construction and Public services. Of these, Ships and Construction appear as labor intensive if human capital is not considered.

3.4.3 *Difference in capital intensity between tradable and non-traded sectors*

A question of particular interest in chapters 6 and 7 is if the aggregate non-traded sector is more or less capital intensive than the tradable sector. The numbers in *table 3.3* throw some light on this question. The non-traded sectors, which have no recorded exports and imports (cf. *table 5.2*), are: Electricity, gas and water, Construction, Housing and Public services. The other 20 sectors are tradable, i.e. they have recorded exports and/or imports.

Table 3.3 Capital-labor ratios in the tradable, non-traded and public sectors in 1950, 1958, 1966 and 1974

Sector	Year	Capital-labor ratio			
		κ_1	κ_2	κ_3	κ_4
Tradable (all other)	1950	2.86	1.72	41.39	17.85
	1958	2.87	1.73	70.62	25.96
	1966	2.92	1.37	130.22	40.97
	1974	1.96	1.32	212.06	70.45
Non-traded (18, 19, 22, 24)	1950	34.01	31.96	1751.33	1708.92
	1958	29.42	27.38	2069.60	1989.18
	1966	18.25	15.84	1661.34	1524.95
	1974	7.36	6.10	1764.17	1559.77
Public	1950	3.35	0.28	119.69	56.42
	1958	3.01	0.27	168.52	61.74
	1966	3.22	0.24	239.08	69.02
	1974	1.34	0.18	313.00	79.98

Source: Based on *table 3.2* and *4.6*.

It can be seen that the aggregate non-traded sector is much more capital intensive than the aggregate tradable sector for all capital-labor ratios. Most of this big difference in capital intensity is attributable to the Housing sector, which is included in the non-traded sector (cf. *table 3.2*). However, also the non-traded Electricity sector is extremely capital intensive, and the Public sector is more capital intensive than the average tradable sector. (We disregard κ_2 in the comparison, since by national accounting convention the physical capital stock in the public sector does not earn net returns.) Of the non-traded sectors only Construction is relatively labor intensive.

Since the relative prices of human and physical capital have decreased over time, and the relative price of labor has increased, we expect substitution of labor for capital to have taken place in all sectors. Substantial increases in the capital-labor ratio over time are visible for κ_3 and κ_4 in the tradable and the Public sectors, but not in the aggregated non-traded sector, which exhibits constant or even falling ratios. However, an inspection of each individual non-traded sector reveals that all have increasing κ_3- and κ_4-ratios over time (not shown here). Hence, the constant or falling ratios for the aggregate non-traded sector are due to changes in the composition of the aggregate.

We do not expect to find significant increases in the κ_1- and κ_2-ratios, since the current factor prices of capital appear in the denominators and the current wage rate in the numerator. If all production functions were of the Cobb-Douglas type, with constant returns to scale and constant elasticity of substitution equal to unity, the ratios would be constant. In fact, we find falling κ_1 and κ_2 for both aggregated sectors and for the Public sector. The fall is more rapid in the non-traded than in the tradable sector. Again, inspection of the individual non-traded sector ratios reveal that the rapid fall to some extent is a result of changing composition of the aggregate.

It is impossible to draw any conclusions about magnitudes of and differences in *elasticities of substitution* from the figures in *table 3.3*. That would require knowledge about each sector production function and, in addition, consideration of changes in the composition of the aggregate.

It is also not possible to draw any conclusions about an eventual *bias in technical change*, which may have affected the proportions in which factors are used in the different sectors. (The circumstance that the relative price of labor has increased substantially and at a fairly constant rate leads us to expect that technical change has been labor-saving in Hicks' sense.)

3.4.4 *Test for factor intensity reversals*

What stability over time do the various rankings exhibit? *Table 3.4* contains matrices of Spearman rank correlation coefficients between rankings at different points in time:

Table 3.4 Correlation over time between capital intensity rankings

a) ranking according to κ_1

	1950	1958	1966	1974
1950	-	0.788	0.757	0.640
1958	0.788	-	0.905	0.750
1966	0.757	0.905	-	0.764
1974	0.640	0.750	0.764	-

b) ranking according to κ_2

	1950	1958	1966	1974
1950	-	0.869	0.821	0.847
1958	0.869	-	0.911	0.893
1966	0.821	0.911	-	0.900
1974	0.847	0.893	0.900	-

c) ranking according to κ_3

	1950	1958	1966	1974
1950	-	0.948	0.933	0.881
1958	0.948	-	0.956	0.889
1966	0.933	0.956	-	0.903
1974	0.881	0.889	0.903	-

d) ranking according to κ_4

	1950	1958	1966	1974
1950	-	0.893	0.834	0.755
1958	0.893	-	0.948	0.890
1966	0.834	0.948	-	0.945
1974	0.755	0.890	0.945	-

All coefficients are significant at the 1 per cent level. There is a clear tendency in all matrices of lower correlation with distance in time. The tendency is however quite weak, and the impression is that rankings are highly stable over time. In other words, although capital intensity reversals have occurred during the period under study, we conclude that such reversals are not an important feature of the development of technology.

3.5 TECHNICAL CHANGE MEASUREMENT

We now wish to determine the rates of change in total factor productivity on the sectoral level. The ambition is not to attain estimates with the highest possible precision; it is sufficient to obtain a *ranking* according to factor productivity change among the different sectors. In this section we develop the theoretical framework. Results are presented in the following section.

Consider again the national accounting identity (2.1) on the general form

$$(3.11) \qquad p_v \cdot V = p_1 \cdot X_1 + p_2 \cdot X_2 + \ldots + p_n \cdot X_n,$$

where V is real value added in sector j (subscripts are omitted), X_i is the real flow of services of input i $(i=1,2,\ldots,n)$ and p_v and p_i are the respective prices.

To define total factor productivity differentiate (3.11) logarithmically to obtain

$$(3.12) \qquad \hat{p}_V + \hat{V} = \sum_{i=1}^{n} \theta_i (\hat{p}_i + \hat{X}_i),$$

where the weights $\theta_i = p_i X_i / \Sigma p_i X_i$, and a circumflex "^" denotes rate of change.

We can now define two useful Divisia indexes of input quantity and input price change from equation (3.12):

$$(3.13) \qquad \hat{X} = \sum_{i=1}^{n} \theta_i \hat{X}_i$$

and

$$(3.14) \qquad \hat{p}_X = \sum_{i=1}^{n} \theta_i \hat{p}_i,$$

where X and p_X are the quantity and price indexes respectively.

Total factor productivity T is now defined as

$$(3.15) \qquad T = \frac{V}{X}$$

or

$$(3.16) \qquad T = \frac{p_V}{p_X},$$

and its rate of change as

$$(3.17) \qquad \hat{T} = \hat{V} - \hat{X} = \hat{V} - \sum_{i=1}^{n} \theta_i \hat{X}_i,$$

or, alternatively, as

$$(3.18) \qquad \hat{T} = \hat{p}_V - \hat{p}_X = \hat{p}_V - \sum_{i=1}^{n} \theta_i \hat{p}_i.$$

Definitions (3.17) and (3.18) are dual to each other, and are equivalent except for sign by (3.12).

An economic interpretation and justification of definitions (3.17) and (3.18) is provided by the theory of production. Assume that producers are in equilibrium and that technology is represented by a constant returns production function with Hicks-neutral technical change:

$$(3.19) \qquad V = A \cdot f(X_1, X_2, \ldots, X_n),$$

where A is the Hicksian efficiency index. Logarithmic differentiation of (3.19) and use of the fact that each input is paid the value of its marginal product yields

$$(3.20) \qquad \hat{V} = \hat{A} + \sum_{i=1}^{n} \theta_i \hat{X}_i.$$

Thus, the rate of change of the total factor productivity index, $\hat{T}$, measures the rate of change of the efficiency parameter, $\hat{A}$, i.e. the extent of the *shift* of the production function.

Alternatively, $\hat{A}$ measures the shift in the factor price frontier. In equilibrium factor payments exhaust the value product so that

$$(3.21) \qquad p_v V = \sum_{i=1}^{n} p_i X_i.$$

Differentiate (3.21) logarithmically to obtain

$$(3.22) \qquad \hat{p} = \Sigma \theta_i \hat{p}_i + \Sigma \theta_i (\hat{X_i/f}) - \Sigma \theta_i \hat{A},$$

where we have used $(\hat{X_i/V}) = (\hat{X_i/f}) - \hat{A}$. By cost minimization $\Sigma \theta_i (\hat{X_i/f}) = 0$. Also, cost shares sum to unity: $\Sigma \theta_i = 1$. Hence, (3.22) can be written as

$$(3.23) \qquad \hat{p} = \Sigma \theta_i \hat{p}_i - \hat{A},$$

which shows that total factor productivity change shifts the factor price frontier.

Estimates of total factor productivity change on the sectoral level are presented in *table 3.5*. They are calculated on the basis of (3.20) as

$$(3.24) \qquad \hat{T} = \hat{V} - \theta_L\hat{L} - \theta_K\hat{K} - \theta_H\hat{H}.$$

Equation (3.24) measures changes in the efficiency of producing *value-added* as opposed to *output* (gross output net of own inputs). An alternative approach to estimating sectoral gains in factor productivity would be to replace value-added by output and to add intermediate inputs from other sectors as factors of production. Using value-added instead of output will give an upward "bias" to our estimates. To see this, consider the production function

$$(3.25) \qquad Q = A^*f(X,Z),$$

where Q is output, A* is the Hicksian efficiency index, and X and Z are the single primary and intermediate input respectively. We will assume that Q is homogeneous in X and Z. Technical change then affects X and Z to an equal degree.

We now have, by differentiating (3.25) logarithmically,

$$(3.26) \qquad \hat{A}^* = \hat{Q} - \alpha\hat{X} - (1-\alpha)\hat{Z},$$

where $0 < \alpha < 1$.

Value-added V is defined as Q - Z. Thus, equation (3.20) can be rewritten as

$$(3.27) \qquad \hat{A} = \frac{Q}{V}\hat{Q} - \frac{Z}{V}\hat{Z} - \hat{X},$$

assuming there is only one primary input X. The difference between $\hat{A}^*$ and $\hat{A}$ is, using $\hat{Q} = \hat{Z}$,

$$(3.28) \qquad \hat{A}^* - \hat{A} = -(1-\alpha)\hat{Q} + (1-\alpha)\hat{X}.$$

Now, with $\hat{Q} = \hat{Z}$ we have $\hat{A} = \hat{Q} - \hat{X}$ from (3.27). Substituting into (3.28) yields

(3.29) $\hat{A}^* = \alpha\hat{A}$

Thus, if there are intermediate inputs so that α is less than unity, then $\hat{A} > \hat{A}^*$. Consequently, estimates of sectoral rates of total factor productivity change based on value-added will be greater than estimates based on output. The difference will vary in strength between sectors depending on the proportion of intermediate inputs in production.

An immediate explanation for the difference between $\hat{A}$ and $\hat{A}^*$ is apparent by considering equation (3.26). The "error" occurs when Q, output, is replaced by V, value-added, and Z, intermediate inputs, are dropped completely. All of the accounting for output growth falls on direct inputs, X (α becomes equal to unity in value), and technical change in intermediate inputs, which affects output, is ignored.

On the aggregate (national) level there will be no difference between $\hat{A}^*$ and $\hat{A}$, simply because national value-added is identical to national output (gross output net of own inputs).[1]

3.6 ESTIMATES OF TECHNICAL CHANGE

The results of technical change measurement are presented in this section, in subsection 3.6.2. Special attention is given the difference in total factor productivity change between the tradable and the non-traded sectors in subsection 3.6.3. But first, in subsection 3.6.1, we give a short account of the data.

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[1] If one were to calculate the aggregate, national residual from sector residuals, one has to *sum* the residuals with $p_iQ_i/\Sigma p_iV_i$ as weights. The weights sum to more than unity, $\Sigma p_iQ_i/\Sigma p_iV_i > 1$. See Nishimitzu and Hulten [1978] and Star [1974].

3.6.1 *Data*

Data on price changes for the three inputs raw labor, physical and human capital are taken from *table 2.1*. The changes in value-added prices are given by the national accounts, which present value-added data in constant as well as nominal prices.[1]

Input of raw labor services are given by the national accounts in terms of man-hours. The national accounts data on physical capital stocks have been used to calculate service flows on the assumption of constant proportions between stocks and flows. As for inputs of human capital services we separated the labor shares of value-added into raw labor and human capital shares in the way described in chapter 2. The nominal rewards to human capital services were then deflated by the price index given in *table 2.1*. Constant price value-added are given by the national accounts, as mentioned.

Nominal value-added was divided into shares for raw labor, human and physical capital for the years 1950, 1958, 1966 and 1974. There are in many cases substantial differences between years, due to changes in relative factor prices and to different rates of change between factor inputs. This gives rise to the question of which year's shares to use. We choose to estimate the total factor productivity residual for three subperiods, 1950-58, 1958-66 and 1966-74, and to use the average of the beginning and end years' shares as weights on the inputs. As estimates of total factor productivity change for the whole period we take the average of the three subperiods. The procedure eliminates the problem of changing shares to some extent without making the computational effort too great.[2]

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1 All national accounts data are from SM N 1975:98.

2 An alternative discrete approximation of the total factor productivity index,

$$T = \frac{V(t)}{V(0)} \Big/ \prod_{1}^{n} \left(\frac{X_i(t)}{X_i(0)} \right)^{\bar{\alpha}_i},$$

where $\bar{\alpha}_i = [\alpha_i(t) + \alpha_i(o)]/2$, is discussed in Star [1974].

3.6.2 *Results*

Results of computing rates of total factor productivity change according to (3.24) are presented in *table 3.5*.

Table 3.5 Total factor productivity rates of change

		Yearly percentage change			
Sector		*1950-58*	*1958-66*	*1966-74*	*Averages*
1.	Agriculture	-0.9	-0.1	4.2	1.0
2	Forestry	-3.7	-0.9	4.2	-0.1
3	Mining	-3.9	-0.3	1.9	-0.8
4	Import-sheltered food mfg.	-4.1	-0.8	-2.4	-2.4
5	Import-competing food mfg.	2.8	4.9	1.3	3.0
6	Beverage and tobacco	0.3	1.8	2.7	1.6
7	Textiles and clothing	-0.7	3.4	4.5	2.4
8	Wood and wood products	-2.4	3.2	2.9	1.3
9	Printing and publishing	-3.8	-1.3	-1.0	-2.0
10 11	Rubber Chemicals	1.6	1.3	4.2	2.4
12	Petroleum	-2.2	7.9	-2.3	1.1
13	Non-metallic minerals	-0.9	2.0	2.2	1.1
14	Iron and steel	3.3	6.1	3.2	4.2
15	Engineering	1.5	4.9	3.5	3.3
16	Ships	-0.9	3.1	3.9	2.0
17	Other mfg.	-0.1	1.2	6.2	2.4
18	Electricity, gas and water	-0.5	0.7	2.5	0.9
19	Construction	-4.2	-0.5	1.5	-1.1
20	Commerce	-1.2	-1.2	2.5	1.6
21	Transport	-0.6	3.9	5.4	2.9
22	Housing	1.2	0.2	-0.9	0.2
23	Private services	-2.1	-4.9	-0.3	-2.5
24	Public sector	-3.2	-1.9	-1.0	-2.0

Source: Based on national accounts data in SM N 1975:98, Appendix 2, 3 and 5.

It may seem odd that for some sectors total factor productivity change has a negative sign, indicating negative technical change. It must be remembered, however, that by our method of calculating the rate of change of aggregate human capital in chapter 2 we by definition rule out any total factor productivity change on the aggregate level. The zero rate for the aggregate is a weighted average (or, more correctly, a weighted sum) of sectoral rates. These latter are based on the definition of zero aggregate productivity change and must be both positive and negative. What matters for our purposes are the *relative* rates of productivity change among the different sectors, i.e. whether a particular sector experiences a low or high rate in relation to other sectors.

Looking at the last column in *table 3.5* with averages for the three subperiods 1950-58, 1958-66 and 1966-74, we see that *services*, both private and public, have significantly negative rates of productivity change. The result conforms to the popular view of slow technical progress in services. The rate for public services is probably too low however (it should be less negative or positive), due to the national accounting practice of measuring output by the value of inputs. Import-sheltered food manufacturing, Printing and publishing, and, to a lesser degree, Construction, are also sectors with slow technical progress. All three are highly protected from foreign competition, which may be an explanation. The three sectors with the highest rates of technical progress, Import-competing food manufacturing, Iron and steel, and Engineering, are highly exposed to foreign competition, both at home and abroad.

3.6.3 *Difference in technical change between tradable and non-traded sectors*

It has already been observed that some sectors which are less exposed to foreign competition have relatively low rates of total productivity change. To find out if there exists a significant difference between tradable and non-traded sectors we have calculated weighted average rates, as shown in the table below:

Table 3.6 Total factor productivity rates of change in the tradable and non-traded sectors 1950-74

	Average yearly rates, weighted by shares of total value-added
Tradable sectors (all other)	1.09
Non-traded sectors (18, 19, 22, 24)	-0.96

Source: Based on *table 3.5* and *4.6*.

The difference is significant. It should be stressed that some sectors which have very little trade relative to output, and the lowest rates of total factor productivity change, namely Import-sheltered food manufacturing, Printing and publishing, and Private services, are included in the tradable sector. If they were included in the non-traded sector, the difference would be even more significant.

3.7 SUMMARY

In the first half of this chapter we measured the capital intensity of 24 different sectors of the economy and also of two aggregates, the tradable and the non-traded sector. The measures take account of human as well as physical capital.

The results are largely consistent with popular conceptions about relative capital intensities. For example, it was found that Textiles, Commerce, and Private services are labor intensive sectors and that such sectors as Electricity, Mining and steel, and Petroleum are intensive in physical capital. Somewhat more surprising is the relative labor intensity of Engineering, a weighty sector in terms of its share of output and of trade.

A comparison of the aggregated tradable and non-traded sectors revealed that the latter is much more capital intensive. Most of the difference is due to the extreme physical capital intensity of the Housing and also of the Electricity sector. However, it was also shown that the Public sector, somewhat unexpectedly, is more capital intensive than the tradable sector, both in terms of physical capital and in terms of physical-*cum*-human capital. The capital intensity of the tradable sector increases substantially over time, while the capital intensity of the non-traded tends to fall, primarily because the composition of the non-traded aggregate changes.

The stability of the observed capital intensity differentials over time was tested by correlating the rankings for the years 1950, 1958, 1966, and 1974. All rank correlation coefficients were found to be positive and highly significant. We concluded that although some capital intensity reversals have taken place, they are not an important feature of technical change.

In the second half of the chapter we attempted to estimate rates of change in total factor productivity for three periods, 1950-58, 1958-66 and 1966-74. It was found that the relative rate of total factor productivity change is low in private and public services. Other sectors with very low rates are Import-sheltered food manufacturing, Printing and publishing and Construction. The three sectors with the highest rate of technical progress are Import-competing food manufacturing, Iron and steel and Engineering, all of which are highly exposed to foreign competition.

Finally, we found a significantly higher rate of change in total factor productivity for the aggregate tradable sector relative to the aggregate non-traded sector.

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CHAPTER 4 CHANGES IN ALLOCATION AND PRICES*

4.1 INTRODUCTION

Changes in the allocation of output (value-added) and of primary resources as well as changes in relative prices of value-added are described in this chapter. As in chapters 2 and 3 the emphasis is on pure description.

As seen within the theoretical framework outlined in chapter 1, this chapter deals with movements both in dependent and independent variables, whereas the previous two chapters were concerned with changes only in independent variables: factor endowments, factor proportions and technical change (total factor productivity change). Allocation of resources and of output within the tradable sector is endogenous within our theoretical framework as well as prices on non-traded goods, while prices on traded goods are assumed to be given on the world market, outside the influence of the small country, and the extent of non-traded output is determined exogenously by domestic demand.

The changes in allocation and prices which are observed in this chapter will allow us to draw conclusions about the properties of the demand for non-traded goods. Changes in

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the demand for non-traded goods affect allocation in the tradable sector and are therefore important to determine.

The plan of the chapter is as follows. Allocations at different points in time are described in section 4.2, for value-added, and in section 4.3, for primary resources. Particular interest is given the allocation between tradable and non-traded goods, because of its central place in the analytical framework. In section 4.4 some important relative price changes are noted. Section 4.5 contains a brief summary and an observation about what implications the recorded development has for the demand for non-traded goods.

4.2 CHANGES IN THE ALLOCATION OF VALUE-ADDED

Consider *table 4.1*, which shows the allocation of value--added in constant prices between 24 sectors of the Swedish economy in 1950, 1958, 1966 and 1974. The disaggregation is the same as in chapter 3.

We note first that there is considerable variation in size between sectors, from Engineering, with a share of total value-added in 1974 of 16.1 per cent, to Other manufacturing, with a share of 0.2 per cent. To get a picture of the degree of concentration in the sector structure, and also of changes in concentration, we have calculated the combined share of the 2, 4 and 8 largest and smallest sectors respectively in 1950, 1958, 1966 and 1974, see *table 4.2*.

A modest tendency towards increased concentration, as measured by these shares, is seen in the table. Most of the increase is due to the relative growth of Engineering.

Table 4.1 Sectoral shares of total value-added in constant prices in 1950, 1958, 1966 and 1974

Sector		Percentage shares			
		1950	1958	1966	1974
1	Agriculture	7.2	5.0	3.1	2.9
2	Forestry	3.9	3.5	2.6	2.4
3	Mining	1.4	1.6	1.7	2.0
4	Import-sheltered food mfg	3.0	2.1	1.4	0.9
5	Import-competing food mfg	0.5	0.7	1.0	1.0
6	Beverage and tobacco	0.5	0.5	0.4	0.4
7	Textiles and clothing	4.4	3.2	2.8	2.1
8	Wood and wood products	4.2	4.0	4.6	5.4
9	Printing and publishing	2.4	2.0	1.7	1.3
10	Rubber	0.3	0.4	0.5	0.5
11	Chemicals	1.3	1.6	1.8	3.0
12	Petroleum	0.2	0.2	0.4	0.4
13	Non-metallic minerals	1.6	1.3	1.5	1.2
14	Iron and steel	1.2	1.8	2.8	3.2
15	Engineering	8.0	10.3	13.9	16.1
16	Ships	1.0	1.2	1.1	1.4
17	Other manufacturing	0.3	0.3	0.2	0.2
18	Electricity, gas and water	2.0	2.6	2.7	3.2
19	Construction	9.8	9.8	10.2	8.7
20	Commerce	8.8	9.3	9.0	8.4
21	Transport	5.5	5.6	6.0	6.5
22	Housing	10.1	10.8	9.2	8.0
23	Private services	11.6	11.1	10.8	9.2
24	Public sector	10.7	11.2	10.7	11.6

Source: SM N 1975:98, Appendix 4.

Table 4.2 Concentration in the sector structure in 1950, 1958, 1966 and 1974

	Percentage shares of total value-added			
	1950	1958	1966	1974
2 largest sectors	22.3	22.3	24.7	27.7
4 " "	42.2	43.4	45.6	45.6
8 " "	71.7	73.1	74.4	73.9
2 smallest sectors	0.5	0.5	0.6	0.6
4 " "	1.5	1.4	1.5	1.5
8 " "	6.4	6.2	6.5	5.9

Source: Table 4.1.

Turning next to changes for individual sectors in *table 4.1* an important change is the drop in Agriculture's share, from 7.2 per cent in 1950 to 2.9 per cent in 1974. Textiles and clothing and Private services also have shares which decrease by more than 2 percentage points. Many sectors experience substantial increases or decreases in relative terms, although their absolute shares generally are quite small. The shares of Mining, Import-competing food, Chemicals, Petroleum and Iron and steel are doubled or more than doubled, while the shares of Import-sheltered food and Textiles and clothing are more than halved.

An important distinction for analytical purposes which is made in chapters 1 and 3 and again in chapter 6, 7 and 8 is that between *tradable* and *non-traded* goods. The shift in output allocation between the tradable and non-traded sector is given in *table 4.3:*

Table 4.3 Total value-added in constant prices divided between the tradable and non-traded sector in 1950, 1958, 1966 and 1974

Sector	*Percentage shares*			
	1950	*1958*	*1966*	*1974*
Tradable	67.4	65.6	67.2	68.5
Non-traded (18,19,22,24)	32.6	34.4	32.8	31.5

Source: Table 4.1.

The non-traded sector of the economy, which consists of sectors 18, 19, 22 and 24, has a fairly constant share of total output over time.

Finally, note in *table 4.1*, that the *Public sector's* share of total output is more or less constant when measured in constant prices.

4.3 CHANGES IN THE ALLOCATION OF FACTORS OF PRODUCTION

The allocation of primary inputs is generally not the same as that of output. Differences are attributable to differences in *factor proportions* between sectors, and to differences in the *efficiency* (factor productivity) with which factors are used in production. A labor intensive sector with low efficiency, such as Commerce, will have a larger share of the total labor supply than it has of output. If its efficiency does not increase over time its labor share is likely to increase relative to its output share. The allocation of factors of production in 1950 and 1974 is shown in *table 4.4:*

Table 4.4 Sectoral shares of total supplies of labor (L), physical (K) and human (H) capital in 1950 and 1974

		Percentage shares					
Sector		*1950*			*1974*		
		L	K	H	L	K	H
1	Agriculture	17.7	8.1	0.0	5.1	4.1	0.0
2	Forestry	3.2	0.5	3.1	1.5	0.6	1.0
3	Mining	0.6	0.3	0.9	0.5	0.7	0.8
4	Import-sheltered food mfg	2.3	1.0	2.1	1.5	0.7	1.2
5	Import-competing food mfg	0.6	0.4	0.5	0.6	0.5	0.7
6	Beverage and tobacco	0.4	0.2	0.7	0.2	0.2	0.3
7	Textiles and clothing	6.3	1.2	4.5	1.8	0.7	1.3
8	Wood and wood products	5.4	2.3	4.6	4.3	3.6	4.6
9	Printing and publishing	1.6	0.7	2.7	1.7	0.9	2.4
10	Rubber	0.5	1.0	0.4	0.4	1.3	0.5
11	Chemicals	1.1		1.4	1.6		2.2
12	Petroleum	0.2	0.1	0.2	0.1	0.2	0.1
13	Non-metallic minerals	1.6	1.0	1.9	1.1	0.9	1.2
14	Iron and steel	1.7	1.4	2.9	2.0	2.3	3.0
15	Engineering	10.2	3.0	13.1	12.8	4.1	12.8
16	Ships	1.0	0.4	1.5	1.0	0.4	1.6
17	Other manufacturing	0.4	0.1	0.4	0.2	0.1	0.2
18	Electricity, gas and water	0.8	4.8	1.2	0.9	8.1	0.8
19	Construction	7.7	0.7	11.8	9.3	1.4	10.5
20	Commerce	11.7	1.6	10.2	13.0	3.5	9.0
21	Transport	7.6	9.4	10.4	7.1	8.8	5.0
22	Housing	0.5	50.5	0.5	0.7	39.5	0.8
23	Private services	9.0	1.2	4.8	11.0	3.3	7.8
24	Public sector	8.2	10.0	20.2	21.8	14.2	32.4

Source: SM N 1975:98, Appendix, 2, 4 and 5.

Agriculture experiences a substantial decrease in its share of labor, which drops from 17.7 per cent to 5.1 per cent between 1950 and 1974. The decrease in its physical capital share is also great, but smaller than the fall in the output share. It is evident that the relative decline of Agriculture has been accompanied by an increasing total factor productivity relative to other sectors (cf. *table 3.2* and *3.5*).

It was shown in the previous section that the Public sector's share of output is constant over time. This can be contrasted with its labor share, which has increased by 166 per cent, and its physical and human capital shares, which have increased by 42 and 60 per cent respectively.

The Housing sector commands a very high proportion of the physical capital supply. Its share has decreased substantially in percentage terms, however, from 50.5 to 39.5 per cent. It is also notable that Engineering does not have as high increases in its factor shares as in its output share, i.e. it has a high rate of total factor productivity advance (cf. *table 3.5*). Textile and clothing's rapid productivity increase is also evident by a comparison of input and output shares in 1950 and 1974. In contrast, the decrease in total factor productivity in Private services is reflected in substantial relative increases in physical and human capital shares, at the same time as the output share is falling, see *table 4.1*.

Let us next turn to the division between tradable and non-traded goods employed in the previous section. *Table 4.5* below shows how factors are allocated between the two sectors in 1950 and 1974:

Table 4.5 The allocation of labor (L), physical (K) and human (H) capital between the tradable and non-traded sector in 1950 and 1974

Sector	Percentage shares					
	1950			*1974*		
	L	K	H	L	K	H
Tradable	82.8	34.0	66.3	67.3	36.8	55.5
Non-traded (18,19,22,24)	17.2	66.0	33.7	32.7	63.2	44.5

Source: Table 4.4.

The non-traded sector increases its shares of labor and human capital substantially between 1950 and 1974. A major part of the increases is due to the Public sector. The physical capital share, on the other hand, falls somewhat. The fall depends on the decrease in Housing's physical capital share, which is only partially countered by increases for the other sectors making up the non-traded sector. A comparison of *table 4.5* with *table 4.4* reveals that while the non-traded sector's shares of inputs generally have increased substantially, its output shares are constant or falling. This is another illustration of the low rate of total productivity change in the non-traded sector compared to the tradable sector which was shown in chapter 3.

4.4 CHANGES IN RELATIVE PRICES

To describe changes in relative prices of value-added we choose to compare the allocation of value-added in *current* prices with that in *constant* prices over time. The current price allocation is shown in *table 4.6:*

Table 4.6 Sectoral shares of total value-added in current prices in 1950, 1958, 1966 and 1974

Sector		Percentage shares			
		1950	*1958*	*1966*	*1974*
1	Agriculture	6.7	4.9	3.2	2.7
2	Forestry	4.4	3.9	2.6	2.6
3	Mining	1.3	1.7	1.2	1,0
4	Import-sheltered food mfg	2.9	2.3	2.5	2,1
5	Import-competing food mfg	0.6	0.6	0.8	0.9
6	Beverage and tobacco	0,6	0.5	0.5	0.4
7	Textiles and clothing	4.9	3.0	2.3	1.4
8	Wood and wood products	5.6	4.2	4.0	6.7
9	Printing and publishing	1.9	1.9	2.1	1.9
10	Rubber	0.4	0.4	0.4	0.4
11	Chemicals	1.4	0.4	1.7	2.6
12	Petroleum	0,2	0.3	0.3	0,3
13	Non-metallic minerals	1.5	1.2	1.4	1.0
14	Iron and steel	1.6	1.8	2.0	2.3
15	Engineering	9.7	10.1	10.7	12.4
16	Ships	1.0	1.1	0.8	1.0
17	Other manufacturing	0.3	0.3	0.2	0.2
18	Electricity, gas and water	2.0	2.6	2,2	2.2
19	Construction	9.0	9.7	11.6	7.2
20	Commerce	9.5	9.3	10.0	9.1
21	Transport	5.6	5.6	5.1	4.8
22	Housing	10.8	10.2	9.2	7.2
23	Private services	8,4	12,5	10,9	10,6
24	Public sector	8.8	10.8	14.3	19.1

Source: SM N 1975:98, Appendix 4.

By comparing *table 4.6* with *table 4.1* we find particularly big differences between changes in current and constant price shares for Import-sheltered food, Printing and publishing, Iron and steel, Engineering, Ships, Electricity, gas and water and the Public sector. (All these sectors have very high or very low rates of total factor productivity change, see *table 3.5*). Note in particular the more or less constant share for the Public sector in constant prices, and the big increase in the current price share, from 8.8 per cent in 1950 to 19.1 per cent in 1974.

Again, let us make a division between tradable and non--traded sectors and see how current price value-added is allocated between them:

Table 4.7 Total value-added in current prices divided between the tradable and non-traded sector in 1950, 1958, 1966 and 1974

Sector	*Percentage shares*			
	1950	*1958*	*1966*	*1974*
Tradable	69.4	66.7	62.7	64.3
Non-traded (18,19,22,24)	30.6	33.3	37.3	35.7

Source: Table 4.6

A comparison between *table 4.7* and *table 4.3*, with constant price shares, reveals that the relative price of non-traded goods has increased. The non-traded sector's constant price shares are constant over time or falling, while its current price shares are rising. Most of this relative price change is due to the sharply increased relative price of public services.

4.5 SUMMARY

The allocation of value-added between 24 sectors of the economy exhibits some substantial changes between 1950 and 1974. In particular, the share of the Engineering sector is doubled, from 8.0 to 16.1 per cent. The degree of concentration in the sector structure is increased somewhat, mostly because of the relative growth of Engineering.

A division of sectors into tradable and non-traded yields the following observations:

1. The non-traded sector has a more or less constant share of value-added in constant prices. Its current price share, on the other hand, is increasing. Hence, the relative price of the non-traded sector is increasing also.

2. Although the non-traded sector's share of constant price value-added is constant, its share of the labor supply is doubled and of the human capital supply increased by some 30 per cent. This reflects both a more or less constant capital intensity and low relative rate of total factor productivity change, as was shown in chapter 3.

The observation made under 1. above allows us to draw conclusions concerning the demand for non-traded goods. A constant proportion of non-traded goods in total output means, when looked at from the demand side, that the *demand* for non--traded goods has been a constant proportion of total demand. Let us view total demand as made up of only two components: demand for non-traded goods and demand for tradable goods. Given the rise in the (relative) price of non-traded goods and the increase in total income, two parameters in the demand function for non-traded goods determine demand, namely the price and income elasticity of demand. If the price elasticity were zero, it follows that the income elasticity is equal to one for both goods; only then will the composition of total demand remain fixed. Hence, at a negative price elasticity the income elasticity for non-traded goods must be greater than one. We make the reasonable assumption that the price elasticity has some negative value. The income elasticity is therefore likely to have a value greater than unity.

Another possible interpretation of the development of demand is that there has been a shift in *taste* towards non--traded goods. It is not possible to discriminate between an explanation in terms of a high income elasticity and an explanation which is based on a shift in taste.

CHAPTER 5 CHANGES IN FOREIGN TRADE*

5.1 INTRODUCTION

Let us briefly recapitulate what the model in chapter 1 has to say about foreign trade. It is technology, tradable prices, factor endowments, and the demand for non-traded goods which determine how much and which tradables are produced. Domestic demand for tradables plays no role for resource allocation within the tradables sector. Once outputs of tradables are determined it is however domestic demand for tradables which determines which of the goods will be exported and which will be imported. Hence, the model determines the *proportion of total trade to total output*, or income. Total income is given once factor endowments and factor prices are known. The *pattern of trade*, the composition of exports and of imports, is also determined.

It was argued that a country will tend to produce more of tradable goods which are intensive in the country's abundant factor(s) and less of tradable goods which are intensive in the scarce factor(s) than is consumed domestically. Hence, in a world with capital and labor as the only factors of production, a capital abundant country will export capital intensive

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and import labor intensive goods. In other words, its *comparative advantage* will depend on its factor endowment position relative to the rest of the world.

Although the small country is assumed to be unable to influence world market prices, it can influence domestic prices by putting tariffs on imports. It was shown that a tariff, or a change in tariffs, affects resource allocation and, hence, both the relative size and the pattern of trade.

In this chapter we attempt to determine and describe the real-world counterparts of the different aspects of trade in the model: the relative size of trade, the trade pattern, comparative advantage, the terms-of-trade and the tariff structure. The contents of the chapter are arranged in the following way. Changes in the relative size of total trade are described in section 5.2. The section also contains a description of the extent of intra-industry trade, a phenomenon which is not present in the theoretical model of chapter 1. The following section 5.3 discusses the theoretical implications of the existence of intra-industry trade, and in particular the implications for our choice of theoretical approach. In section 5.4 changes in the pattern of exports and imports are shown. An attempt to test for Sweden's comparative advantage and its change over time is in section 5.5. In section 5.6 we give a brief account of the results of other tests of Sweden's comparative advantage. It serves to put our conclusions in section 5.5 on somewhat firmer ground. The development over time of the terms-of-trade is described in section 5.7. Section 5.8 describes the tariff structure and also the association between tariff levels and factor proportions. Section 5.9, finally, contains a summary of the main findings.

5.2 CHANGES IN THE RELATIVE SIZE OF TRADE

The extent to which a country participates in the international division of labor is commonly (but not always) measured by the ratio between aggregate exports (or imports) and aggregate output. Changes in the degree of international specialization over time are interesting in themselves, and this is one reason for our interest in the export-output ratio.

Another reason for our interest is that the ratio under some assumptions about changes in export and import prices is an elasticity of real national income with respect to the terms-of-trade. Terms-of-trade effects on real income can be expressed as (see Caves and Jones [1973])

$$(5.1) \qquad \hat{y} = \sum_{i=1}^{n} \beta_i \hat{p}_i ,$$

where $\hat{y}$ is the relative change in real income y, $\hat{p}_i$ is the relative change in price p_i of good i (i=1,...,n) and $\beta_i = p_i(X_i - D_i)/y$ is the value share of excess demand i (i = 1,...,n). The excess demand for good i is positive for exportables i = 1,...,m and negative for importables i = m+1,...,n.

Assume now that all prices on exportables change at the same rate, and likewise for all prices on importables, i.e.

$$\hat{p}_i = \hat{p}_E \qquad i = 1,\ldots,m$$

$$\hat{p}_i = \hat{p}_M \qquad i = m+1,\ldots,n$$

Substitute these price changes into (5.1) to obtain

$$(5.2) \qquad \hat{y} = \sum_{i=1}^{m} \beta_i \hat{p}_E + \sum_{i=m+1}^{n} \beta_i \hat{p}_M.$$

The sum of positive value shares $\sum_{i=1}^{m} \beta_i$ is simply the aggregate export-income (output) ratio, which is equal to the sum of negative value shares $\sum_{i=m+1}^{n} \beta_i$ except for sign. Hence, we can write (5.2) as

$$(5.3) \qquad \hat{y} = \beta_E(\hat{p}_E - \hat{p}_M),$$

where $\beta_E = \sum_{i=1}^{m} \beta_i$. By (5.3) the aggregate export-income ratio is the elasticity of real national income with respect to changes in the terms-of-trade.

It should be stressed that to arrive at (5.3) we held relative prices among exportables and among importables constant. All exportables have effectively been aggregated to one export good and all importables aggregated to one import good.

5.2.1 *The aggregate export-output ratio*

The development of the ratio between total exports and GNP from 1950 to 1954 is shown in *table 5.1* below. (The import--output ratio shows an almost identical development over time.)

Table 5.1 Export-GNP ratios. 4-year averages (except for 1950-54)

	1950-54	*1955-58*	*1959-62*	*1963-66*	*1967-70*	*1971-74*
Current prices	0.23	0.23	0.22	0.22	0.23	0.29
Constant prices	0.19	0.21	0.23	0.28	0.30	0.39

Sources: SM N 1975:98, Appendix 3 and 4.

As can be seen, the constant price ratio rises steadily, from 0.19 to 0.39. The ratio in terms of current prices, on the other hand, is more or less constant, with the exception of the last period 1971-74.[1] The conflicting trends are explained by two factors. First, there has been a rise in the volume of trade relative to the output volume, as recorded by the constant price time series. Second, the relative price of tradable commodities has been falling, as described in the previous chapter. The rise in volume has been sufficient to counter the fall in relative price for the current price ratio to remain constant for most of the period.

5.2.2 *Sectoral export-output and import-output ratios*

The trend of increased trade relative to output is quite strong in some sectors, see *table 5.2* which shows export--output and import-output ratios in 1959, 1966 and 1974. (We cannot go back to 1950, because official trade statistics classified according to industry do not exist earlier than 1959.)

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[1] The upturn in 1971-74 was temporary, as data for the end of the 1970's show, and was mainly caused by a temporary shift in relative prices towards natural resource based goods, such as iron ore and forest products, which are important Swedish exportables.

Table 5.2 Sectoral export-output (E/O) and import-output (M/O) ratios.[1] Constant prices.

	Sector	*1959*		*1966*		*1974*	
		E/O	M/O	E/O	M/O	E/O	M/O
1	Agriculture	4.4	20.3	5.7	25.6	7.7	25.9
2	Forestry	5.2	3.3	7.2	2.0	4.6	3.9
3	Mining	70.7	64.4	59.6	54.8	66.9	61.1
4	Import-sheltered food mfg.	3.0	4.3	4.0	5.0	4.2	7.4
5	Import-competing food mfg.	5.7	30.7	3.9	28.5	7.2	34.5
6	Beverage and tobacco	2.2	15.1	2.1	24.6	3.8	26.2
7	Textiles and clothing	5.0	24.8	12.1	38.1	30.0	74.4
8	Wood and wood products	44.9	2.0	42.9	3.4	44.1	5.3
9	Printing and publishing	1.1	1.7	2.8	3.0	4.7	4.7
10	Rubber	15.2	19.3	23.4	32.9	40.9	54.6
11	Chemicals	17.2	43.6	22.9	55.4	30.3	61.2
12	Petroleum	23.7	282.8	30.5	288.6	70.7	196.0
13	Non-metallic minerals	7.6	13.8	7.5	14.4	14.5	23.1
14	Iron and steel	28.7	37.4	31.9	31.7	41.8	34.9
15	Engineering	26.0	32.7	33.0	31.8	49.3	40.3
16	Ships	50.4	22.4	45.7	20.9	52.4	37.0
17	Other mfg.	9.4	36.8	25.4	64.7	52.8	90.0
18	Electricity, gas and water[2]	-	-	-	-	-	-
19	Construction[2]	-	-	-	-	-	-
20	Commerce	2.0	1.7	1.5	1.5	6.5	3.7
21	Transport	26.4	4.9	24.2	5.8	29.5	10.4
22	Housing[2]	-	-	-	-	-	-
23	Private services	6.7	3.8	5.8	2.9	8.7	5.5
24	Public sector[2]	-	-	-	-	-	-

1) Export and import values divided by output values.

2) No exports and imports reported.

Sources: Unpublished data from Ministry of Economic Affairs; SM N 1975:98 Appendix 4.

There is considerable variation in the degree to which goods are traded in the different sectors. A few sectors have no recorded trade at all: Electricity, gas and water, Construction, Housing, and the Public sector. Four sectors have quite small export- and import-output ratios: Forestry, Import-sheltered food manufacturing, Printing and publishing, and Commerce. Among the most traded sectors are Mining, Textiles and clothing (in 1974), Rubber (in 1974), Chemicals, Petroleum, Engineering and Ships.

Obviously there is also considerable variation in the degree of trade *within* sectors, since many are made up of quite heterogeneous goods. The Transport and Private services sectors are cases in point. Most of the exports of transport services are due to the shipping industry. Its services are certainly traded to a much greater extent than, say, those of Swedish railroads. Many private services are virtually non-traded, as restaurant services, while others are traded extensively, as for example the services of management and engineering consultants.

Another general observation which can be made based on *table 5.2* is the presence of substantial *intra-industry trade*. Few sectors can be classified as exportables or importables.

In a loose way we can classify Agriculture, Import--competing food manufacturing, Beverage and tobacco and, possibly, Petroleum as importable sectors. In the same manner Wood and wood products stands out as a sector which produces exportables. But most sectors have export-output and import--output ratios which are of the same order of magnitude or where both are of significant size.

The amount of intra-industry trade recorded in *table 5.2* is to some extent a function of a high level of aggregation. For example, disaggregation of Engineering would dissolve much of the intra-industry trade, as demonstrated by

Lundberg [1981]. Section 5.3 contains a discussion of the determinants of intra-industry trade, including the effects of statistical classification and aggregation.

5.3 INTRA-INDUSTRY TRADE

We have observed that Sweden's aggregate export-output ratio, in terms of constant prices, has been increasing, mainly as a result of increasing *intra*-industry trade and not inter--industry trade. Such a development is difficult to explain within the framework of Heckscher-Ohlin theory. If all goods produced within a sector uses factors of production in identical proportions there is no basis for Heckscher-Ohlin trade.

How is one to explain the existence of intra-industry trade? The answer to this question, which by now has given rise to a considerable literature, has obvious relevance for the present study, which rests on Heckscher-Ohlin theory. Of Sweden's trade in 1974 some 67 per cent was intra-industry trade at the level of aggregation employed here.[1] Many industrial countries have intra-industry trade as a proportion of total trade in manufactured commodities in excess of 70 per cent, as France, the United Kingdom, the Netherlands, West Germany, Austria, Canada, Italy, Denmark, and Belgium in 1972 according to Aquino [1978]. Moreover, the proportion of intra--industry seems to be rising, Lundberg [1981] reports such a development in Swedish manufacturing trade and Balassa [1966], Grubel [1967], Hesse [1974], Grubel and Lloyd [1975] and Aquino [1978] all show growing intra-industry trade in the trade of other industrialized countries.

It is commonly thought that much of what is registered as intra-industry trade is due to statistical misrepresentation. Activities with different factor proportions have

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1 Defined as $1 - \frac{\Sigma |X_i - M_i|}{\Sigma X_i + \Sigma M_i}$.

wrongly been put in the same statistical sector so that what in fact is inter-industry trade is registered as intra-industry trade.

It is certainly true that our sector disaggregation is based on other considerations than factor proportions similarity, as was noted in chapter 3, and therefore that some intra-industry trade is a statistical phenomenon. Also, the level of aggregation is quite high, with all engineering industries in one sector, so that one expects a high degree of variation in factor proportions within the different sectors.

However, when Hesse [1974] calculates the proportion of intra-industry trade on the basis of more disaggregated classifications than the three-digit SITC he still finds a high level of intra-industry trade. In a recent study of Swedish intra-industry trade and its determinants Lundberg [1981] calculates the proportion of intra-industry trade for 3-, 4- and 5-digit SNI manufacturing industries. His results are reproduced in *table 5.3* below:

Table 5.3 Intra-industry trade in per cent of total Swedish trade with groups of countries in 1977, computed on different aggregations levels.

Country group	*3-digit*	*4-digit*	*5-digit*
1. Other LDC:s	7.6	6.8	5.7
2. Asian NIC:s	17.1	14.4	12.5
3. South Europe	28.5	25.9	14.2
4. EEC	57.6	55.8	52.6
5. Other Western Europe	68.1	65.9	65.8
6. Other Industrial Countries	70.9	51.5	51.4
7. Planned economies	28.9	23.2	27.4

Table 5.3 (continued)

Notes: Shares are unadjusted for current account imbalances in bilateral flows. Trade data have been computed for manufacturing industries on the 3-digit (first column) and 4-digit (second column) levels of the SNI, which is practically identical with the ISIC. There are in all 29 3-digit and 77 4-digit groups. For 23 4-digit groups, trade data have been disaggregated to a 5-digit industry level (third column), following a classification made by the World Bank (*Manufacturing, Concordance between ISIC and SITC classifications*, Mimeo, May 1979), giving 62 sub-groups. Note that the data in column 3, unlike columns 1 and 2, do not cover all trade in manufactured products.

Country notes:

1. Africa, excl. Rhodesia and South Africa, Middle East, excl. Israel and Turkey, South Asia, South East Asia, excl. Singapore, Pacific Islands, Central and South America.
2. Hongkong, Macao, Singapore, Taiwan, South Korea.
3. Greece, Portugal, Spain, Cyprus, Gibraltar, Israel, Malta, Turkey, Yugoslavia.
4. Belgium, Denmark, France, Fed. Rep. of Germany, Ireland, Italy, Luxembourg, Netherlands, United Kingdom.
5. Austria, Finland, Iceland, Norway, Switzerland.
6. USA, Canada, Japan, Australia, New Zealand, Rhodesia, South Africa.
7. Albania, Bulgaria, Czechoslovakia, Dem. Rep. of Germany, Hungary, Poland, Romania, USSR, China, Cuba, Kampuchea, North Korea, Laos, Mongolia, Vietnam.

Source: Reproduced from Lundberg [1981], *table 2*.

The proportion of intra-industry trade is in most cases affected very little by disaggregation. About 60 per cent of Sweden's trade is with EEC and Other Western Europe, and here the proportion is reduced only marginally.

Aquino [1978] tries a different route to resolve the problem of inappropriate industry classification. He reclassifies products according to *technology intensity*, which he considers to be a key variable. Hence, his classification is based on factor proportions differences, namely differences in the proportion of technology inputs in total inputs. Despite the reclassification intra-industry trade as a proportion of total trade remains high.

If one accepts the existence of intra-industry trade even at much lower levels of aggregation, it becomes necessary to resort to other explanations of trade than the factor proportions theory. This is even more so when one considers the fact that intra-industry trade is a growing proportion of trade, and that trade relative to output is also growing. Within the Heckscher-Ohlin framework the tendency in Sweden and other industrialized countries of growing trade-output ratios must be explained by increasing dissimilarity in factor endowments (assuming a neutral influence from demand). Such an explanation is hardly plausible, since it is probable that postwar economic development has made the industrialized countries, which mainly trade with each other, more similar in their endowments.[1]

Among alternative or rather complementary theories of trade we will only mention two, namely the theories of Burenstam-Linder [1961] and others, which build on a combination of differences in income levels, economies of scale, product differentiation and monopolistic competition, and the Ricardian theory, based on differences in technology.[2]

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[1] In chapter 6 it is demonstrated, as a special case, that a country can change its factor endowments in its tradables sector in a more specialized direction, so that trade's relative share increases, by changing the factor proportions in the non-traded sector, or by expanding or contracting the non-traded sector. Thus, it is the factor endowments of the tradable sector which are relevant.

[2] For a further discussion of the role of income levels, product differentiation, dynamic technology differences, and economies of scale for foreign trade, particularly intra-industry trade, see Caves and Jones [1973], chapter 11. Hufbauer [1970] gives a comprehensive survey of hypotheses and tests of trade patterns up to 1970.

It seems likely that factor proportions differ not only within a statistical sector at a given set of factor prices, but also between countries in the production of narrowly defined commodities. Comparative costs should differ for this reason and give rise to intra-industry trade. Such technology differences may be dynamic as well as static in nature. Vernon's [1966] product cycle theory of trade should be seen as a dynamic version of the Ricardian theory. It is possible that the theory explains more of international trade than the Heckscher-Ohlin theory. Some studies confirm the product cycle character of trade for countries with a high level of innovation, such as the U.S. See Gruber, Mehta and Vernon [1967] and Hufbauer [1970].

A second set of theories, associated with the names of Burenstam-Linder [1961], Drèze [1960], and Grubel and Lloyd [1975], builds on several elements, which are given different weights in the different versions of the theory. Very briefly, it is argued that similarity in income levels, product differentiation, monopolistic competition, and economies of scale combine to give more trade between countries, and more intra-industry trade.[1]

Products, it is argued, are typically differentiated by design, functional details, image created by advertising, etc., and the market structure is one of monopolistic competition. Trade gives consumers the possibility to buy variants of a product which is not available in the home country. The more

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[1] Recently a number of formal trade models have been constructed to incorporate product differentiation, monopolistic competition, and economies of scale, e.g. by Krugman [1980], Dixit and Norman [1980], Lancaster [1980], and Helpman [1980]. The models explain *inter*-industry trade by factor endowments differences and the relative size of *intra*-industry trade by economies of scale, monopolistic competition and product differentiation. Helpman obtains the result that the proportion of intra-industry trade in total trade declines when the difference in factor endowments (capital-labor ratios) becomes greater. When there is no difference in factor endowments all trade is intra-industry trade.

differentiated products are, the greater is the potential trade between countries, in particular within the same industries (Grubel and Lloyd [1976]). If in addition income levels are similar in trading countries, one expects demand to be similar also. This will increase the possibility that consumers want to buy product variants from other countries (Burenstam Linder [1961]).[1] Furthermore, it is sometimes postulated that the degree of differentiation in demand increases with income. The existence of economies of scale makes the number of variants produced in a country less than the number demanded and makes consumers buy imported variants instead of those available at home. This is particularly true for small countries. Drèze [1960] argues that Belgian exports are characterized by relatively few standardized intermediate commodities (intermediate commodities without national characteristics) produced under economies of scale and imports by differentiated consumer goods.

In conclusion, it is probable that a substantial part of the trade between industrialized countries can be explained by the theories mentioned above and that a relatively small part is explained by Heckscher-Ohlin theory. Most trade between industrialized countries is intra-industry trade, even on very disaggregated levels, which, as mentioned, is hard to reconcile with the factor proportions theory. Factor proportions differences probably are more important in explaining inter-industry trade and trade between countries at quite different stages of economic development.

However, one should therefore *not* draw the conclusion that it is wrong to use Heckscher-Ohlin theory as the basis for the present study. Firstly, it must be observed that the Heckscher-Ohlin model is a full general equilibrium model which is firmly based on standard neoclassical theory, and which has thoroughly investigated and well-known properties. As of now the same cannot be said about the theories outlined

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1 The results in *table 5.3* are in agreement with this hypothesis.

above, although formalized models do exist and rapid progress seems assured in the area. Secondly, the present study is also a test of the usefulness for empirical research of the standard Heckscher-Ohlin model. In other words, although it is known at the outset that much trade cannot be explained by factor proportions differences, we wish to gain more precise knowledge about how useful the model is.

5.4 TRADE PATTERN CHANGES

The pattern of trade has undergone considerable change during the period 1959-74. We are going to describe these changes in two ways, namely in terms of changes in export and import patterns and in terms of changes in the degree of sectoral trade specialization. The purpose is to see if the patterns are stable, or if there are some significant and systematic changes.

5.4.1 *Changes in export and import patterns*

Sectoral shares of exports and imports in 1959, 1966 and 1974 are shown in *table 5.4* below.

Table 5.4 Sectoral shares of total exports and imports.
Constant prices.

Sector		Imports			Exports		
		Percentage shares					
		1959	*1966*	*1974*	*1959*	*1966*	*1974*
1	Agriculture	1.8	1.4	1.1	8.6	6.7	4.2
2	Forestry	0.7	0.6	0.3	0.5	0.2	0.3
3	Mining	4.6	3.8	3.3	4.3	3.6	3.4
4	Import-sheltered food mfg.	1.8	1.6	0.9	2.6	2.0	1.7
5	Import-competing food mfg.	0.7	0.5	0.6	3.9	4.1	3.3
6	Beverage and tobacco	0.1	0.1	0.1	0.8	1.0	0.8
7	Textiles and clothing	1.5	2.4	2.9	7.7	8.0	8.3
8	Wood and wood products	23.8	19.9	15.5	1.1	1.6	2.1
9	Printing and publishing	0.2	0.4	0.4	0.4	0.5	0.5
10	Rubber	0.5	0.7	0.8	0.7	1.1	1.3
11	Chemicals	2.7	3.5	4.9	7.1	8.9	11.2
12	Petroleum	0.8	1.0	2.1	9.8	10.0	6.7
13	Non-metallic minerals	0.9	0.9	0.9	1.7	1.7	1.6
14	Iron and steel	7.3	8.5	7.8	9.6	8.8	7.4
15	Engineering	23.6	31.8	37.2	30.2	31.8	34.4
16	Ships	5.6	4.7	4.2	2.5	2.2	3.4
17	Other manufacturing	0.3	0.5	0.6	1.2	1.3	1.2
20	Commerce	1.9	1.1	2.9	1.6	1.1	1.9
21	Transport	16.1	12.2	10.1	3.1	3.1	4.0
23	Private services	4.9	4.1	3.5	2.8	2.1	2.5

Source: Unpublished data from the Ministry of Economic Affairs.

Under the given sector disaggregation a few sectors dominate both exports and imports. Of total exports in 1974, 63.4 per cent come from the Wood and wood products, Engineering and Transport sectors. On the import side, the three biggest sectors in 1974 are Textiles and clothing, Chemicals and Engineering, which have 53.9 per cent of all imports.

Although trade in both directions is concentrated to a few sectors there is no upward or downward trend in concentration. The Gini coefficients of concentration for exports and imports are:

Table 5.5 *Concentration in exports and imports.* Gini coefficients for sectoral shares of total exports and imports.

	1959	*1966*	*1974*
Exports	0.67	0.69	0.68
Imports	0.58	0.59	0.59

Source: Based on *table 5.4.*

The more important changes in the trade pattern are the following. On the import side Agriculture's share is halved, from 8.6 per cent in 1959 to 4.2 per cent in 1974. There is a 4 percentage point increase in Engineering's share, from 30.2 to 34.4 per cent, and in Chemicals' share, from 7.1 to 11.2 per cent.

On the export side the major drops in shares are for Wood and wood products, from 23.8 to 15.5 per cent, and for Transport, from 16.1 to 10.1 per cent. The share for Engineering exports rises from 23.6 to 37.2 per cent.

5.4.2 *Changes in net export ratios*

Consider first *table 5.6*. It contains much of the same information as in *table 5.4.* But here the interest is on the *net* of exports and imports for each sector, and, more precisely, on the degree in which a sector is a net importer or exporter. The reason for the interest in net trade is that net trade is thought to reveal comparative advantage. More precisely, intra-industry trade is "eliminated" and inter-industry trade, which presumably is explained by factor proportions, remains.

Table 5.6 contains *net export ratios,* defined as (exports - imports)/(exports + imports). The value of the ratio is + 1 when a sector only exports, - 1 when it only imports, and zero when exports and imports balance.

Table 5.6 Net export ratios[1)]

Sector		*1959*	*1966*	*1974*
1	Agriculture	-0.57	-0.64	-0.43
2	Forestry	+0.21	+0.49	+0.25
3	Mining	+0.05	+0.04	+0.18
4	Import-sheltered food mfg.	-0.18	-0.11	-0.11
5	Import-competing food mfg.	-0.69	-0.76	-0.53
6	Beverage and tobacco	-0.75	-0.85	-0.11
7	Textiles and clothing	-0.67	-0.52	-0.20
8	Wood and wood products	+0.91	+0.85	+0.80
9	Printing and publishing	-0.21	-0.04	+0.11
10	Rubber	-0.12	-0.17	0.00
11	Chemicals	-0.44	-0.42	-0.24
12	Petroleum	-0.85	-0.81	-0.20
13	Non-metallic minerals	-0.29	-0.31	-0.14
14	Iron and steel	-0.13	0.00	+0.14
15	Engineering	-0.12	+0.02	+0.20
16	Ships	+0.39	+0.37	+0.20
17	Other manufacturing	-0.59	-0.44	+0.10
20	Commerce	+0.08	+0.01	+0.29
21	Transport	+0.69	+0.61	+0.64
23	Private services	+0.28	+0.34	+0.17

1) Defined as (X-M)/(X+M).

Source: Unpublished data from the Ministry of Economic Affairs.

As from *table 5.3,* with export-output and import-output ratios, we get a picture of relatively little specialization on the sectoral level. Only a few ratios have high absolute values, above 0.80.

Sweden has a marked export specialization only in Wood and wood products and in Transport. Sectors with high negative ratios over time are Agriculture and Import-competing food manufacturing. Beverage and tobacco and Petroleum have very high negative ratios in 1959 and 1966, but not in 1974.

Of greater interest than the absolute size of the ratios is their change over time. If there is a tendency for net export sectors to become net import sectors, and *vice versa*, we have an indication that Sweden's comparative advantage is shifting. To detect such or other tendencies from the ratios in *table 5.6 figures 5.1 a)* and *b)* have been constructed. There, the absolute change in the ratio for each sector has been plotted against its initial value.[1] As an example, if the initial value is 0.50 in 1959 and 1.00 in 1966 a point is obtained on the 45^{o}-line in the north-east quadrant. If the initial ratio is - 0.50 and does not change the point will be on the negative part of the horizontal axis.

An immediate observation is that the two periods 1959--1966 and 1966-1974 are different with respect to change in net export ratios. In the first period the observations are quite close to the horizontal axis, indicating little overall change in ratios and, hence, in sector specialization. In the second period, on the other hand, there is a clear tendency towards a *reversal* in specialization. Observations between the horizontal axis and the 135^{o}-315^{o}-line mean that the initial ratio has taken on a smaller value but not changed sign. Most observations, 11 of 20, are in this category. Two sectors have changed specialization, from being net importers to being net exporters. It is interesting that no net import sector becomes more specialized and that changes towards more export specialization are quite small.

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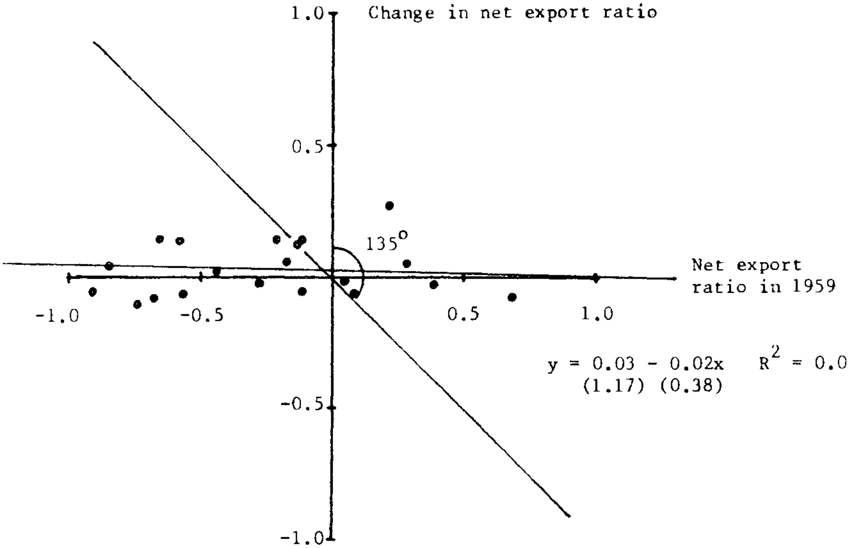
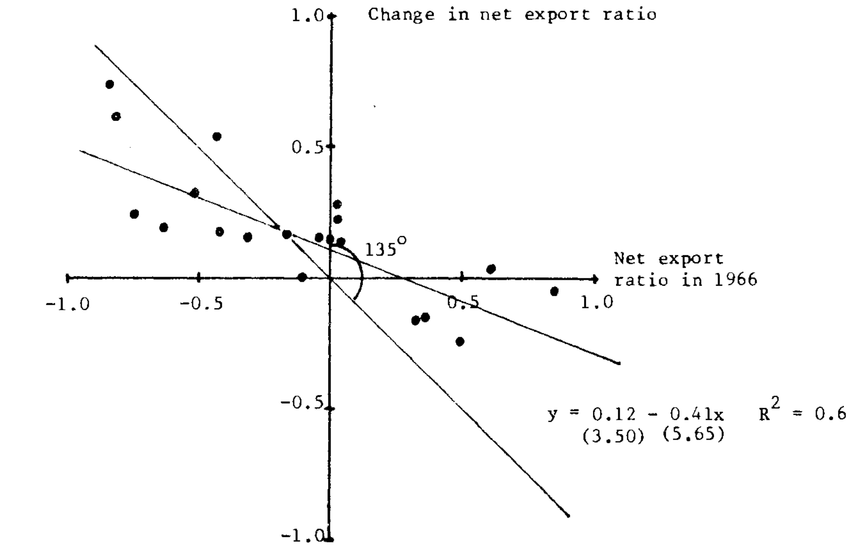
[1] The diagrammatic technique is taken from Ohlsson [1980].

Figures 5.1 Change in net export ratios

a) 1959-1966



b) 1966-1974



Source: Unpublished data from the Ministry of Economic Affairs.

5.5 SWEDEN'S COMPARATIVE ADVANTAGE

According to the factor abundance version of the Heckscher-Ohlin theorem a country will export goods which are intensive in the country's abundant factors, and import goods which are intensive in the scarce factors. In other words, a country's comparative advantage is determined by her factor endowments relative to the rest of the world. Goods which are intensive in the abundant factors will have relatively low autarchy prices and will be exported when trade takes place. We will assume, based on some evidence referred to below, that Sweden is a country which is abundant in physical and human capital and scarce in raw labor relative to the rest of the world. We will then test the prediction of Heckscher-Ohlin theory that Sweden exports capital intensive and imports labor intensive goods.

First, let us state a strict formulation of the Heckscher-Ohlin theorem and the assumptions. The formulation is that of Leamer [1980], except that he interprets the theorem as conditions for determination of a country's factor abundance whereas we interpret them as conditions for the factor content of trade and consumption *given* the factor abundance. For proofs, see Leamer.

Theorem: One of the following sets of inequalities must be satisfied for a capital abundant country:

(a) $K_x - K_m > 0;\ L_x - L_m < 0$

(b) $K_x - K_m > 0;\ L_x - L_m > 0;\ (K_x - K_m)/(L_x - L_m) > K_c/L_c$

(c) $K_x - K_m < 0;\ L_x - L_m < 0;\ (K_x - K_m)/(L_x - L_m) < K_c/L_c$

where K_x, K_m, L_x, L_m, K_c, L_c are capital and labor embodied in exports, imports and consumption.

The assumptions are:

(i) Commodities are freely mobile internationally.

(ii) Factors are perfectly immobile internationally.

(iii) All individuals have identical homothetic preferences.

(iv) Production functions are the same in all countries and exhibit constant returns to scale.

(v) There is perfect competition in the goods and factor markets.

(vi) Factor prices are equalized across countries.

Inequalities (b) and (c) are applicable for the case when a country runs a trade surplus or deficit and may be a net exporter or importer of both capital and labor. However, Swedish trade was practically balanced in the three years for which we test the theorem.[1] Hence, we are going to see if inequality (a) is fulfilled.

We note that inequality (a) is equivalent to

$$\frac{K_x}{L_x} > \frac{K_m}{L_m} .$$

$K_x - K_m > 0$ implies $K_x/K_m > 1$, and $L_x - L_m < 0$ implies $L_x/L_m < 1$. Thus $K_x/K_m > L_x/L_m$, and $K_x/L_x > K_m/L_m$.

As mentioned, our test assumes that Sweden is a capital abundant country. Ohlsson [1980] has surveyed the evidence on Sweden's factor endowment position. They show that Sweden is not the most human and physical capital abundant industrial country in the early 1960's, but Ohlsson concludes that "a comparison between Sweden and the rest of the world as a whole would probably rank Sweden as the more capital abundant area".

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[1] Exports of goods and services in current prices were 14,400, 26,280, and 81,230 million SK and imports 14,372, 27,060, and 83,189 million SK in 1959, 1966 and 1974 respectively (SM N 1975:98, Appendix 3).

The test amounts to computing the weighted average capital-labor ratio in exports and imports, and to a comparison of the ratios. As weights we use the sectoral shares of exports and imports shown in *table 5.4*, and the capital-labor ratios are from *table 3.2*. All four capital-labor ratios are used, although we consider the ratios based on value-added data to be less reliable than the ones based on stock data for reasons given in chapter 3.

It should be stressed that the four capital-labor ratios are based on direct (value-added) input requirements, and not on total requirements, as for example in Leontief's [1954] study. On theoretical grounds total input requirements are preferred. Our reason for using direct requirements is that we wish to test the theorem for three different years to see if there are changes over time. Compatible input-output tables, which are necessary for computing total requirements, do not exist for all three years. We have chosen instead to base the test on direct input requirements, on the assumption that direct and total requirements are similar. An alternative would have been to assume that a particular set of input-output coefficients are constant over time, and to use the same set for all three years.

However, we have also calculated the weighted average (human and physical) capital-labor ratio of exports and imports for one of the years, 1966, using *total* input requirements. Hence, *table 5.7* contains five different measures of the factor content of Swedish foreign trade.

Table 5.7 Weighted average capital intensity of Swedish exports and imports in 1959, 1966 and 1974.

Capital-labor ratio	*Exports*			*Imports*		
	1959	*1966*	*1974*	*1959*	*1966*	*1974*
κ_1	3.25	3.60	2.63	2.87	2.83	2.24
κ_2	1.81	1.90	1.78	1.41	1.14	1.36
κ_3	88.91	147.07	261.90	96.05	151.90	253.96
κ_4	31.61	50.23	96.70	38.28	53.03	87.04
κ_{TOT} 1)	-	2.23	-	-	1.94	-

1) Value of total requirement of human and physical capital service flows over value of total requirement of labor services.

Source: Based on *table 3.2, 5.4,* and *7.8.*

Consider first the first row in the table. κ_1 denotes the ratio between human plus physical capital services and labor services. The ratio is significantly higher in all years in exports. Next, consider the corresponding ratio κ_3, which also has human and physical capital in the denominator and labor in the numerator, but measured from stock data. Now exports are slightly labor intensive in 1959 and 1966, and slightly capital intensive only in 1974.

The results are qualitatively the same when only physical capital is in the numerator, as in κ_2 and κ_4.

Finally, the κ_{TOT} ratios based on total requirements give a somewhat higher capital content of exports than imports.[1]

The results are conflicting and do not lend themselves to certain conclusions. The service flow measures κ_1, κ_2 and κ_{TOT} all indicate that exports are relatively capital intensive, both in terms of physical capital and in terms of physical-*cum*-human capital, while the stock measures κ_3 and κ_4 are

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[1] The difference in order of magnitude between the κ_1 ratios and the κ_{TOT} ratios is explained by the circumstance that κ_1 is in 1966 prices while κ_{TOT} is in 1968 prices.

inconclusive. On balance, it seems that Swedish exports are capital intensive and imports labor intensive, and that no significant change in this position has occurred during the period 1959-1974.

5.6 OTHER EVIDENCE ON SWEDEN'S COMPARATIVE ADVANTAGE

The evidence on Sweden's comparative advantage in section 5.5 indicates that Sweden is a net exporter of physical and human capital. Since the evidence is far from conclusive and since the comparative advantage position of Sweden is crucial in the analysis in chapter 6 and 7 we will survey other available evidence.

The earliest known study of the factor content of a part of Swedish exports and imports is that by Keesing [1965]. Keesing postulates "that the availability of labor skills determines patterns of international location and trade for a broad group of manufactured products, those not tied to natural resources". He assumes that U.S. skill requirements are applicable to Sweden's and other countries' trade flows. Keesing finds that the ratio of "professional, technical, managerial" plus "craftsmen and foremen" man-years per million dollars of value-added to those of "operatives" and "laborers" is 0.7830 in Swedish manufacturing exports in 1957, compared to 0.5677 in imports. Only the U.S. and West Germany have a greater divergence between the ratios. Keesing also calculates the physical capital content, based on U.S. value-added coefficients. Exports of manufactures are slightly more capital intensive than imports in 1957 (the index is 1.7957 compared to 1.6900). In a later study Keesing [1971] investigates the assumption of using U.S. coefficients for other countries and concludes that his earlier results would roughly be duplicated if coefficients from any other leading industrial country, including Sweden, were used instead.

Another study of a partial nature is that by Carlsson and Sundström [1973]. They investigate Sweden's comparative advantage over low-wage countries, as it is revealed in the manufacturing imports of 55 industry-classified commodities in 1969. Low-wage countries are defined as countries with a wage level which is 30 per cent of the Swedish level in 1965 or lower.

Dependent variables are the share of low-wage imports in total imports and the share of low-wage imports in total imports plus domestic supply. Independent variables are human capital, physical capital, economies of scale, "raw material dependence" (a dummy variable which is assigned the value + 1 for goods dependent on domestic raw materials and - 1 for goods dependent on foreign raw materials), and trade barriers (tariffs and a proxy for discrimination in public sector purchases).

In the several regressions run the independent variables explain around 50 per cent of the variation in the dependent variable. The human capital variables have the highest explanatory power and are negative and significant in all regressions. Thus, it is safely concluded that imports from low-wage countries contain relatively little human capital. In addition, they are determined by raw materials not available in Sweden.

It is interesting that when Carlsson and Sundström repeat their regressions for total imports, not just imports from low-wage countries, then human capital does not have a significant influence. Hence, it seems as if Sweden has a comparative advantage in human capital intensive production over low-wage countries, but a disadvantage *visavi* high-wage countries.

Carlsson and Ohlsson [1976] base their study of Sweden's comparative advantage on the 1957 input-output table compiled by Höglund and Werin [1964], which has 127 sectors. Of these, 23 raw material producing, service, and non-traded sectors are excluded. The use of the input-output table enables Carlsson and Ohlsson to have direct as well as total (direct-and--indirect) input requirements as independent variables. These are: physical capital per employee, the proportion of technicians and foremen, the proportion of workers (skilled and unskilled), domestic iron raw materials per employee, domestic forest raw materials per employee, domestic non-iron metal raw materials per employee, non-competing imports of raw materials, and the tariff rate. As dependent variables the ratio between exports and domestic production and the ratio between net exports and consumption are used. Two sets of regressions are run, with direct and total input requirements respectively. This is motivated by the *a priori* assumption that raw materials play a different role when indirect inputs are taken into account compared to when only direct inputs are considered. The tariff rates are nominal in the regressions with total requirements and effective otherwise.

Both sets of regressions explain fairly much of the variation in dependent variables, with R^2:s of 0.33 and 0.40 for the regressions with direct inputs and 0.48 and 0.58 for the other. The proportion of technicians and foremen is significant in explaining the export ratios, but not the net export ratios. The authors draw the conclusion that imports as well as exports are intensive in technical know-how. Physical capital has small positive and significant coefficients in the regressions with direct inputs, but insignificant coefficients when total inputs are used as independent variables. The exact opposite is true for the coefficients for iron and forest raw materials. At the same time a positive correlation is found between physical capital on one hand, and iron and forest raw materials on the other. Carlsson and Ohlsson's conclusion is that Swedish comparative advantage lies in raw material based production which at the same time is capital intensive, and in production which uses relatively much technical know-how. A puzzling result is that labor has a positive and significant coefficient in all but one of the regressions. A hypothesis put forward by the authors is that the variable is an aggregate of skilled and unskilled labor and that, accordingly, it is unclear what it actually measures.

In a study of the Swedish trade in engineering products, Ohlsson [1980] finds that net export ratios, [(X-M)/(X+M)], of 34 engineering industries in 1970 are weakly explained by the proportion of skilled manual workers and not at all by the capital-labor ratio or the proportion of technical personnel in the total labor force (the last variable has a negative but not significant coefficient in some regressions). In 1960, on the other hand, he finds that physical capital intensity explains some of the variation in net export ratios ($R^2 = 0.10$). The *change* in net export ratios between 1960 and 1970 is rather well explained by the factor intensity variables, the net export ratios in 1960, the change in tariffs and the ratio between domestic consumption in 1970 and 1960. Capital and technical personnel intensity in 1970 have a significant negative and positive influence respectively. Ohlsson suggests that a change has occurred in Swedish engineering trade specialization during the 60's, from being capital intensive to being intensive in technical personnel and skilled labor.

Finally, in a recent working paper Gavelin [1981] presents some preliminary results on the specialization pattern of 77 Swedish manufacturing industries in 1970 and 1977. He uses two different kinds of regression models, one additive and one multiplicative. The same explanatory variables are used in both models: value-added per employee (i.e. total capital services per employee), alternatively physical and human capital services, energy per employee, the proportion of technical personnel in the labor force, and a measure of concentration in the industry. The regressions explain 20-30 per cent of the variation in net export ratios. The Swedish manufacturing industry seems to be specialized in human capital intensive and labor intensive goods, and possibly in production with economies of scale, according to the additive model. The multiplicative model points to comparative advantage in human capital intensive goods and goods using much energy (in 1977), and in activities with economies of scale.

In summary, nearly all the available evidence indicates that Sweden has a comparative advantage in human capital intensive production. (Carlsson and Sundström [1973] is inconclusive.) The studies by Keesing [1965], Carlsson and Ohlsson [1976] and Ohlsson [1980] also point to a comparative advantage in goods which are intensive in physical capital, at least earlier in the postwar period. Ohlsson [1980] finds a shift in comparative advantage away from physical to human capital in engineering industries.

5.7 CHANGES IN TERMS-OF-TRADE

The preceding part of this chapter has described various changes in the Swedish foreign trade sector which, within the theoretical framework outlined in chapter 1, are looked upon as endogenous. In contrast, the terms-of-trade are exogenous within that framework. We will in this section describe changes in Swedish terms-of-trade during the period 1950-74, see *table 5.8*.

Table 5.8 Indices for the volume, value and price of aggregate exports and imports 1950-74.

	Volume[1] *1974/1950*	*Value 1974/1950*	*Value/Volume = = Price 1974/1950*
Exports	528	1145	217
Imports	527	1208	229

1) In 1959 prices for the period 1950-63, and in 1968 prices for the period 1963-74.

Source: SM N 1975:98, Appendix 3.

As can be seen, the terms-of-trade changed very little between 1950 and 1974. The slight fall in the terms-of-trade which is seen in the table is the net effect of a terms-of-trade improvement in the first half and a deterioration in the second half of the period (not shown here).

Note that the volume indices for exports and imports are almost the same in 1974. Sweden's aggregate exports and imports of goods and services practically balanced during the 1950's and 1960's.

5.8 CHANGES IN TARIFFS

World market prices are assumed to be given to the small country modelled in chapter 1. However, domestic prices on tradable goods can be altered by the government by putting tariffs on imports. The Swedish government has, by continuously reducing tariff rates, changed the trade pattern, resource allocation and domestic prices. This section describes the structure of tariffs in different years and the extent of tariff reductions. Tariff rates are then correlated with factor proportions to see if a systematic relation exists.

Tariff rates and tariff changes are shown in *table 5.9*:

Table 5.9 Tariff receipts in per cent of import value in 1959, 1966 and 1974[1)]

Sector		1959	1966	1974
1	Agriculture	7.8	7.3	7.0
2	Forestry	0.0	0.0	0.0
3	Mining	0.0	0.0	0.0
4	Import-sheltered food mfg.	41.3	37.1	30.1
5	Import-competing food mfg.	18.1	16.3	13.9
6	Beverage and tobacco	18.9	18.2	18.2
7	Textiles and clothing	7.1	6.4	5.0
8	Wood and wood products	2.5	2.3	2.1
9	Printing and publishing	0.0	0.0	0.0
10	Rubber	6.6	6.2	5.8
11	Chemicals	2.9	2.6	2.2
12	Petroleum	0.0	0.0	0.0
13	Non-metallic minerals	5.5	5.0	4.7
14	Iron and steel	2.7	2.7	2.2
15	Engineering	6.2	5.7	4.9
16	Ships	1.0	1.0	0.8
17	Other manufacturing	7.7	5.5	5.5
20	Commerce	0.0	0.0	0.0
21	Transport	0.0	0.0	0.0
23	Private services	0.0	0.0	0.0
Unweighted average		*6.4*	*5.9*	*5.2*
Weighted average[2)]		*5.8*	*4.7*	*4.2*

1) Includes import and compensation levies (införsel- och kompensationsavgifter).

2) The weights are the import shares in *table 5.4*.

Source: Unpublished data from the Ministry of Economic Affairs.

The general level of tariffs is low, see the weighted and unweighted averages at the bottom of the table. Consequently, the reduction in the general level is small in percentage terms, only 1.6 and 1.2 percentage points between 1959 and 1974 for the weighted and unweighted average respectively.

In relative terms, the weighted average was reduced by 28 and the unweighted average by 19 per cent.[1]

The variation in the tariff level between sectors is considerable. There are three quite distinct groups of sectors: those with high, low and no tariffs. In the first group we find processed foods and beverages. The second group, to which half of the sectors belong, have rates below 8 per cent. Seven sectors have no tariff protection.[2]

Sweden follows an official policy of a high degree of self sufficiency in food production. This is the main reason for the high rates in sectors 4, 5 and 6. Where imports are not competing with domestic production, as for some agricultural products, forestry, crude oil, commerce and most private and transport services, or where import competition is very weak, as in Printing and publishing, there is no import protection. The rest of the sectors enjoy a small degree of protection.

Hence, it is possible to explain the main features of the tariff structure by agricultural policy and by the extent of import competition. A perhaps more sophisticated and in this context more relevant approach to explain the structure is to relate tariffs to comparative advantage, and specifically to factor proportions. It is expected that a negative correlation exists between the tariff level and the degree of comparative advantage, i.e. the degree of capital intensity. *Table 5.9* below contains rank correlations between tariff rates and capital intensities.

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1 Lundberg [1976].has calculated nominal and effective rates for 42 groups of commodities in 1959 and 1962. Raw materials, fuels, food and some other commodities were excluded. The unweighted average nominal rates were 9.14 and 6.86 per cent in 1959 and 1972 respectively, and the unweighted average effective rates 17.82 and 13.59 per cent.

2 It should be pointed out that domestic taxes in some cases are equivalent to tariffs, namely when there is no domestic production. An obvious example is crude oil in sector 12. Such *de facto* tariffs are not recorded here.

Table 5.10 Rank correlation between tariff rates and sectoral factor proportions in 1959, 1966 and 1974

Capital-labor ratio	*1959*	*1966*	*1974*
κ_1	-0.096	+0.117	+0.105
κ_2	-0.062	+0.223	+0.130
κ_3	-0.155	-0.261	-0.018
κ_4	+0.095	-0.014	-0.054

Source: Based on *table 3.2* and *table 5.9*

All coefficients are highly insignificant. In other words, there exists no systematic relation between the structure of tariffs and the ranking of sectors according to capital intensity. Thus, whatever the reasons behind the tariff structure, there is no indication that protection of labor intensive goods is among the motives.

5.9 SUMMARY

In section 5.2 it was shown that the ratio between exports and GNP grows from 0.19 to 0.39 between 1959 and 1974, when exports and GNP are in constant prices. In current prices the ratio has a constant value of about 0.23 (except for an upward jump in the early 1970's). The increase in the constant price ratio was found to be a result of growing intra-industry trade and not inter-industry trade. Most sectors have substantial intra-industry trade and few can be labelled as export or import sectors.

To explain much of intra-industry trade one has to resort to other theories of trade than Heckscher-Ohlin theory. Some alternative theories were outlined in section 5.3.

The trade pattern exhibits some important changes between 1959 and 1974, as shown in section 5.4. There are significant changes in export and import shares: the Engineering sector's share of both exports and import rises, Agriculture's import share is halved, and the sectors Wood and wood products and Transport experience substantial drops in their shares of exports. Despite these changes there is virtually no change in the Gini coefficient of concentration for exports and imports. Net export ratios show that sectors with net exports and net imports in 1966 tend to move to more balanced trade in 1974.

These changes in the trade pattern seem not to be the result of a change in Sweden's presumed comparative advantage in producing capital intensive goods. The factor content of Swedish trade should, according to the Heckscher-Ohlin theorem, reflect the Swedish factor endowment relative to the rest of the world. We assume that Sweden is abundant in human and physical capital. Our computations of the capital intensity of exports and imports indicated, but not conclusively, that exports are relatively capital intensive in 1959, 1966 and 1974. This finding in section 5.5 is confirmed by evidence from other studies, which is presented in section 5.6.

Finally, we found in section 5.7 that the terms-of-trade have been more or less constant during the period under study, and, in section 5.8, that tariff rates have been quite low. The unweighted average tariff rate dropped from 6.4 per cent in 1959 to 5.2 per cent in 1974. If it is correct that Sweden has a comparative disadvantage in labor intensive goods, we expect tariffs to be negatively correlated with sectoral capital intensities. No significant correlation was found however.

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CHAPTER 6 CHANGES IN PRICES, ALLOCATION AND TRADE - A HECKSCHER-OHLIN ANALYSIS*

6.1 INTRODUCTION

The purpose of this chapter is to determine what effects some empirical facts presented in chapters 2-5 have in a model economy of the kind described in chapter 1. For this purpose we construct a Heckscher-Ohlin type general equilibrium model of the Swedish economy. Into this model a number of stylized facts of Swedish post-war growth are fed and their *ceteris paribus* effects analyzed. In particular, we wish to determine the effects on *allocation*, both of factors and of outputs, *factor prices* and the *degree of international specialization*.

It should be stressed that the method of analysis is that of comparative statics, i.e. comparison of states, and not comparative dynamics, i.e. comparison of time paths. The empirical facts in chapters 2-5 describe the development over time of the Swedish economy, and the most appropriate method of analysis is therefore comparative dynamics. What we do instead is to translate rates of change into different states at different points in time, and then conduct comparative static experiments based on these differences in states. As an example, we translate the rates of growth in factor endowments between 1950 and 1974 into two different factor endowments and compare the states of the model economy for these different endowments.

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The chapter is arranged as follows. In section 6.2 the stylized facts of Swedish post-war growth are presented. Section 6.3 contains a more detailed discussion of the choice of model, in particular of how it simplifies reality and what basic assumptions are made. The model is presented in section 6.4. Sections 6.5-6.8 contain the comparative static analysis of the effects of various exogenous influences. Finally, section 6.9 summarizes and comments on the results.

6.2 THE STYLIZED FACTS

The stylized facts of growth, taken from chapters 2-5, are summarized below. Note tnat most are changes in exogenous variables, as seen within the Heckscher-Ohlin model in chapter 1: changes in factor endowments, preferences, technology and prices on tradable goods. Other stylized facts concern the value of what can be considered as parameters: factor proportions differences and the endowment position of Sweden relative to the rest of the world.

1. *Increased endowment capital-labor ratio.*
2. *Higher income elasticity for non-traded than tradable goods and/or a shift in taste towards non-traded goods.*
3. *Increased total factor productivity of the tradable relative to the non-traded sector.*
4. *Constant terms-of-trade.*
5. *Small tariff reductions.*
6. *The non-traded sector is capital-intensive relative to the tradable sector, but the difference is decreased.*
7. *Sweden exports capital intensive and imports labor intensive goods.*

6.3 ON THE CHOICE OF MODEL

The Heckscher-Ohlin framework of this study was presented in chapter 1, where a model of a small, trade-dependent country in a world with many goods was outlined. The focus of the presentation lay on demonstrating the relations between some central variables, such as those between factor endowments, technology and factor prices, or between demand for non-traded goods and specialization in the traded sector. Less or no attention was given some other features of the model, and some of the assumptions it rests on. In particular, the dimensionality of the model was discussed in terms of a comparison of the number of goods and factors, but not relative to the type of problems one might wish to analyze. Prices of traded goods were assumed given (a definition of small country), as were technology and factor endowments. No mention of adjustment costs was made as factors and productions were reallocated. Before we present the model used for analysis in this chapter it is therefore appropriate to justify the choice of model in somewhat more detail.

First, we turn to the question of *dimensionality.* The number of factors and goods in the model should, of course, be appropriate for the problems we want to analyze. One set of questions concerns the role which demand for non-traded goods plays in an economy which is open to international trade. Because demand for non-traded goods is directly tied to the quantity produced, whereas demand for tradables is not, it has a decisive influence on allocation and prices in the whole economy. We are also interested in what determines allocation in the tradables sector, and the degree of international specialization. These sets of questions require a distinction between tradable and non-traded goods as well as further disaggregation in the tradable sector. The smallest number of goods, therefore, is three, one non-traded and two traded goods, and this is the dimension we have chosen.

A fundamental characteristic of technology is that factor proportions differ between productive activities. A change in aggregate factor endowments must therefore, if prices are kept constant and full employment of factors is imposed, cause a reallocation of resources and production. We are interested in how changes in factor endowments have affected the allocation of factors and outputs and need therefore allow for at least two factors in the model. In chapter 2 we recognized three factors of production: raw labor, human and physical capital. To make the analysis as simple as possible we will treat human and physical capital as homogenous capital.[1] It is not thought that much, if anything essential is lost by this simplification: what matters for the problems we wish to analyze is Sweden's comparative advantage, which is in both forms of capital intensive goods and not in labor intensive goods, and the factor proportions differences between tradable and non-traded goods. Hence, the important difference is in the labor intensity, not in differentiated capital intensities.

Thus, so far the dimension of the model is 3×2. We should also add that since we will treat Sweden's trading partners as an aggregate, we have a world consisting effectively of only two countries. The dimension of the model should therefore be stated as 2×3×2.

By having an equal number of tradable goods and factors, and the number equal to two, we have ensured that some of the basic propositions of Heckscher-Ohlin theory hold. For example, when the number of goods is larger than the number of factors as in chapter 7, the results obtained below cannot be expected to hold unless further assumptions are made. This is discussed in chapter 7, section 7.3. For general investigations of the dependence of the basic trade theorems on dimensionality, see e.g. Samuelson [1953], Ethier [1974], Jones and Scheinkman [1977], and Chang [1979].

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[1] We also assume homogeneity of human and physical capital respectively.

We maintain the assumption throughout the analysis that all three goods are produced. In terms of a production surface, production takes place away from the boundaries of a ruled production surface (of a cone or cylinder) and along straight lines on it. Melvin [1968] gives a detailed discussion and diagrammatic illustration of this particular production surface. This implies that assumptions are made about relations between factor endowments, technology, world prices and demand for non-traded goods. This is evident from the model presented in chapter 1 and in particular from *figure 1.4* there. In that figure we are on a horizontal segment of the heavy-lined curve where two tradables are produced, as well as non-traded goods. Although complete specialization in one of the two traded goods is ruled out by assumption in the comparative static analysis, it is in most cases easy to see the effects of complete specialization. The most interesting effect is on relative factor prices, see *figure 1.4*. If the economy turns to specialization in the relatively capital (labor) intensive good, the wage-rental ratio will increase (decrease). We will extend the comparative statics by indicating, where it is appropriate, effects of complete specialization which is the limit of the case being analyzed. It is judged that such a non-formalized extension of the analysis to cover the case of complete specialization is sufficient. Complete specialization is less interesting than incomplete specialization, since resource allocation within the tradable sector is eliminated, and the degree of international specialization is fixed.

The two traded goods are termed exportables and importables in the model. Exportables may be exported, as the name implies, but they cannot simultaneously be imported; and *vice versa* for importables. Two considerable abstractions of reality are involved here, aggregation of a great number of goods into two and "netting out" very significant intra-industry trade. Industries which are net exporters are aggregated into exportables, and similarly for importables. Standard Heckscher-Ohlin theory cannot explain two-way trade in the same goods, i.e. in goods with the same factor proportions (cf. the discussion in section 5.6.2). Hence, the trade "explained" here is only factors-in-goods-trade, which may be a small part of total trade, as was indicated in the previous chapter.

Next, we turn to the choice of *exogenous variables*. Central variables such as factor endowments, technology and prices of traded goods are treated as given in the model. That factor supplies and technology are exogenous is somewhat unsatisfactory, since they must be influenced to a significant degree by economic forces, particularly in the long-run perspective applied here. There exist established theories for capital and labor markets, and empirical research on technical progress seems to demonstrate that economic factors are decisive, see Schmookler [1966]. However, we lack a theory which incorporates endogenous determination of factor endowments and technology in the traditional Heckscher-Ohlin type models.

The justification for having given world market prices of traded goods is that Sweden is small enough to be a price taker, at least in the long run. This assumption is probably closer to the truth than its opposite, although we have no systematic evidence to base it on.

Finally, we need to comment on the assumption about *factor mobility* made in the model. Factors are assumed to be completely and costlessly mobile between sectors. Clearly this is not true in the short run, and we can easily think of factors, e.g. machines, which can only be used for a particular purpose and are immobile even in the long run. However, as a general proposition about the long run, complete factor mobility seems plausible.[1]

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[1] It deserves mentioning that in recent years the Heckscher-Ohlin model has been modified to allow for factors which are specific to some sector. Such modified models are called *specific-factor models*, and they yield different results than the traditional Heckscher-Ohlin model for factor endowment and price changes. See Neary [1977] for a comparison of the basic results. The introduction of sector-specific factors constitutes a return to the models of David Ricardo and Jacob Viner.

Nothing explicit is assumed about factor mobility internationally. The empirical data on capital and labor supplies reflect some exports and imports of these factors, particularly imports of labor. Presumably factors move across borders in pursuit of higher rewards. This is not captured by the model, except that the net of international factor movements shows up in the exogenously given capital and labor endowments.

6.4 THE MODEL[1]

There are two factors of production, called labor L and capital K. Total factor supplies are given and fixed, and both factors are always fully employed. Three goods are produced by capital and labor, at constant returns to scale. They are exportables X_1, importables X_2 and non-traded goods X_N.[2] We can now write

$$(6.1) \qquad a_{L1}X_1 + a_{L2}X_2 + a_{LN}X_N = L$$

$$(6.2) \qquad a_{K1}X_1 + a_{K2}X_2 + a_{KN}X_N = K$$

where a_{ij} is per unit input of factor i into good j.

Perfect competition in product and factor markets is assumed. Under competitive conditions the price of a commodity equals the unit cost. Hence, we can write

$$(6.3) \qquad a_{L1}w + a_{K1}r = p_1$$

$$(6.4) \qquad a_{L2}w + a_{K2}r = p_2$$

$$(6.5) \qquad a_{LN}w + a_{KN}r = p_N$$

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1 The first presentation of a Heckscher-Ohlin model with two factors and three goods, one of which is non-traded, is in Komiya [1967], who analyzes the validity of the basic trade theorems in such a model. The model is presented in rates of change in Batra [1973].

2 The singular and plural of exportable, importable and non-traded goods are used interchangeably in what follows.

where w is the wage rate and r is the rental of capital. The prices of exportables, p_1, and importables, p_2, are given in the world market.

The input-output coefficients a_{ij} are functions of relative factor prices and a given state of technology τ:

$$(6.6)-(6.11) \quad a_{ij} = a_{ij}(w/r,\tau) \qquad i = K,L \quad j = 1,2,N$$

National or aggregate income Y is defined as

$$(6.12) \qquad Y = wL + rK$$

We now choose good X_1 as *numeraire*, so that all prices, including w and r, are relative to p_1, which always is set equal to one. Y is therefore national income in terms of the exportable good.

Demand for goods is determined by relative prices p_2 and p_N and national income:

$$(6.13)-(6.15) \quad D_j = D_j(p_2,p_N,Y) \qquad j = 1,2,N$$

We impose that demand for the non-traded good is equal to supply:

$$(6.16) \qquad D_N = X_N$$

Finally, we have that aggregate supply equals demand:

$$p_1D_1 + p_2D_2 + p_ND_N = p_1X_1 + p_2X_2 + p_NX_N$$

Since, by (6.16), $X_N = D_N$, we can rewrite this equation to state that exports equal imports.

We now have 17 equations to determine 16 endogenous variables, namely 6 quantities X_1, X_2, X_N, D_1, D_2, D_N, 3 prices w, r, p_N, 6 input-output coefficients a_{ij}, and national income Y. By Walras' law one equation is redundant; we choose to eliminate the last equation, which states that demand equals supply. We assume that there exists a unique solution to this system.

It is more convenient to work with the model when it is expressed in rates of change, instead of absolute values.[1] Therefore, differentiate equations (6.1)-(6.16) logarithmically and substitute the equations for rates of change of the input-output coefficients into the other equations to get:

(6.17) $\lambda_{L1}\hat{X}_1 + \lambda_{L2}\hat{X}_2 + \lambda_{LN}\hat{X}_N - \delta_L(\hat{w}-\hat{r}) = \hat{L} + \Pi_L$

(6.18) $\lambda_{K1}\hat{X}_1 + \lambda_{K2}\hat{X}_2 + \lambda_{KN}\hat{X}_N + \delta_K(\hat{w}-\hat{r}) = \hat{K} + \Pi_K$

(6.19) $\theta_{L1}\hat{w} + \theta_{K1}\hat{r} = \hat{p}_1 + \Pi_1$

(6.20) $\theta_{L2}\hat{w} + \theta_{K2}\hat{r} = \hat{p}_2 + \Pi_2$

(6.21) $\theta_{LN}\hat{w} + \theta_{KN}\hat{r} - \hat{p}_N = \Pi_N$

(6.22) $\hat{Y} - \theta_L\hat{w} - \theta_K\hat{r} = \theta_L\hat{L} + \theta_K\hat{K}$

(6.23) $\hat{D}_1 - [\eta_{12}\hat{p}_2 + \eta_{1N}\hat{p}_N + \eta_{1Y}\hat{Y}] = 0$

(6.24) $\hat{D}_2 - [\eta_{22}\hat{p}_2 + \eta_{2N}\hat{p}_N + \eta_{2Y}\hat{Y}] = 0$

(6.25) $\hat{D}_N - [\eta_{N2}\hat{p}_2 + \eta_{NN}\hat{p}_N + \eta_{NY}\hat{Y}] = 0$

(6.26) $\hat{D}_N - \hat{X}_N = 0$

where

"^" = rate of change. For example $\hat{X}_1 = dX_1/X_1$.

λ_{ij} = the share of total supply of factor i (i = L,K) used in production of good j (j = 1,2,N). For example $\lambda_{L1} = (a_{L1}X_1)/L$.

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[1] Hence, we follow the tradition initiated in Jones' [1965] article. Also, the generalized Stolper-Samuelson and Rybczynski theorems as formulated by Jones [1965] are in terms of rates of change.

θ_{ij} = the cost share of factor i (i = L,K) of the price of good j (j = 1,2,N). For example, $\theta_{L1} = (a_{L1}w)/p_1$.

θ_i = the share of factor i (i = L,K) in national income.

η_{ij} = the price elasticity of demand of good i (i = 1,2,N) with respect to price j (j = 2,N). We assume that $\eta_{ij} > 0$ for $i \neq j$ and $\eta_{ij} < 0$ for i = j.

η_{iY} = the income elasticity of demand of good i (i = 1,2,N).

Π_i = $\lambda_{i1}\hat{c}_{i1} + \lambda_{i2}\hat{c}_{i2} + \lambda_{iN}\hat{c}_{iN}$, the rate of reduction in the use of factor i (i = L,K) due to pure technical progress τ. The symbol $\hat{c}_{ij}$ (i = L,K; j = 1,2,N) denotes the (negative) rate of change of input-output coefficient a_{ij} due to factor-saving technical progress.

Π_j = $\theta_{Lj}\hat{c}_{Lj} + \theta_{Kj}\hat{c}_{Kj}$, the rate of reduction in unit cost (price) of good j (j = 1,2,N) due to factor-saving technical progress.

δ_i = $\lambda_{i1}\theta_{j1}\sigma_1 + \lambda_{i2}\theta_{j2}\sigma_2 + \lambda_{iN}\theta_{jN}\sigma_N$ $(i,j = L,K;\ i \neq j)$, the change in use of factor i (i = L,K) due to factor substitution following factor price changes.

The terms Π_i, Π_j and δ_i are derived in the following way. Differentiate (6.6)-(6.11) totally and divide through by a_{ij} to obtain

$$\hat{a}_{ij} = \frac{1}{a_{ij}} \frac{\partial a_{ij}}{\partial (w/r)} d(w/r) - \frac{1}{a_{ij}} \frac{\partial a_{ij}}{\partial \tau} d\tau$$

The first term on the right-hand side is the effect of factor substitution and the second term the effect of technical change on the rate of change of the input-output coefficients. The second term is defined to be negative, i.e. increases in τ, the state of technology, reduces input requirements. We define $\hat{b}_{ij}$ and $\hat{c}_{ij}$ as

$$\hat{b}_{ij} = \frac{1}{a_{ij}} \frac{\partial a_{ij}}{\partial (w/r)} d(w/r)$$

and

$$\hat{c}_{ij} = \frac{1}{a_{ij}} \frac{\partial a_{ij}}{\partial \tau} d\tau .$$

Next, we week the form of the functions $\hat{b}_{ij} = \hat{b}_{ij}[d(w/r)]$. First, use the definition of the elasticity of substitution to obtain

$$(6.27)-(6.29) \quad \sigma_j = \frac{(w/r)}{(K_j/L_j)} \frac{\partial (K_j/L_j)}{\partial (w/r)} = \frac{\hat{K}_j - \hat{L}_j}{\hat{w} - \hat{r}} =$$

$$= \frac{(\hat{K}_j - \hat{X}_j) - (\hat{L}_j - \hat{X}_j)}{\hat{w} - \hat{r}} = \frac{\hat{b}_{Kj} - \hat{b}_{Lj}}{\hat{w} - \hat{r}} \quad j = 1,2,N$$

Then we make use of the fact that competitive producers minimize costs, so that the first derivative of unit costs can be set equal to zero. For given factor prices we have that

$$a_{Lj}\, w\, \hat{b}_{Lj} + a_{Kj}\, r\, \hat{b}_{Kj} = 0 \qquad j = 1,2,N$$

Divide by p_j to get

$$(6.30)-(6.32) \quad \theta_{Lj}\hat{b}_{Lj} + \theta_{Kj}\hat{b}_{Kj} = 0 \qquad j = 1,2,N$$

Solving for $\hat{b}_{ij}$ from the six equations (6.27)-(6.32) yields

$$\hat{b}_{Lj} = -\theta_{Kj}\sigma(\hat{w}-\hat{r}) \qquad j = 1,2,N$$

$$\hat{b}_{Kj} = \theta_{Lj}\sigma(\hat{w}-\hat{r}) \qquad j = 1,2,N$$

Now, if these results of decomposing a_{ij} are substituted into equations (6.1)-(6.5) after logarithmic differentiation the end result is equations (6.17)-(6.21), with the given meaning of the Π_i, Π_j and δ_j terms.

This ends the presentation of the model. To avoid much repetition when working through the various cases below we now solve for all variables of interest. Note the recursive character of the model. It can be solved in the following order. See equations (6.17)-(6.26):

Step 1. (6.19) and (6.20) give $\hat{w}$ and $\hat{r}$.

Step 2. Given $\hat{w}$ and $\hat{r}$, (6.21) gives $\hat{p}_N$ and (6.22) gives $\hat{Y}$.

Step 3. Given $\hat{p}_N$ and $\hat{Y}$, (6.23), (6.24) and (6.25) give $\hat{D}_1$, $\hat{D}_2$ and $\hat{D}_N$.

Step 4. Given $\hat{D}_N$, (6.26) gives $\hat{X}_N$.

Step 5. Given $\hat{w}$, $\hat{r}$ and $\hat{X}_N$, (6.17) and (6.18) give $\hat{X}_1$ and $\hat{X}_2$.

We begin with steps 1 and 2 by setting up the system of equations (6.19)-(6.22) in matrix format and solving for all endogenous prices and national income:

$$\begin{bmatrix} \theta_{L1} & \theta_{K1} & 0 & 0 \\ \theta_{L2} & \theta_{K2} & 0 & 0 \\ \theta_{LN} & \theta_{KN} & -1 & 0 \\ -\theta_L & -\theta_K & 0 & 1 \end{bmatrix} \begin{bmatrix} \hat{w} \\ \hat{r} \\ \hat{p}_N \\ \hat{Y} \end{bmatrix} = \begin{bmatrix} \hat{p}_1 + \Pi_1 \\ \hat{p}_2 + \Pi_2 \\ \Pi_N \\ \theta_L \hat{L} + \theta_K \hat{K} \end{bmatrix}$$

Using Cramer's rule we obtain:

(6.33) $$\hat{w} = \frac{-\theta_{K2}(\hat{p}_1+\Pi_1) + \theta_{K1}(\hat{p}_2+\Pi_2)}{-|\theta_{12}|}$$

(6.34) $$\hat{r} = \frac{-\theta_{L1}(\hat{p}_2+\Pi_2) + \theta_{L2}(\hat{p}_1+\Pi_1)}{-|\theta_{12}|}$$

(6.35) $$\hat{p}_N = \frac{(\hat{p}_1+\Pi_1)|\theta_{2N}| - (\hat{p}_2+\Pi_2)|\theta_{1N}| + \Pi_N|\theta_{12}|}{-|\theta_{12}|}$$

(6.36) $$\hat{Y} = \frac{(\hat{p}_1+\Pi_1)(\theta_{L2}\theta_K-\theta_{K2}\theta_L) + (\hat{p}_2+\Pi_2)(\theta_{K1}\theta_L-\theta_{L1}\theta_K) - (\theta_L\hat{L}+\theta_K\hat{K})|\theta_{12}|}{-|\theta_{12}|}$$

where $|\theta_{ij}| = \begin{vmatrix} \theta_{Kj} & \theta_{Lj} \\ \theta_{Ki} & \theta_{Li} \end{vmatrix} = \theta_{Kj}\theta_{Li} - \theta_{Ki}\theta_{Lj}$ $(i,j = 1,2,N;\ i \neq j)$.

Solutions for demands are obtained by substituting the above results into the demand equations (6.23)-(6.25):

(6.37) $$\hat{D}_1 = \eta_{12}\hat{p}_2 + \eta_{1N}\frac{(\hat{p}_1+\Pi_1)|\theta_{2N}| - (\hat{p}_2+\Pi_2)|\theta_{1N}| + \Pi_N|\theta_{12}|}{-|\theta_{12}|} +$$
$$+ \eta_{1Y}\frac{(\hat{p}_1+\Pi_1)(\theta_{L2}\theta_K-\theta_{K2}\theta_L) + (\hat{p}_2+\Pi_2)(\theta_{K1}\theta_L-\theta_{L1}\theta_K) - (\theta_L\hat{L}+\theta_K\hat{K})|\theta_{12}|}{-|\theta_{12}|}$$

(6.38) $$\hat{D}_2 = \eta_{22}\hat{p}_2 + \eta_{2N}\frac{(\hat{p}_1+\Pi_1)|\theta_{2N}| - (\hat{p}_2+\Pi_2)|\theta_{1N}| + \Pi_N|\theta_{12}|}{-|\theta_{12}|} +$$
$$+ \eta_{2Y}\frac{(\hat{p}_1+\Pi_1)(\theta_{L2}\theta_K-\theta_{K2}\theta_L) + (\hat{p}_2+\Pi_2)(\theta_{K1}\theta_L-\theta_{L1}\theta_K) - (\theta_L\hat{L}+\theta_K\hat{K})|\theta_{12}|}{-|\theta_{12}|}$$

$$(6.39) \qquad \hat{D}_N = \eta_{N2}\,\hat{p}_2 + \eta_{NN}\,\frac{(\hat{p}_1+\Pi_1)\,|\theta_{2N}| - (\hat{p}_2+\Pi_2)\,|\theta_{1N}| + \Pi_N|\theta_{12}|}{-\,|\theta_{12}|} + $$

$$+ \eta_{NY}\,\frac{(\hat{p}_1+\Pi_1)(\theta_{L2}\theta_K-\theta_{K2}\theta_L) + (\hat{p}_2+\Pi_2)(\theta_{K1}\theta_L-\theta_{L1}\theta_K) - }{}$$

$$\frac{-\,(\theta_L\hat{L}+\theta_K\hat{K})\,|\theta_{12}|}{-\,|\theta_{12}|}$$

The output of the non-traded good is now determined:

$$(6.40) \qquad \hat{X}_N = \hat{D}_N$$

Next, solve for $\hat{X}_1$ and $\hat{X}_2$ from equations (6.17) and (6.18) to get

$$(6.41) \qquad \hat{X}_1 = \frac{|\lambda_{2N}|}{|\lambda_{12}|}\,\hat{X}_N + \frac{\lambda_{K2}}{|\lambda_{12}|}\,\Pi_L - \frac{\lambda_{L2}}{|\lambda_{12}|}\,\Pi_K - \frac{\lambda_{L1}}{|\lambda_{12}|}\,\hat{K} + \frac{\lambda_{K1}}{|\lambda_{12}|}\,\hat{L} +$$

$$+ \frac{(\delta_L\lambda_{K2}+\delta_K\lambda_{L2})}{|\lambda_{12}|}\,(\hat{w}-\hat{r}) =$$

$$= \frac{|\lambda_{2N}|}{|\lambda_{12}|}\Bigg[\eta_{N2}\hat{p}_2 + \eta_{NN}\,\frac{(\hat{p}_1+\Pi_1)\,|\theta_{2N}| - (\hat{p}_2+\Pi_2)\,|\theta_{1N}| + \Pi_N|\theta_{12}|}{-\,|\theta_{12}|} +$$

$$+ \eta_{NY}\,\frac{(\hat{p}_1+\Pi_1)(\theta_{L2}\theta_K-\theta_{K2}\theta_L) + (\hat{p}_2+\Pi_2)(\theta_{K1}\theta_L-\theta_{L1}\theta_K) - }{}$$

$$\frac{-\,(\theta_L\hat{L}+\theta_K\hat{K})\,|\theta_{12}|}{-\,|\theta_{12}|}\Bigg] + \frac{\lambda_{K2}}{|\lambda_{12}|}\,\Pi_L - \frac{\lambda_{L2}}{|\lambda_{12}|}\,\Pi_K -$$

$$- \frac{\lambda_{L2}}{|\lambda_{12}|}\,\hat{K} + \frac{\lambda_{K2}}{|\lambda_{12}|}\,\hat{L} + \frac{(\delta_L\lambda_{K2}+\delta_K\lambda_{L2})}{|\lambda_{12}|}\left[\frac{-\hat{p}_k-\Pi_1 + \hat{p}_2+\Pi_2}{-\,|\theta_{12}|}\right]$$

$$(6.42)\qquad \hat{X}_2 = \frac{-|\lambda_{1N}|}{|\lambda_{12}|}\hat{X}_N - \frac{\lambda_{K1}}{|\lambda_{12}|}\Pi_L + \frac{\lambda_{L1}}{|\lambda_{12}|}\Pi_K - \frac{\lambda_{L2}}{|\lambda_{12}|}\hat{K} - \frac{\lambda_{K2}}{\lambda_{12}}\hat{L} -$$

$$- \frac{(\delta_L\lambda_{K1}+\delta_K\lambda_{L1})}{|\lambda_{12}|}(\hat{w}-\hat{r}) =$$

$$= \frac{-|\lambda_{1N}|}{|\lambda_{12}|}\left[\eta_{N2}\hat{p}_2 + \eta_{NN}\frac{(\hat{p}_1+\Pi_1)|\theta_{2N}| - (\hat{p}_2+\Pi_2)|\theta_{1N}| + \Pi_N|\theta_{12}|}{-|\theta_{12}|}\right.$$

$$+ \eta_{NY}\frac{(\hat{p}_1+\Pi_1)(\theta_{L2}\theta_K-\theta_{K2}\theta_L) + (\hat{p}_2+\Pi_2)(\theta_{K1}\theta_L-\theta_{L1}\theta_K) -}{-|\theta_{12}|}$$

$$\left.\frac{-(\theta_L\hat{L}+\theta_K\hat{K})|\theta_{12}|}{}\right] - \frac{\lambda_{K1}}{|\lambda_{12}|}\Pi_L + \frac{\lambda_{L1}}{|\lambda_{12}|}\Pi_K +$$

$$+ \frac{\lambda_{L2}}{|\lambda_{12}|}\hat{K} - \frac{\lambda_{K2}}{|\lambda_{12}|}\hat{L} - \frac{(\delta_L\lambda_{K1}+\delta_K\lambda_{K1})}{|\lambda_{12}|}\left[\frac{-\hat{p}_1-\Pi_1 + \hat{p}_2+\Pi_2}{-|\theta_{12}|}\right]$$

where $|\lambda_{ij}| = \begin{vmatrix}\lambda_{Kj} & \lambda_{Lj}\\ \lambda_{Ki} & \lambda_{Li}\end{vmatrix} = \lambda_{Kj}\lambda_{Li} - \lambda_{Ki}\lambda_{Lj}$ $(i,j = 1,2,N;\ i \neq j)$.

Throughout equations (6.33)-(6.39) and (6.41)-(6.42) the determinants $|\theta_{ij}|$ appear and in equations (6.41) and (6.42) new determinants $|\lambda_{ij}|$ are introduced. The sign of these depend on the capital intensity of good i relative to good j. If $(K_i/L_i) > (K_j/L_j)$, then $|\theta_{ij}| < 0$ and $|\lambda_{ij}| < 0$. To see this, write out two determinants:

$$|\theta_{12}| = \theta_{L1}\theta_{K2} - \theta_{L2}\theta_{K1} = \frac{wr}{p_1p_2}(a_{L1}a_{K2} - a_{L2}a_{K1})$$

$$|\lambda_{12}| = \lambda_{L1}\lambda_{K2} - \lambda_{L2}\lambda_{K1} = \frac{X_1X_2}{KL}(a_{L1}a_{K2} - a_{L2}a_{K1})$$

For example, $K_2/L_2 > K_1/L_1 \Leftrightarrow a_{K2}/a_{L2} > a_{K1}/a_{L1} \Leftrightarrow$

$\Leftrightarrow a_{K2}a_{L1}-a_{K1}a_{L2} > 0.$

6.5 INCREASED CAPITAL ABUNDANCE

In this section we ask what the effects are on prices, income, allocation and international specialization of a *ceteris paribus* increase in the supply of capital. All other exogenous variables are constant.

Factor prices and the price of the non-traded good are not affected by capital accumulation:

(6.33a) $\hat{w} = 0$

(6.34a) $\hat{r} = 0$

(6.35a) $\hat{p}_N = 0$

The only exogenous variables which can affect endogenous prices are technology and prices on tradables. Changes in factor endowments and in demand for the non-traded good have no influence (as long as both tradables are produced), see equations (6.33)-(6.35).

National income, on the other hand, will increase, since the economy's factor endowments are increased at constant factor prices:

(6.36a) $\hat{Y} = \Theta_K \hat{K}$

In the absence of price and taste changes, the change in income is the only influence on domestic demand:

(6.37a) $\hat{D}_1 = \eta_{1Y} \Theta_K \hat{K}$

(6.38a) $\hat{D}_2 = \eta_{2Y} \Theta_K \hat{K}$

(6.39a) $\hat{D}_N = \eta_{NY} \Theta_K \hat{K}$

All goods are assumed to be normal and gross substitutes. We have little evidence as to the magnitudes of the various price and income elasticities. In chapter 4 it was observed that tradable and non-traded goods have been demanded in about constant proportions at the same time as the relative price of non-traded goods has been increasing. We concluded that the income elasticity is higher than unity for non-traded goods and lower than unity for tradable goods, and/or that taste has shifted towards non-traded goods.

With respect to the empirical evidence we will henceforth assume that

$$\eta_{NY} > \eta_{iY} \qquad i = 1,2$$

Also, we assume that the utility functions are on the form

$$U(D_1, D_2, D_N) = U(f(D_1, D_2), D_N),$$

where f is linearly homogenous, and that

$$\eta_{1Y} = \eta_{2Y}.$$

We note that the weighted average income elasticity is unity:

$$\Sigma\alpha_i\eta_{iY} = 1 \qquad i = 1,2,N$$

where $\alpha_i = (p_i D_i)/Y$.

Under these assumptions we find that (6.37a)-(6.39a) give the following ordering of the rates of change in demand:

$$\hat{D}_N > \hat{D}_1 = \hat{D}_2 > 0.$$

Empirically the value of Θ_K, capital's national income share, is around 0.75. (Capital now includes physical as well as human capital.) We find it likely that although the income elasticity of demand for the non-traded good is higher than unity, it nevertheless is lower than 1/0.75 = 1.33 in value. Hence, the ordering of the rates of change of demand in relation to that of capital and income is

$$\hat{K} > \hat{D}_N > \hat{Y} > \hat{D}_1 = \hat{D}_2 > 0.$$

Next, we turn to the output rates of change. First, we have that

$$(6.40) \qquad \hat{X}_N = \hat{D}_N.$$

The movements of the tradables are given by

$$(6.41a) \qquad \hat{X}_1 = \frac{|\lambda_{2N}|}{|\lambda_{12}|}\hat{X}_N - \frac{\lambda_{L2}}{|\lambda_{12}|}\hat{K} = \frac{|\lambda_{2N}|}{|\lambda_{12}|}\eta_{NY}\theta_K\hat{K} - \frac{\lambda_{L2}}{|\lambda_{12}|}\hat{K}$$

$$(6.42a) \qquad \hat{X}_2 = -\frac{|\lambda_{1N}|}{|\lambda_{12}|}\hat{X}_N + \frac{\lambda_{L1}}{|\lambda_{12}|}\hat{K} = -\frac{|\lambda_{1N}|}{|\lambda_{12}|}\eta_{NY}\theta_K\hat{K} + \frac{\lambda_{L1}}{|\lambda_{12}|}\hat{K}$$

To say something about the sign of $\hat{X}_1$ and $\hat{X}_2$ we need to know the sign of the $|\lambda_{ij}|$-determinants. It was shown in the previous section that the sign depends on relative factor intensities, i.e. on the ranking according to the capital-labor ratio of exportables, importables and non-traded goods. In chapter 3 it was found that non-traded goods are more capital intensive than tradable goods, and in chapter 5 that exportables are more capital intensive than importables. Hence, $|\lambda_{12}|<0$ and $|\lambda_{2N}|>0$. We assume that non-traded goods also are more capital intensive than exportable goods, so that $|\lambda_{1N}|>0$. The assumption is justified by the relatively big difference in capital intensity between non-traded and tradable goods shown in *table 3.3*. Thus, the complete ranking assumed throughout the chapter is $(K_N/L_N)>(K_1/L_1)>(K_2/L_2)$.

Consider (6.41a) and (6.42a). The effect of an increase in capital is to raise output of exportables and lower output of importables, as shown by the second term on the right-hand side. The mechanism at work is simple: relatively capital intensive exportable production must expand and relatively labor intensive importable production must contract in order for both factors to be fully employed when the economy becomes more capital abundant (and output of non-traded goods is kept constant). This is the standard Rybczynski [1955] effect.

A second, indirect Rybczynski effect on the output of tradables comes from the change in output of non-traded goods, and is represented by the first term on the right-hand side of (6.41a) and (6.42a). It is positive for importables and negative for exportables under the assumed capital intensity ordering. When non-traded output expands, capital and labor are drawn from the tradable sector in proportions which make the sector more labor intensive. Capital intensive exportables must contract and labor intensive importables expand for capital and labor in the tradable sector to be fully employed.

Is the primary effect of capital accumulation stronger than the secondary effect of an increase in the non-traded good, i.e. is

$$\lambda_{Lj} \gtrless |\lambda_{iN}| \eta_{NY}\theta_K, \quad (i = j = 1,2)?$$

Remember that $\lambda_{ij}<1$ $(i = K,L;\ j = 1,2,N)$. Thus, $\lambda_{Lj}>|\lambda_{iN}| = \lambda_{KN}\lambda_{Lj} - \lambda_{Kj}\lambda_{LN}$. Also, under our assumptions we have that $1>\eta_{NY}\theta_K>0$. Hence, the net effect of capital accumulation is to increase the production of exportables and decrease the production of importables. In fact, the output changes of exportables and importables will be greater in relative terms than the factor changes. By equations (6.17) and (6.18) the rate of change in a factor is a weighted average of output rates of change:

(6.17a) $$\lambda_{L1}\hat{X}_1 + \lambda_{L2}\hat{X}_2 + \lambda_{LN}\hat{X}_N = \hat{L}$$

(6.18a) $$\lambda_{K1}\hat{X}_1 + \lambda_{K2}\hat{X}_2 + \lambda_{KN}\hat{X}_N = \hat{K}$$

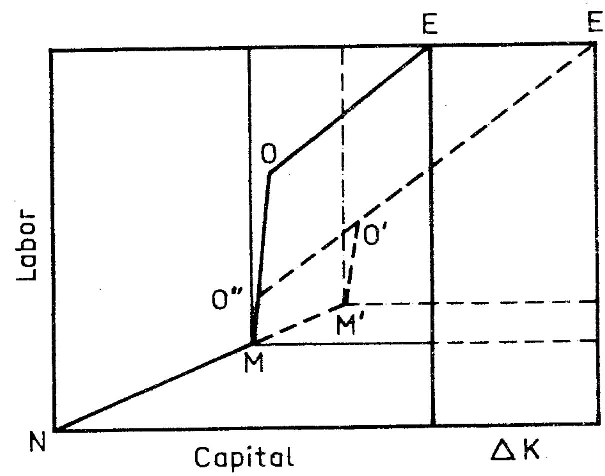
We know that $\hat{K}>\hat{X}_N>\hat{L} = 0>\hat{X}_2$. Hence,

$$\hat{X}_1>\hat{K}>\hat{X}_N>\hat{L}>\hat{X}_2.$$

This is an example of what Jones calls the magnification effect of factor changes on output changes (Jones [1965]).[1]

The effects on allocation in the tradables sector of capital accumulation and an expansion of non-traded output can conveniently be seen in the following box diagram:

Figure 6.1



Total factor endowments are given by the sides of the box. ΔK denotes the addition to the capital stock. Before capital increases NM of the non-traded good, MO of the importable good and EO of the exportable good are produced. The length of each line or ray shows the quantity produced, and the slope indicates the technology, or factor combination, at given factor prices. Clearly, the non-traded good is more capital intensive than exportables which in turn are more capital intensive than importable goods. Note that when the non-traded good's factor requirements are subtracted from total endowments, the tradables sector is left with a lower capital-labor ratio than the aggregate, as

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1 Chapter 8 contains a generalization of the above result in a model with inter-industry flows.

shown by the proportions of the "inner" box relative to those of the "outer" box.

The addition of capital, ΔK, means that the box expands; the new box has the diagonal NE'. (This diagonal and other diagonals in figure 6.1-3 are not drawn.) Assume for a moment that demand for and output of non-traded goods is constant at NM. The new box for tradables is more capital "intensive" than the old box, as shown by the diagonal ME', which is less steep than ME. Output of exportables expands from EO to E'O", and output of importables contracts from MO to MO". However, output of non-traded goods will expand, which will serve to attenuate the effect of capital accumulation on the increased specialization in the tradable sector. Let non-traded output expand from NM to NM'. The inner tradables box becomes less capital intensive, but not as labor intensive as before the capital increase; the slope of the diagonal M'E' is between that of ME and ME'. As a result, exportable output decreases from E'O" to E'O', and importable output expands from MO" to M'O'. The net effect of capital accumulation and expansion of non-traded output is an absolute increase in exportables and an absolute decrease in importables.

For a sufficiently large increase in capital and small increase in the non-traded good, production of importables will cease altogether. With complete specialization in production, changes in capital (or in demand for non-traded goods) lead to changes in relative factor prices, in this case a rise in the wage-rental ratio, see *figure 1.4*.

We now leave price, income and output changes and turn to the effect of capital accumulation on the degree of international specialization, which we in chapter 5 have defined as the ratio between export (or import) value and national income (or GNP). The condition for the degree of international specialization to rise, when income is increasing, is that the marginal trade share exceeds the average share:

$$\frac{d(p_i X_i) - d(p_i D_i)}{dY} > \frac{p_i X_i - p_i D_i}{Y} \qquad i = 1,2$$

Note that the condition is in value terms. It can be manipulated to yield

$$(6.43) \qquad \frac{\hat{p}_1}{\hat{Y}} + \frac{\hat{X}_1}{\hat{Y}} - 1 > \frac{D_1}{X_1}\left(\frac{\hat{p}_1}{\hat{Y}} + \frac{\hat{D}_1}{\hat{Y}} - 1\right)$$

$$(6.44) \qquad \frac{\hat{p}_2}{\hat{Y}} + \frac{\hat{D}_2}{\hat{Y}} + 1 > \frac{X_2}{D_2}\left(\frac{\hat{p}_2}{\hat{Y}} + \frac{\hat{X}_2}{\hat{Y}} + 1\right)$$

Consider inequality (6.44). The price is constant, so the $\hat{p}_2/\hat{Y}$ terms are zero. The term $\hat{X}_2/\hat{Y}$ is negative and X_2/D_2 is less than one. Hence, the right-hand side is less than one in value. The left-hand side is greater than one. Thus, the condition for an increased trade share is fulfilled.

6.6 AN INCREASE IN TASTE FOR NON-TRADED GOODS

One stylized fact of post-war economic development is a high income elasticity of demand for non-traded goods, in particular for private and public services, or alternatively, a shift in taste towards non-traded goods. It was noted in chapter 4 that we cannot discriminate between the two alternative influences on the demand for non-traded goods. We now want to analyse the effects of a higher share of non-traded output and demand in total output and total demand. We will assume that the increased share is caused by a taste shift. An alternative would be to investigate the effects of a high income elasticity *per se*. This could be done by increasing the supplies of capital and labor in the same proportions as the endowment capital-labor ratio. The results would then be the same as that of a shift in taste towards the non-traded good.

We choose to introduce a taste shift into the model by letting demand for non-traded goods be exogenous. Hence, for this case, equation (6.15) is eliminated in the system (6.1)-(6.16). Assume that non-traded demand is increased: $\hat{D}_N>0$.

There will be no price or income changes for this shift in taste, see equations (6.33)-(6.36), which become

(6.33b)-(6.36b) $\hat{w} = \hat{r} = \hat{p}_N = \hat{Y} = 0$

Then, from Walras' law it follows that the changes in demands fulfill

$$\alpha_1\hat{D}_1 + \alpha_2\hat{D}_2 + \alpha_N\hat{D}_N = 0$$

where $\alpha_i = (p_iD_i)/Y$. In analogy with the assumption about homotheticity in the demand for tradables we assume that $\hat{D}_1 = \hat{D}_2$. Since $\hat{D}_N>0$, it follows that $\hat{D}_1 = \hat{D}_2<0$. Specifically, we have that

$$-\hat{D}_1 = -\hat{D}_2 = \frac{\alpha_N}{\alpha_1 + \alpha_2}\hat{D}_N.$$

Next, consider output changes for exportables and importables, where we have used that $\hat{X}_N = \hat{D}_N$:

(6.41b) $\hat{X}_1 = \frac{|\lambda_{2N}|}{|\lambda_{12}|}\hat{X}_N$

(6.42b) $\hat{X}_2 = \frac{-|\lambda_{1N}|}{|\lambda_{12}|}\hat{X}_N$

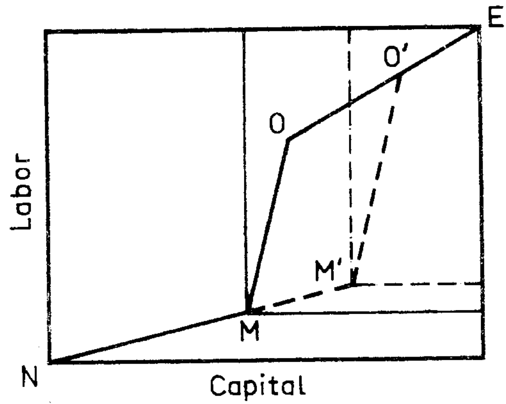
At the given capital intensity ranking of the goods, it is seen that exportables will contract and importables expand. The rate at which exportables contract is higher than the rate of expansion of non-traded goods; we have that

$$\left|\frac{\lambda_{2N}}{\lambda_{12}}\right| > 1$$

in equation (6.41b), since the difference in capital intensity between goods 2 and N is greater than between goods 1 and 2. Similarly, should good 1 and N differ more in capital intensity than 1 and 2, then importables will expand at a higher rate than non-traded goods.

Again, the mechanism at work is conveniently illustrated in a box diagram:

Figure 6.2



When expanding from NM to NM', the non-traded sector draws factors out of the tradables sector. The non-traded good is more capital intensive than both tradables, and therefore leaves the tradables sector with a more labor intensive endowment of factors than before; compare the proportions of the two "inner" boxes for the tradables sector. In order to maintain full employment, exportables, which are capital intensive relative to importables, must contract, from EO to EO', and importables expand, from MO to M'O'.

Because an expansion of non-traded output has the effect of decreasing the output of exportables and increasing the output of importables we expect that the degree of international specialization will fall. Consider inequality (6.44), which is rewritten to be consistent with the present case as

$$\hat{D}_2 > \frac{X_2}{D_2} \hat{X}_2. \qquad (6.44b)$$

Since $\hat{D}_2<0$ and $\hat{X}_2>0$ condition (6.44b) is not fulfilled, and, hence, the ratio of exports to total output will fall, as expected.[1]

6.7 TECHNICAL CHANGE

In this section we will analyze the effects on prices, income, allocation and the degree of international specialization of technical change. Two cases of technical change will be dealt with separately. In section 6.7.1 we consider the case of increased efficiency of the tradable relative to the non-traded sector. The increase in efficiency is assumed to be neutral in Hicks' sense. Then, in section 6.7.2, we let the change in efficiency in the tradable sector be labor-saving, while the change is capital-saving in the non-traded sector.

6.7.1 *Increased efficiency of the tradable relative to the non-traded sector*

We will assume that there is technical change in the tradables sector, in both tradables, and no technical change in the non-traded sector. Nothing essential is lost by letting technical change in the non-traded sector be zero, instead of some positive rate which is lower than that in the tradable sector. Furthermore, we assume that the rate of technical change is equal in exportables and importables. Then we have that

$$\Pi_1 = \Pi_2 > \Pi_N = 0$$

There is no bias in the change in technology. To define what is meant by neutrality and bias we consider the capital-labor ratios, which are functions of the wage-rental ratio and technology:

[1] It is interesting to note a somewhat paradoxical result, which occurs if the non-traded sector is *less* capital intensive than both tradables. In this case an expansion of non-traded output leads to an expansion of exportables and a contraction of importables, i.e. to a trade biased reallocation in the tradables sector. If demand for exportables and importables is homothetic it must be that the export-output ratio *increases*. This result still holds if capital is increased and non-traded demand increases at a lower rate than capital.

$$\frac{a_{Kj}}{a_{Lj}} = k_j = k_j(w/r,\ \tau), \qquad j = 1,2,N.$$

Differentiate and divide through by k_j to obtain

$$\hat{k}_j = \sigma_j \hat{w} + \frac{1}{k_j}\frac{\partial k_j}{\partial \tau} d\tau, \qquad j = 1,2,N.$$

The second term on the right-hand-side shows the change in the capital-labor ratio due to a change in technology *at constant factor prices*. Set

$$\frac{1}{k_j}\frac{\partial k_j}{\partial \tau} d\tau = \gamma_j, \qquad j = 1,2,N.$$

The Hicks definitions of technical change then are

$\gamma_j = 0$ *neutral*

$\gamma_j > 0$ *capital-using (labor-saving)*

$\gamma_j < 0$ *labor-using (capital-saving)*

We can now turn to the results of technical change on the endogenous variables. Consider first the changes in factor prices, the price of the non-traded good and income:

(6.33c) $\hat{w} = \Pi_1 = \Pi_2$

(6.34c) $\hat{r} = \Pi_1 = \Pi_2$

(6.35c) $\hat{p}_N = \Pi_1 = \Pi_2$

(6.36c) $\hat{Y} = \Pi_1 = \Pi_2$

Factor prices, the non-traded goods price and income are all increased at the same rate, equal to the uniform rate of technical progress in tradables. Factor rewards are raised because the factors are now more productive in terms of exportables. The price rise of non-traded goods reflects increased costs and the increase in total income increased factor rewards.

The demand equations now become

(6.37c) $\hat{D}_1 = \eta_{1N}\Pi_1 + \eta_{1Y}\Pi_1$

(6.38c) $\hat{D}_2 = \eta_{2N}\Pi_1 + \eta_{2Y}\Pi_1$

(6.39c) $\hat{D}_N = \eta_{NN}\Pi_1 + \eta_{NY}\Pi_1$

Both the demand for exportables and the demand for importables will rise, assuming that cross-price elasticities are positive. The demand for non-traded goods increases if $|\eta_{NY}| > |\lambda_{NN}|$, otherwise it decreases.

Next, we turn to the output changes. Note first that

(6.40) $\hat{X}_N = \hat{D}_N$.

Substitute (6.39c) into (6.40c) and then substitute the result into (6.41) and (6.42) to get

(6.41c) $$\hat{X}_1 = \frac{|\lambda_{2N}|}{|\lambda_{12}|}\hat{X}_N + \frac{\lambda_{K2}}{|\lambda_{12}|}\Pi_L - \frac{\lambda_{L2}}{|\lambda_{12}|}\Pi_K =$$

$$= \frac{|\lambda_{2N}|}{|\lambda_{12}|}\hat{X}_N + \Pi_1 = \Pi_1\left[\frac{|\lambda_{2N}|}{|\lambda_{12}|}(\eta_{NY}+\eta_{NN}) + 1\right]$$

(6.42c) $$\hat{X}_2 = \frac{-|\lambda_{1N}|}{|\lambda_{12}|}\hat{X}_N - \frac{\lambda_{K1}}{|\lambda_{12}|}\Pi_L + \frac{\lambda_{L1}}{|\lambda_{12}|}\Pi_K =$$

$$= \frac{-|\lambda_{1N}|}{|\lambda_{12}|}\hat{X}_N + \Pi_1 = \Pi_1\left[\frac{-|\lambda_{1N}|}{|\lambda_{12}|}(\eta_{NY}+\eta_{NN}) + 1\right]$$

The effect of a change in non-traded goods output on exportables and importables, the first term on the right-hand side of (6.41c) and (6.42c), depends on the sign of the change. If non-traded output is increased, then exportables contract and importables expand, and *vice versa* if it is decreased. The effect of technical change itself, the term Π_1 on the right-hand side of (6.41c) and (6.42c), is of course positive; the isoquants are simply renumbered at the rate of technical change.

The net effect of technical change on the output of exportables depends on the sign of

$$\left|\frac{\lambda_{2N}}{\lambda_{12}}\right| (\eta_{NY} + \eta_{NN}) + 1$$

and the net effect on importables on the sign of

$$-\frac{|\lambda_{1N}|}{|\lambda_{12}|} (\eta_{NY} + \eta_{NN}) + 1 \ .$$

We expect the value of $\eta_{NY} + \eta_{NN}$ to be between zero and unity, since η_{NN} is somewhat greater than unity, and η_{NN} is negative but probably not greater than unity in absolute value. The ratios $|\lambda_{2N}|/|\lambda_{12}|$ and $-|\lambda_{1N}|/|\lambda_{12}|$ are negative and positive respectively. Hence, it is likely that the output of importables is increased; technical change and the probable increase in non-traded output work in the same direction. As for exportables we must conclude that the outcome is more ambiguous. It depends on the magnitudes of the price and income elasticities and on the factor proportions differences.

Finally, we examine the effects on the degree of international specialization. Consider the necessary condition for an increased import-output ratio (6.44) appropriately rewritten as

$$\text{(6.44c)} \qquad \frac{\hat{D}_2}{\hat{Y}} + 1 > \frac{X_2}{D_2}\left(\frac{\hat{X}_2}{\hat{Y}} + 1\right)$$

A sufficient condition for the ratio to increase is that $\hat{D}_2 > \hat{X}_2$, i.e. that, substituting in (6.38c) and (6.42c),

$$\eta_{2N} + \eta_{2Y} > \frac{-|\lambda_{1N}|}{|\lambda_{12}|}\left(\eta_{NN} + \eta_{NY}\right) + 1$$

However, it is not possible to say whether this condition is likely to be met or not. The value on the left-hand side is probably greater than one, but the first term on the right-hand-side is likely to be positive (the output of the non-traded good increases) so that the value of the right-hand side is also greater than one. We conclude that the outcome for the degree of international specialization of an increased relative efficiency of the tradable sector is uncertain.

6.7.2 *A decrease in the difference in capital intensity between the tradable and the non-traded sector*

In chapter 3 we recorded a sizable difference in capital intensity between the tradable and the non-traded sector, but also a significant decrease in this difference over time. The decrease can in principle be due to three factors: a) a changed composition within the aggregate tradable and/or non-traded sector, b) different elasticities of substitution so that capital is substituted for labor at a higher rate in the tradable sector when the wage-rental ratio is increasing, and c) labor-saving technical change in the tradable sector and/or capital-saving technical change in the nontraded sector.

We have little evidence to enable us to put weights on these three factors. A changed composition of the non-traded sector seems to account for the more or less constant capital-labor ratio in that sector (cf. chapter 3). But we do not have any estimates of elasticities of substitution or of bias in technical change.

In this section we choose to let a labor-saving bias in technical change in the tradable sector and a capital-saving bias in the non-traded sector be the sole cause of a decreased difference in capital intensity between the two sectors. To analyze the effects of different elasticities of substitution we would need a rise in the wage-rental ratio, and this could be brought about in our model by a change in the terms of trade (or other exogenous changes when there is complete specialization in the tradable sector, which we have ruled out). However, a terms-of-trade change is not backed up by our empirical findings. The third alternative, a changed composition within the tradable and non-traded sector, is not suitable for analysis within our model, which only has one non-traded good.

In addition to assuming labor-saving bias in technical change in the tradable sector and capital-saving technical change in the non-traded sector, i.e. $\gamma_1 > 0$, $\gamma_2 > 0$ and $\gamma_N < 0$ according to our definition of bias in section 6.7.1, we assume that the rate of technical change is equal in all three goods, i.e. that

$$\Pi_1 = \Pi_2 = \Pi_N = \Pi$$

This assumption is justified on the grounds that we wish to analyse the effects *only* of bias (more correctly, of a decrease in the capital intensity differential), and consequently do not want any differentials in the rate of technical change to play a role as well.

Finally, it is assumed that technical change does not change the *ranking* of sectors according to capital-intensity. The ranking still is $K_N/L_N > K_1/L_1 > K_2/L_2$ so that $|\lambda_{12}| < 0$, $|\lambda_{1N}| > 0$, $|\lambda_{2N}| > 0$ and $|\theta_{12}| < 0$, $|\theta_{1N}| > 0$, $|\theta_{2N}| > 0$.

Let us now turn to the effects on endogenous prices and on income. Equations (6.33) - (6.36) become

(6.33d) $\hat{w} = \Pi$

(6.34d) $\hat{r} = \Pi$

(6.35d) $\hat{p}_N = 0$

(6.36d) $\hat{Y} = \Pi$

Note that the price of the non-traded good is constant. The reason is that technical change in the non-traded good proceeds at the same rate as the increase in production costs.

The only influence on demands comes from the change in income:

(6.37d) $\hat{D}_1 = \eta_{1Y}\,\Pi$

(6.38d) $\hat{D}_2 = \eta_{2Y}\,\Pi$

(6.39d) $\hat{D}_N = \eta_{NY}\,\Pi$

Under our assumptions about income elasticities we have that

$$0 < \hat{D}_1 = \hat{D}_2 < \Pi < \hat{D}_N .$$

Next, consider output movements. From (6.40) we obtain

(6.40d) $$\hat{X}_N = \hat{D}_N .$$

The outputs of exportables and importables change according to

(6.41d) $$\hat{X}_1 = \frac{|\lambda_{2N}|}{|\lambda_{12}|} \hat{X}_N + \frac{\lambda_{K2}}{|\lambda_{12}|} \Pi_L - \frac{\lambda_{L2}}{|\lambda_{12}|} \Pi_K$$

$$= \frac{|\lambda_{2N}|}{|\lambda_{12}|} \eta_{NY} \Pi + \frac{\lambda_{K2}}{|\lambda_{12}|} \Pi_L - \frac{\lambda_{L2}}{|\lambda_{12}|} \Pi_K$$

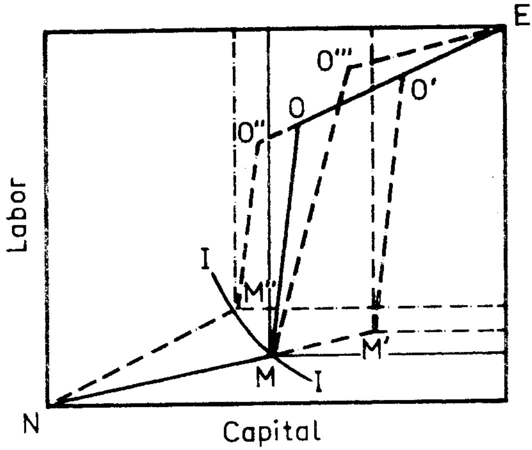
(6.42d) $$\hat{X}_2 = \frac{-|\lambda_{1N}|}{|\lambda_{12}|} \hat{X}_N - \frac{\lambda_{K1}}{|\lambda_{12}|} \Pi_L + \frac{\lambda_{L1}}{|\lambda_{12}|} \Pi_K$$

$$= \frac{-|\lambda_{1N}|}{|\lambda_{12}|} \eta_{NY} \Pi - \frac{\lambda_{K1}}{|\lambda_{12}|} \Pi_L + \frac{\lambda_{L1}}{|\lambda_{12}|} \Pi_K$$

The first two terms on the right-hand side of (6.41d) and (6.42d) are the effects of an increase in the non-traded good and of labor-saving (capital-using) bias in technical change respectively. Both effects work to decrease the output of exportables and increase the output of importables. The third term is the effect of capital-saving (labor-using) technical change. It works opposite the first two effects, i.e. it serves to increase the output of exportables and decrease the output of importables. The net effect depends on the capital intensity differences, the initial resource allocation and the income elasticity of demand for the non-traded good. It is simply not possible to give an intuitively satisfying condition for determinate signs on (6.41d) and (6.42d). It should be noted that if technical change in the non-traded sector were *not* biased, then the signs would be determinate.

The various effects on the output of tradables are conveniently illustrated in a box diagram. Consider *figure 6.3*.

Figure 6.3



Initially the output of the non-traded good is NM, of the exportable EO and of the importable MO. The expansion of non-traded output, holding technology constant, is given by MM'. The capital-labor ratio of the tradable factor endowment is raised (M'E is steeper than ME), and consequently the importable expands from MO to M'O' and the exportable contracts from EO to EO'. Next, assume that there only is capital-saving (labor using) technical change in the non-traded sector. The ray NM shifts to NM". M" and M lie on an isoquant II which is renumbered when we move from M to M". The capital-labor ratio of the tradable endowment is now raised (M"E is less steep than ME), and consequently the output of the importable contracts from MO to M"O" and the output of the exportable expands from EO to EO". Finally, assume that the only change is labor-saving (capital-using) technical change in the tradable sector. The ray for the importable shifts down from MO to MO''' and the ray for the exportable shifts up from EO to EO'''. As a result, the output of the importable expands and that of the exportable contracts.

The ambiguity surrounding the movement of the tradables makes the change in the degree of international specialization uncertain as well.

6.8 TARIFF REDUCTION

An analysis of tariff changes presents a complication which has not been encountered earlier. The complication concerns the way in which tariff proceeds are spent. If the government, which receives the tariff income, spends it differently than private consumers, the difference must be specified and allowed for in the analysis. The standard way to avoid this complication is to assume that tariff income does not accrue to the government, but to private consumers, who spend it in the same way as other income. That assumption is adopted here for analytical convenience and because it brings out the effects of a tariff change *per se* more clearly.

A tariff creates a wedge between the domestic price of importables, p_2^D, and the world market price p_2, such that

$$p_2^D = (1+t)p_2 .$$

where t is the *ad valorem* tariff rate. A reduction in the tariff rate, which we are going to analyze, lowers the domestic price, and gives rise to other price changes throughout the economy. Consider equations (6.33)-(6.35):

$$(6.33e) \quad \hat{w} = \frac{\theta_{K1}\hat{p}_2^D}{-|\theta_{12}|}$$

$$(6.34e) \quad \hat{r} = \frac{-\theta_{L1}\hat{p}_2^D}{-|\theta_{12}|}$$

$$(6.35e) \quad \hat{p}_N = \frac{-|\theta_{1N}|\hat{p}_2^D}{-|\theta_{12}|}$$

As could be expected from the Stolper-Samuelson [1941] theorem, a reduced tariff on the labor intensive good raises the price of capital and lowers the price of labor. The price of non-traded goods, which are even more capital intensive than exportables, is raised. By using equations (6.19)-(6.21), which give goods price changes as weighted averages of factor price changes, we can establish the ordering of price changes as

$$\hat{r} > \hat{p}_N > \hat{p}_1 (=0) > \hat{p}_2^D > \hat{w}$$

It is seen that factor price changes are more pronounced than goods price changes. This is an example of what Jones [1965] calls the magnification effect, which we encountered earlier in section 6.5, in terms of factor and output movements. Note that factor owners gain or lose in terms of *all* commodities, including the non-traded commodity.

Note that national income now consists of factor returns and also of tariff receipts, i.e.

(6.12a) $$Y = wL + rK + tp_2M,$$

where M denotes imports, $D_2 - X_2$.

The rate of change of national income can be written as

(6.22a) $$\hat{Y} = \theta_L(\hat{L}+\hat{w}) + \theta_K(\hat{K}+\hat{r}) + \theta_t(\hat{t}+\hat{p}_2+\hat{M}),$$

where θ_t is the share of tariff receipts in national income.

We can now no longer solve for the change in national income on the basis of known values of factor price changes alone; we also have to know the changes in demand and output of non-traded goods and importables. In other words, we have to solve a system of four equations, namely equation (6.22a) and equations (6.38), (6.39) and (6.42), which will give us

$$\hat{Y},\ \hat{D}_2,\ \hat{D}_N \text{ and } \hat{X}_2.$$

The solution for $\hat{Y}$ is[1]

$$\text{(6.36e)} \qquad \hat{Y} = \frac{-\mu_x}{\Delta}\left[\frac{-(\delta_L\lambda_{K1} + \delta_K\lambda_{L1})(\hat{w}-\hat{r})}{|\lambda_{12}|} - \left|\frac{\lambda_{1N}}{\lambda_{12}}\right| (\eta_{N2}\hat{p}_2^D + \eta_{NN}\hat{p}_N)\right] + \frac{1}{\Delta}\left[\Theta_K\hat{r} + \Theta_L\hat{w} + \Theta_t\hat{t} + \mu_D(\eta_{22}\hat{p}_2^D + \eta_{2N}\hat{p}_N)\right]$$

where $\Delta = 1 - \mu_x\eta_{NY}\left|\frac{\lambda_{1N}}{\lambda_{12}}\right| - \eta_{2Y}\mu_D$

$$\mu_x = \frac{tp_2X_2}{Y}$$

$$\mu_D = \frac{tp_2D_2}{Y}$$

An examination of the terms on the right-hand side of (6.36e) does not lead to any definite conclusion as to the movement of national income. It is easier to see the sources of ambiguity from the appropriately rewritten version of (6.22a)

$$\text{(6.22b)} \qquad \hat{Y} = \Theta_K\hat{r} + \Theta_L\hat{w} + \Theta_t\hat{t} + \mu_D\hat{D}_2 - \mu_x\hat{X}_2$$

We have seen that $\hat{r} > 0$ and $\hat{w}<0$. Also, $\hat{t}<0$. The last two terms on the right-hand side of (6.22b) is the effect on national income of a change in imports. In the presence of non-traded goods we cannot be certain that imports will rise following a reduction in the tariff rate and thus give an increase in tariff income.

Below are the solutions for $\hat{D}_2$, $\hat{D}_N$ (which is equal to $\hat{X}_N$ by (6.40)) and $\hat{X}_2$,

[1] The solutions for $\hat{Y}$, $\hat{D}_2$, $\hat{X}_2$ and $\hat{D}_N$ below contain $\hat{w}$, $\hat{r}$ and $\hat{p}_N$ as independent variables on the right-hand side, since we have solutions for the price changes.

(6.38e)
$$\hat{D}_2 = \frac{-\mu_x}{\Delta}\left[-\frac{\eta_{2Y}\,|\lambda_{1N}|\,(\eta_{N2}\hat{p}_2^D + \eta_{NN}\hat{p}_N)}{|\lambda_{12}|} + \right.$$
$$\left. + \frac{\eta_{NY}\,|\lambda_{1N}|\,(\eta_{22}\hat{p}_2^D + \eta_{2N}\hat{p}_N)}{|\lambda_{12}|}\right] +$$
$$+ \frac{1}{\Delta}\left[\eta_{22}\hat{p}_2^D + \eta_{2N}\hat{p}_N + \eta_{2Y}(\theta_K\hat{r} + \theta_L\hat{w} + \theta_t\hat{t})\right]$$

(6.39e)
$$\hat{D}_N = \frac{+\mu_x}{\Delta}\left[\frac{\eta_{NY}(\delta_L\lambda_{K1} + \delta_K\lambda_{L1})(\hat{w}-\hat{r})}{|\lambda_{12}|}\right] +$$
$$+ \frac{1}{\Delta}\left[\eta_{N2}\hat{p}_2^D + \eta_{NN}\hat{p}_N + \mu_D\eta_{NY}(\eta_{22}\hat{p}_2^D + \eta_{2N}\hat{p}_N) - \right.$$
$$\left. - \eta_{2Y}\mu_D(\eta_{N2}\hat{p}_2^D + \eta_{NN}\hat{p}_N) + \eta_{NY}(\theta_K\hat{r} + \theta_L\hat{w} + \theta_t\hat{t})\right]$$

(6.42e)
$$\hat{x}_2 = \frac{-\mu_D}{\Delta}\left[\frac{-\eta_{2Y}\,|\lambda_{1N}|\,(\eta_{N2}\hat{p}_2^D + \eta_{NN}\hat{p}_N)}{|\lambda_{12}|} + \right.$$
$$- \frac{\eta_{NY}\,|\lambda_{1N}|\,(\eta_{22}\hat{p}_2^D + \eta_{2N}\hat{p}_N)}{|\lambda_{12}|} -$$
$$\left. - \frac{\eta_{2Y}(\delta_L\lambda_{K1} + \delta_K\lambda_{K1})(\hat{w}-\hat{r})}{|\lambda_{12}|}\right] +$$
$$+ \frac{1}{\Delta}\left[\frac{-(\delta_L\lambda_{K1} + \delta_L\lambda_{L1})(\hat{w}-\hat{r})}{|\lambda_{12}|} - \right.$$
$$- \frac{\eta_{NY}\,|\lambda_{1N}|\,(\theta_K\hat{r} + \theta_L\hat{w} + \theta_t\hat{t})}{|\lambda_{12}|} -$$
$$\left. - \frac{|\lambda_{1N}|\,(\eta_{N2}\hat{p}_2^D + \eta_{NN}\hat{p}_N)}{|\lambda_{12}|}\right]$$

Instead of trying to discuss the sources of ambiguity in the above expressions we rewrite (6.24) and (6.25) below:

(6.24e) $$\hat{D}_2 = \eta_{22}\hat{P}_2^D + \eta_{2N}\hat{P}_N + \eta_{2Y}\hat{Y}$$

(6.25e) $$\hat{D}_N = \eta_{N2}\hat{P}_2^D + \eta_{NN}\hat{P}_N + \eta_{NY}\hat{Y}$$

In (6.24e) the first term on the right-hand side is positive, the second is negative and the third is ambiguous in sign. In (6.25e) the first term is negative on the right-hand side, the second is positive and the third is ambiguous as to the sign.

The basic source of ambiguity is the presence of a non-traded good. In the standard 2×2×2 model a decrease in the tariff rate, i.e. in the domestic price of the importable, must result in a rise in output of the importable good and to a fall in output of the exportable good. This link between prices and outputs is broken by the introduction of a non-traded good. The reason is that the non-traded good may increase or decrease in demand and output following a reduction in the tariff. Given a change in the non-traded output, the tradable outputs will also change. The direction of change depends on the configuration of factor proportions. In our case, for example, a decrease in non-traded output will make the exportable good expand and the importable good contract, despite the fact that the price of the importable good has fallen.[1]

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[1] The first to show the ambiguity of price and output responses for tradable goods in a three-good, two-factor model, where one good is non-traded, is Komiya [1967].

6.9 SUMMARY

It is clear that the stylized facts of Swedish post-war growth, which were enumerated in section 6.2, do not produce uniform effects on prices, allocation and the degree of international specialization.

The first case to be analyzed was an increase in the economy's capital abundance. It was found that factor prices and the price of non-traded goods were not affected by the change in factor endowments. As long as both tradables are produced only technical change and changes in world market prices influence domestic factor prices; domestic demand has no influence. The price of non-traded goods is determined by costs, and not by demand.

At constant factor prices an increase in the endowment of capital implies an increase in national income. This in turn affects the demand for and the output of non-traded goods. Demand and output are increased, so that resources are drawn to the non-traded sector from the tradable sector. Since the non-traded sector was found to be relatively capital intensive, it leaves the tradable sector with a more labor intensive endowment than before. Resources within the tradable sector now have to reallocate in order to remain fully employed. Specifically, it is the labor intensive importable good which has to expand, and the relatively capital intensive exportable good which has to contract. This is an example of the Rybczynski effect.

A second influence on the output of tradables comes from the factor endowment change itself. An increasing capital abundance has Rybczynski effects which are opposite those of the non-traded sector expansion: exportables expand and importables contract for factors to be fully employed. It is found that this second influence is stronger than the first, so that the net effect is a trade-biased reallocation. Also, exportables will expand at a higher rate than capital, and importables will fall in output while the supply of labor is constant, i.e. output movements bound factor movements.

Finally, it was found that the trade-biased reallocation following an increase in the capital stock will raise the export-output ratio.

The case of increased capital abundance has been recounted in some detail, because it demonstrates how, first, the non-traded sector, and second, factor endowments available to the tradables sector affect allocation in the tradables sector. The effects of a change in taste for non-traded goods, technical change, and a reduction in tariffs on allocation also work through an indirect change of the factor endowments of the tradables sector caused by a change in non-traded output, and/or through a direct change of the same endowments.

The experiment of letting taste shift towards non-traded goods gives no changes in prices and income. Allocation in the tradables sector changes because the expansion of the non-traded sector makes the tradables sector less capital intensive. Hence, exportables contract and importables expand. The rate at which output of importables expand is higher than the expansion rate for non-traded output. We also find that the degree of international specialization must be lower.

One stylized fact of technical change is a higher rate of Hicks-neutral technical progress in tradables than in non-traded goods. For simplicity we have assumed a positive rate in the tradables sector and zero technical progress in the non-traded sector. The result is that factor prices, the non-traded goods' price and income all increase at the same rate as technical progress in tradables. Demand for exportables and importables will also increase, while some ambiguity surrounds the movement of demand for and output of non-traded goods. Therefore, we cannot be certain that both tradables will expand following neutral technical progress. An increase in the non-traded sector strengthens the effect of technical change for importables, but attenuates the effect on exportables.

Another stylized fact of technology change is that the substantial difference in capital intensity between the non-traded and the tradable sector has decreased significantly. This decrease can in principle depend on changes in sector composition, differences in elasticities of substitution and bias in technical change. We have chosen to let a labor-saving bias in the tradable sector and a capital-saving bias in the non-traded sector be the sole cause of the decrease in capital intensity between the two sectors.

It was found that such biases in technical change produce no changes in relative factor prices, provided that the rate of technical change is the same in the two tradable sectors. The wage, the rental and income all increase at the same rate as the progress in technology. The demand for all goods also increases, since income is raised and all goods prices are constant. In contrast to the changes in prices, income and demand, output changes are ambiguous. The increase in the non-traded output and the labor-saving bias in the tradable sector both work to raise the output of the importable good and lower the output of the exportable good. However, a contrary effect on the tradable outputs comes from the capital-saving bias of technical change in the non-traded sector. If such a bias were absent, the output movements would be unambiguous. Because of the ambiguity surrounding the change in the exportable and the importable good we cannot say how the export-output ratio will change.

The last case to be analyzed was a reduction in the tariff rate. It was found that the rates of change in prices are ordered as

$$\hat{r} > \hat{p}_1 = 0 > \hat{p}_2^D > \hat{p}_N > \hat{w},$$

i.e. that factor price movements bound goods price movements. All other changes in income, demand and output were found to be ambiguous, with little possibility for having presumptions as to what directions of change are likely. In contrast to the standard 2x2 model of trade, the 3x2 model with one non-traded good leaves open the possibility of "perverse" output change of tradables following a change in price, i.e. an output may fall (rise) following an increase (decrease) in its price.

In view of the somewhat different and in many cases ambiguous results for price, demand and output changes which the various stylized facts are seen to produce, can some definite conclusions be drawn about the net results?

To answer this question we first must try to rank the various exogenous changes according to their strength. Such a ranking must be quite impressionistic. It seems that the increased capital abundance constitutes the strongest exogenous influence, because of the magnitude of the change in factor endowments. Another important exogenous change is the differential in the rates of technical change between tradable and non-traded goods. In comparison, the change in capital intensity differences, the shift in taste towards non-traded goods, and, in particular, the reduction of the tariff rate seem to be less important.

If this is a correct ranking of the various stylized facts in terms of the strength of their effects, is it then possible to draw conclusions about the net outcome of all exogenous changes, in particular for allocation in the tradable sector and for the export-output ratio? Remember that the increase in capital abundance leads to a higher rate of expansion of the exportable good than of capital, and to a fall in the output of importables. The export-output ratio increases. A higher rate of technical progress in tradables than in non-traded goods is likely to result in higher output of importables and perhaps also of exportables, but probably not to a higher export-output ratio. We conclude that it is likely that these two exogenous changes produce a more trade-biased allocation and also a higher export-output ratio, but not at all certain.

The remaining exogenous changes give rise to ambiguous output responses, or, in the case of a taste shift towards non-traded goods, to an anti-trade-biased output response and a lower export-output ratio. Hence, the tendency towards a more specialized allocation and a higher degree of international specialization which is produced by the two most important exogenous changes is made weaker, or at least less certain.

No exogenous change except the tariff reduction causes a change in relative factor prices. At the same time we have observed a substantial increase in the wage rate in the real world. To explain such an increase within the theoretical framework of chapter 1 we have to abandon the assumption of incomplete specialization, which we have maintained throughout this chapter. Instead we have to reason that an increasing capital abundance has driven the economy successively to eliminate labor intensive goods and start production of new, more capital intensive goods. When the labor intensive importable no longer is produced and there is complete specialization in the exportable good the wage rate will rise when the economy becomes more capital abundant. At some point the wage-rental ratio is sufficiently high to permit production of a new good, which is capital intensive relative to the old exportable good. The economy again produces two tradables, and increases in the aggregate capital-labor ratio will not alter the wage-rental ratio but instead result in higher production of the new exportable good and lower production of the old exportable good, now a relatively labor intensive importable good. Thus, increasing capital abundance is seen to cause a rising wage-rental ratio through successive switches in the kind of tradables produced.

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CHAPTER 7 CHANGES IN PRICES, ALLOCATION AND TRADE - A SIMULATION ANALYSIS*

7.1 INTRODUCTION

The analytical approach in this chapter is in principle the same as that in chapter 6, which has the title "Changes in prices, allocation and trade - a Heckscher-Ohlin analysis". As in chapter 6 we construct a model of the economy and feed empirically observed facts into the model in order to obtain their *ceteris paribus* effects on prices, income, allocation and trade.

However, whereas the Heckscher-Ohlin model of chapter 6 is a highly stylized and qualitative picture of the real world, the present model is a much more detailed and quantitative general equilibrium representation of the Swedish economy. In particular, the properties of the two models differ in such a way that it can be expected to affect the results of the analysis.

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* I am grateful for the help of several persons; to Lars Bergman for corrections, for suggestions and for guidance in handling the model, Urban Bäckström for research assistance, Henrik Horn for some last-minute calculations, Hans Lind for comments, Håkan Lyckeborg for programming and especially Stefan Lundgren for a generous effort in programming and helping me to get the model through the computer. Errors are of my own making.

The purpose of the analysis in this chapter is to see if the properties of the standard Heckscher-Ohlin model and the properties of a widely used many-sector, quantitative, general equilibrium model are sufficiently different to produce fundamentally different results for the same exogenous changes, or if the properties are sufficiently similar so that the two models give the same qualitative results.

It should be stressed at the outset that although the simulation model is quantitative, and many of its parameters have been estimated on Swedish data or obtained from national accounts statistics, such as input-output tables, the purpose is not to obtain as precise quantitative results as possible. Most of the data, which are accounted for in the *Appendix*, are obtained from other sources, and some of the estimates are judged to be of rather poor quality.

The simulation model is presented in section 7.2. Section 7.3 discusses in what way basic trade theorems, in particular the Rybczynski theorem, may hold in the simulation model. Section 7.4 contains a presentation of the simulations and their results. Finally, some comments and conclusions are presented in section 7.5.

7.2 THE SIMULATION MODEL

The simulation model builds on a quantitative general equilibrium model of the Swedish economy developed by Bergman and Por [1980] for analysing effects of different energy policies and energy prices. Our model differs from theirs in several respects: The demand system in our model holds linear expenditure functions while their system contains multiplicative expenditure functions; their single public sector is disaggregated into seven public sectors in our model; we do not allow for substitution in production between energy inputs and between a composite energy and a composite capital-labor input;

we allow for price elasticity in energy (crude oil) import demand; capital, which in our model consists of physical as well as human capital, and labor are assumed to be homogeneous and earn the same return in all sectors while Bergman and Por allow for rate of return differentials; finally, we have eliminated tax parameters, except for tariffs, as changes in indirect taxes other than in tariffs are of no interest in our application of the model.

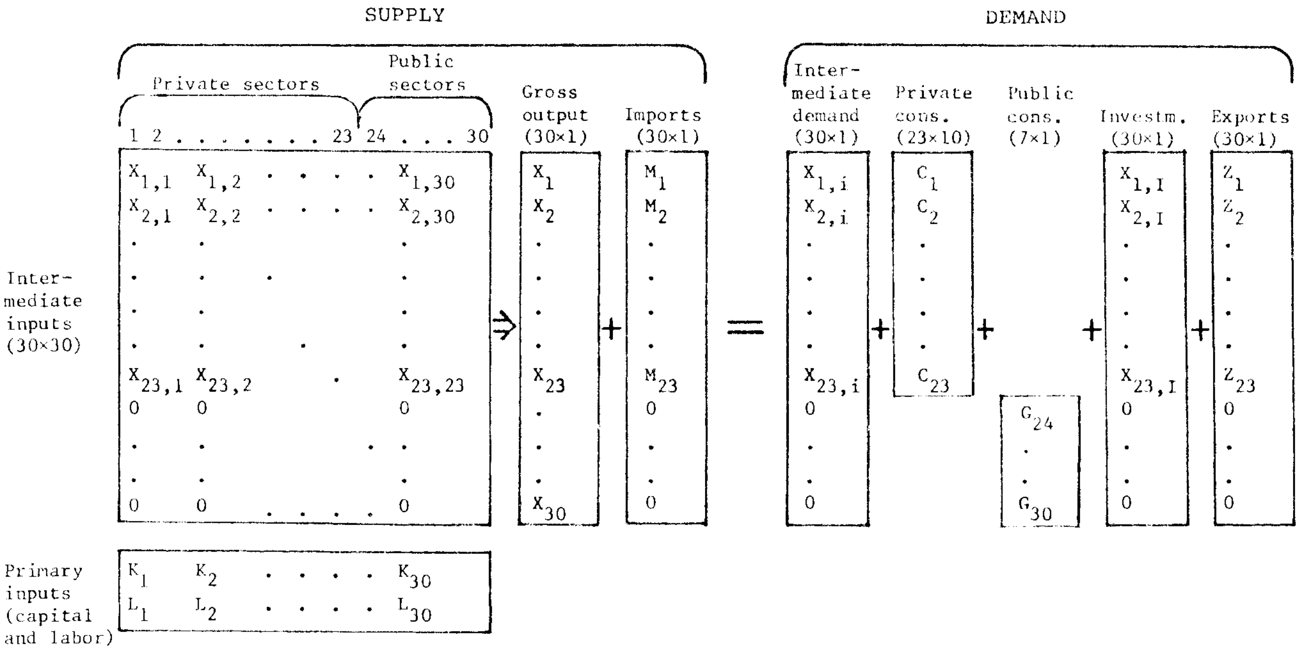
The model of Bergman and Por draws in turn much on the so-called Multi-Sectoral Growth Model (MSG-model) developed by Johansen [1974] in the late 1950's and on similar models for medium-term forecasting by e.g. Restad [1976] and Førsund [1977]. Different versions of Johansen's MSG-model are used extensively in analysing medium-term economic policy in Norway and Sweden.

7.2.1 *An overview of the model*

Figure 7.1 on the next page is designed to demonstrate the input-output structure of the model. Primary and intermediate inputs are combined in each sector on the supply side to produce one, homogeneous output. Intermediate inputs are used in fixed proportions, i.e. the input-output coefficients are invariant with respect to prices, while primary inputs, capital and labor, are combined via production functions, allowing for substitution and technical change.

Total supply is made up of gross domestic production, i.e. output for use as intermediate inputs as well as for final demand, and of imports. The size of imports is determined by import functions.

Figure 7.1


SUPPLY
DEMAND
Public sectors
Private sectors
1 2 . . . . 23 24 . . . 30
Gross output (30×1)
Imports (30×1)
Intermediate demand (30×1)
Private cons. (23×10)
Public cons. (7×1)
Investm. (30×1)
Exports (30×1)
Intermediate inputs (30×30)
Primary inputs (capital and labor)
X1,1 X1,2 . . . . . X1,30
X2,1 X2,2 . . . . . X2,30
X23,1 X23,2 X23,23
K1 K2 . . . . . K30
L1 L2 . . . . . L30
X1 X2 X23 X30
M1 M2 M23
X1,i X2,i X23,i
C1 C2 C23
G24 G30
X1,I X2,I X23,I
Z1 Z2 Z23

There are five different uses for the total supply of commodities: as intermediate inputs, as private and public consumption, as investment, and as exports. Demand for intermediate inputs is determined by fixed input-output coefficients, as already mentioned. Note that public goods are not used as inputs in other production, according to official input-output tables. Private consumption is determined endogeneously by a standard linear expenditure system. Public consumption, on the other hand, is determined exogeneously. Exports are given endogenously by export functions.

Investments constitute the resource cost for maintaining and expanding *part* of the capital stock. Capital is a composite of physical and human capital. It is only the physical capital component which requires resources explicitly, in the form of investments. Human capital is assumed to be formed via various forms of public production and consumption, such as education and health care, and by learning-by-doing. Investments in physical capital are determined exogenously, as is the growth of the aggregate capital stock. The homogeneous investment good is formed by "production", where the inputs are combined with fixed coefficients.

World market prices, other than Swedish export prices, are assumed to be given. All other prices, i.e. factor prices, domestic prices of goods, and the exchange rate, are determined endogenously.

The solution of the model gives a complete allocation on the production side, with output and inputs in each sector, imports and exports, also by sector, private consumption and all prices, except world market prices of traded goods. All factor and goods markets are cleared. The solution requires exogenously given aggregate capital and labor input, public consumption, aggregate net investment, and world market prices, plus values on input-output coefficients and parameters in the various functions.

The more detailed presentation of the simulation model below is divided into subsections. In section 7.2.2 endogenous variables, exogenous variables and parameters are listed. The supply and demand parts of the model are presented in sections 7.2.3 and 7.2.4 respectively. Price formation and related questions are dealt with in section 7.2.5 and equilibrium conditions and national accounting identities are given in section 7.2.6.

7.2.2 *A list of variables and parameters*

Endogenous variables

X_j	gross output in sector j = 1, 2, ..., 23
X_{ij}	input of good i into good j; i = 1, 2, ..., 23; j = 1, 2, ..., 30
K_j	capital stock in sector j = 1, 2, ..., 30
L_j	labor supply in sector j = 1, 2, ..., 30
M_j	import of commodity j = 1, 2, ..., 23
M	aggregate imports
Z_j	export of commodity j = 1, 2, ..., 23
Z	aggregate exports
C_h	private consumption of consumer good h = 1, 2, ..., 10
C	aggregate private consumption
E	aggregate private expenditure
Y	gross national product
P_j	domestic cost of production equal to price of domestically produced commodity j = 1, 2, ..., 30
P_j^D	domestic price of commodity j = 1, 2, ..., 30
P_h^C	price of consumption good h = 1, 2, ..., 10
w	wage rate
r	net rate of return to capital
R	user cost of capital
V	exchange rate (units of domestic currency per unit of foreign currency)
P_I^D	price of capital.
X_I	output of gross investments

<u>Exogenous variables</u>

L aggregate supply of labor

K aggregate stock of capital

G aggregate public consumption

G_j consumption of public good $j = 24, 25, \ldots, 30$

X_j output of public good $j = 24, 25, \ldots, 30$

I aggregate net investments

D surplus/deficit on the current account

P_j^{WZ} world market price, in foreign currency, of exported commodity $j = 1, 2, \ldots, 23$

P_j^{WM} world market price, in foreign currency, of imported commodity $j = 1, 2, \ldots, 23$

ϕ_j *ad valorem* tariff on commodity $j = 1, 2, \ldots, 23$.

<u>Parameters</u>

a_{ij} input of commodity $i = 1, 2, \ldots, 23$ per unit of output of commodity $j = 1, 2, \ldots, 30, I$

A_j constant in production function for gross output $j = 1, 2, \ldots, 30$

α_j distribution parameter in the production function of sector $j = 1, 2, \ldots, 30$

λ_j rate of technical change in sector $j = 1, 2, \ldots, 30$

δ rate of depreciation

σ_j rate of change of rest of the world output of commodity $j = 1, 2, \ldots, 23$

γ_j, ξ_j residual rate of growth of exports $j = 1, 2, \ldots, 23$ and of imports $j = 1, 2, \ldots, 23$ respectively[1]

ε_j, μ_j price elasticity parameters in the export and import function for sector $j = 1, 2, \ldots, 23$

η_h marginal propensity to consume good $h = 1, 2, \ldots, 10$

f_{jh} "input" of commodity $j = 1, 2, \ldots, 23$ per unit of private consumption good $h = 1, 2, \ldots, 10$.

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[1] Explained in section 7.2.4.

7.2.3 *Production functions and production costs*

Production is carried out under constant returns to scale. There is some scope for factor substitution between capital and labor. Other inputs are used in constant proportions:

$$(7.1) \qquad X_{ij} = a_{ij}X_j \qquad i = 1, 2, .., 23; \quad j = 1, 2, .., 30$$

Capital and labor are combined by Cobb-Douglas production functions to produce value-added. Value-added is then combined with intermediate inputs in fixed proportions to produce gross output according to

$$(7.2) \qquad X_j = A_j K_j^{\alpha_j} L_j^{(1-\alpha_j)} e^{\lambda_j t} \qquad j = 1, 2, ..., 30$$

where A_j describes the proportions between value-added and intermediate inputs.

It is assumed that producers in private sectors maximize profits, subject to their production functions, and that producers in public sectors minimize costs, subject to their production functions. We note that profit maximization and cost minimization yield the same first order conditions for an optimal factor combination with constant returns to scale production functions.

The user cost of capital, R, is defined as

$$(7.3) \qquad R = (r+\delta)P_I^D$$

where P_I^D is the price of capital, defined as

$$(7.4) \qquad P_I^D = \sum_{i=1}^{23} a_{iI}P_i^D.$$

Note that capital, which consists of both human and physical capital, earns the same net return everywhere and has the same rate of depreciation.

The wage rate, w, is also assumed to be the same in all sectors. It has been set equal to the dish-washer wage, and human capital has been computed in the way described in chapters 2 and 3.

7.2.4 *Demand for commodities*

The demand for commodities can be classified into six categories: for private consumption, for public consumption, for investment, for imports, for exports, and for intermediate inputs.

Private consumption is determined endogenously by Stone's linear expenditure system.[1]

$$(7.5) \qquad C_h = C_h(0) + \frac{\eta_h}{P_h}\left(E - \sum_{k=1}^{10} P_k^C C_k(0)\right) \qquad h = 1,2,\ldots,10$$

The notation (0) means consumption dated at time 0, i.e. the base year. Other quantities and all prices are for some other year *t*.

Each private consumption good h is composed of commodities supplied by the private sector in fixed proportions:

$$(7.6) \qquad X_j^C = \sum_{h=1}^{10} C_h f_{hj} \qquad j = 1,\ldots,23$$

where X_j^C is the amount of good j allocated to private consumption.

Demand for public consumption and for physical capital investment, both their aggregate levels and their composition, are determined exogenously. Intermediate input demand is given by equation (7.1).

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1 The consumption functions (7.5) satisfy the budget restriction, are linearly homogeneous and satisfy the Slutsky condition that cross-price substitution effects be symmetrical. These are conditions generally required from demand systems. For a further discussion of Stone's linear expenditure system and its properties, see e.g. Deaton and Muellbauer [1980].

Private and public consumption and investment consists of domestically produced and also of imported commodities. The share of imports in domestic demand is determined by the relative price of imports, by the historically given share of imports in domestic supply and a residual growth of imports. The import functions give imports as a proportion of output less exports:

$$(7.7) \qquad m_i = \frac{M_i}{X_i - Z_i} = \frac{M_i(0)}{X_i(0) - Z_i(0)} \left(\frac{P_i}{(1+\phi_i) VP_i^{WM}} \right)^{\mu_i} e^{\xi_i t}$$

$$i = 1,2,\ldots,23$$

Export demand is a function of the relative price of exports, of the growth of output in the rest of the world and of residual growth:

$$(7.8) \qquad Z_i = Z_i(0) \left(\frac{P_i}{VP_i^{WE}} \right)^{\varepsilon_i} e^{(\sigma_i + \gamma_i)t} \qquad i = 1,2,\ldots,23$$

The residual growth rates ξ_i and γ_i are such that in the standard simulation (see section 7.4) the growth of the import shares and of exports equal the actual growth rates.

Import and export functions on the form of (7.7) and (7.8), which are common in many-sector macro models, have been given a theoretical foundation by Armington [1969]. Very briefly, Armington argues that goods can be differentiated in demand not only by their kind, e.g. as machinery and chemicals, but also by their place of production. Thus, in a world with two countries, Sweden and Norway, and two kinds of goods, chemicals and machinery, there will be four different kinds of goods in demand, namely chemicals produced in Sweden, chemicals produced in Norway, machinery produced in Sweden, and machinery produced in Norway. Armington then derives demand functions for goods which are defined by kind and place of production in the usual way by maximizing a welfare function (for a country) subject to a budget constraint. By employing the assumptions a) the marginal rates of substitution between goods of the same kind (and from different places of production) are independent of the quantities of all other kinds of goods (i.e. separability), and b) that each good's share of the market for goods from different places of production but of the same kind is unaffected by the size of the market as long as relative prices in the market are constant (i.e. homotheticity), he derives demand functions where demand for a good defined by kind and origin depends on money income, the price of each general kind of good, and the price of the good relative to every other good in the same market. To simplify the demand functions further and to collapse the number of goods in each market, i.e. the number of places of origin, he assumes that a) elasticities of substitution between products competing in any market are constant (they are independent of market shares) and b) the elasticity of substitution between any two goods competing in a market is the same as that between any other pair of goods competing in the same market. For a more detailed discussion and derivation of (7.7) and (7.8) see Armington [1969].

Armington's way of differentiating products in demand by location of production (and not by technology characteristics) provides an explanation for intra-industry trade which in principle is the same as that discussed in chapter 5. A difference is that here countries are completely specialized in particular varieties, whereas other product differentiation theories allow for production of the same variety in different countries.

It should be pointed out that Armington's approach means that there are separate markets for goods which in the simulation model have been aggregated into one good (or sector). Strictly, aggregation of these different goods must be non-linear by the form of the export and import functions and not linear, as in (7.9) below, for prices, and in (7.13), for goods.

However, for relatively small differences in relative prices, the linear aggregation in (7.9) is probably a good approximation.[1]

7.2.5 *Prices*

The world market prices, P_i^{WM} and P_i^{WZ}, are given.

The wage rate, w, and the rental rate, r, are market clearing prices in the labor and capital markets respectively (see (7.16) and (7.17)).

Producer costs, P_j, are given by production costs. In equilibrium they are equal to the prices of domestically produced goods. They need not be and usually are not equal to prices of the same *consumption* goods, since the latter are aggregates of domestically produced goods and imports.

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[1] In addition to the theoretical construction by Armington there may be other explanations for having export and import functions with less than infinite elasticities. One explanation, pointed out by Lars Bergman, is that the convention used by the National Central Bureau of Statistics to aggregate domestic output means that the domestic aggregates are different from the imports which are classified under the same sector heading. Aggregation of domestic output follows the *main* good of the plant. If the plant produces goods which come under a different sector heading, these goods are nevertheless considered to be of the same kind as the main good. Import aggregates, on the other hand, only contain the goods which strictly belong under the sector heading. Hence, domestic aggregates and import aggregates have different composition and, therefore, normally different prices. If the goods are not perfect substitutes, import functions should be on the form (7.7).

Yet another explanation in terms of "erroneous" aggregation has been suggested by Karl-Göran Mäler in conversation. He argues that the home country and the rest of the world each are completely specialized in a large number of goods. Each sector supply contains a set of goods produced domestically and a set of different goods produced abroad. This explains the less than infinitely elastic supply of imports and exports. When comparative costs change the composition of the sector supply between domestic production and imports is altered, as some domestic production of previously foreign-produced goods is started, or some domestic production is dropped completely and is moved to other countries. Consequently, the relative price of the import aggregate will also change.

Prices, P_j^D, are weighted averages of the import price and and the producer cost:

$$(7.9) \qquad P_j^D = \frac{m_j}{1+m_j} (1+\phi_j) VP_j^{WM} + \frac{1}{1+m_j} P_j \qquad j = 1,2,...,23$$

The prices of the composite consumption goods, P_h^C, are then simply weighted averages of the prices:

$$(7.10) \qquad P_h^C = \sum_{j=1}^{23} f_{jh} P_j^D \qquad h = 1,2,...,10$$

The price of the investment good, P_I^D, is determined according to equation (7.4) above.

In order for the price *level* to be determinate we normalize it and hold it constant at unity:

$$(7.11) \qquad \sum_{j=1}^{30} P_j X_j + \sum_{j=1}^{23} VP_j^{WM} M_j = \sum_{j=1}^{30} X_j + \sum_{j=1}^{23} M_j$$

The normalization of the price level in effect is the endogenous determination of the exchange rate, V.

There is no explicit budget restriction for households in the model. Such a restriction is implied by the trade balance condition

$$(7.12) \qquad \sum_{j=1}^{23} \frac{P_j}{V} Z_j - \sum_{j=1}^{23} P_j^{WM} M_j = D$$

7.2.6 *Equilibrium conditions and accounting identities*

The following equilibrium conditions must be fulfilled and are needed to close the model:

(7.13) $$X_i = \sum_{j=1}^{30} a_{ij}X_j + X_i^C + X_{i,I} + Z_i - M_i \qquad i = 1,2,\ldots,23$$

(7.14) $$X_i = G_i \qquad i = 24,\ldots,30$$

(7.15) $$X_I = I + \sum_{j=1}^{30} \delta K_j$$

(7.16) $$\sum_{j=1}^{30} K_j = K$$

(7.17) $$\sum_{j=1}^{30} N_j = N$$

The aggregate variables Y, C, G, Z and M are defined as

(7.18) $$Y = C + G + X_I + Z - M$$

(7.19) $$C = \sum_{h=1}^{10} C_h$$

(7.20) $$G = \sum_{j=24}^{30} G_j$$

(7.21) $$Z = \sum_{j=1}^{23} Z_j$$

(7.22) $$M = \sum_{j=1}^{23} M_j$$

7.3 BASIC TRADE THEOREMS AND THE SIMULATION MODEL

There exist two differences between the Heckscher-Ohlin model in chapter 6 and the simulation model which are of fundamental importance. One difference is that the Heckscher-Ohlin model has exogenous prices on tradable goods, while the simulation model has endogenous prices on domestically produced tradables. In trade literature language the difference is that between a "small" and a "large" country. This means that production of tradables in the Heckscher-Ohlin model is not influenced by domestic demand for tradables, while the opposite is true for the simulation model.

A second difference is that the Heckscher-Ohlin model has an equal number of tradable and produced goods as factors, while the simulation model has a greater number of goods than factors. As a result, we cannot apply the Rybczynski and Stolper-Samuelson theorems, which are basic for the analysis in chapter 6 without making some further assumptions. With more goods than factors we can no longer say, for example, how a particular output will change following an increase in the endowment capital-labor ratio, or how a change in the price of a particular good will affect the wage-rental ratio.

Having said this much, what reasons do we have to expect that the Heckscher-Ohlin model in chapter 6 and the simulation model will yield the same qualitative results for the same changes in exogenous variables? To answer this question we will first study a model of a closed economy having only two goods and two factors and then continue the discussion in a many good - two factor context. The model is described by the following equations, where the meaning of all symbols is identical to those in the Heckscher-Ohlin model in chapter 6 (see pp. 116 - 119):[1]

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[1] The model is practically identical to a model in Jones [1965].

(7.23) $\lambda_{L1}\hat{X}_1 + \lambda_{L2}\hat{X}_2 = \hat{L} + \delta_L(\hat{w}-\hat{r}) + \Pi_L$

(7.24) $\lambda_{K1}\hat{X}_1 + \lambda_{K2}\hat{X}_2 = \hat{K} - \delta_K(\hat{w}-\hat{r}) + \Pi_K$

(7.25) $\theta_{L1}\hat{w} + \theta_{K1}\hat{r} = \hat{p}_1 + \Pi_1$

(7.26) $\theta_{L2}\hat{w} + \theta_{K2}\hat{r} = \hat{p}_2 + \Pi_2$

(7.27) $\hat{D}_1 = \eta_{11}\hat{p}_1 + \eta_{12}\hat{p}_2 + \eta_{1Y}\hat{Y}$

(7.28) $\hat{D}_2 = \eta_{21}\hat{p}_1 + \eta_{22}\hat{p}_2 + \eta_{2Y}\hat{Y}$

(7.29) $\hat{Y} = \theta_L(\hat{w}+\hat{L}) + \theta_K(\hat{r}+\hat{K})$

(7.30) $\hat{X}_1 = \hat{D}_1$

(7.31) $\hat{X}_2 = \hat{D}_2$

There are 9 endogenous variables in the model, namely $\hat{X}_1$, $\hat{X}_2$, $\hat{D}_1$, $\hat{D}_2$, $\hat{p}_1$, $\hat{p}_2$, $\hat{w}$, $\hat{r}$, and $\hat{Y}$. Two variables are exogenous, $\hat{L}$ and $\hat{K}$.

Quantities, prices and income are determined by factor endowments, by preferences, as given by price and income elasticities, and by technology. Already at this point we make the crucial assumption that demand is homothetic, i.e. that $\eta_{1Y} = \eta_{2Y} = 1$. This assumption is discussed below. Also, as *numeraire* we use good 1, so that $\hat{p}_1 = 0$. In what follows we are not going to study effects of technical progress; for simplicity we set $\Pi_L = \Pi_K = \Pi_1 = \Pi_2 = 0$.

We will solve for the differences $(\hat{X}_1-\hat{X}_2)$, $(\hat{w}-\hat{r})$ and $(\hat{p}_1-\hat{p}_2)$. Subtract (7.24) from (7.23), (7.26) from (7.25) and (7.28) from (7.27) to obtain

(7.32) $$(\hat{X}_1-\hat{X}_2) = \frac{(\hat{L}-\hat{K})}{|\lambda_{12}|} + \frac{(\hat{w}-\hat{r})(\delta_L+\delta_K)}{|\lambda_{12}|}$$

(7.33) $$(\hat{w}-\hat{r}) = \frac{(\hat{p}_1-\hat{p}_2)}{|\theta_{12}|}$$

(7.34) $$(\hat{p}_1-\hat{p}_2) = \frac{-(\hat{D}_1-\hat{D}_2)}{(\eta_{12}-\eta_{22})}$$

Define $(\hat{D}_1-\hat{D}_2)/(\hat{p}_2-\hat{p}_1) = (\eta_{12}-\eta_{22})$ as the elasticity of demand substitution, σ_D. In a two-good model with homothetic preferences $\sigma_D > 0$.

Substitute (7.33) into (7.32) to obtain

(7.35) $$\frac{(\hat{X}_1-\hat{X}_2)}{(\hat{p}_1-\hat{p}_2)} = \frac{(\hat{L}-\hat{K})}{|\lambda_{12}|(\hat{p}_1-\hat{p}_2)} + \frac{(\delta_L+\delta_K)}{|\lambda_{12}||\theta_{12}|}$$

At constant factor supplies and technology (7.35) gives the elasticity of commodity substitution along the transformation curve. Define σ_S as

$$\sigma_S = \frac{(\hat{X}_1-\hat{X}_2)}{(\hat{p}_1-\hat{p}_2)} = \frac{(\delta_L+\delta_K)}{|\lambda_{12}||\theta_{12}|}$$

The elasticity is positive, since $\delta_L > 0$ and $\delta_K > 0$, and $|\lambda_{12}|$ and $|\theta_{12}|$ always have the same sign.

Solving for the three differences in rates of change in terms of exogenous variables now yields

$$(7.36) \qquad (\hat{X}_1-\hat{X}_2) = \frac{(\hat{L}-\hat{K})\ \sigma_D}{|\lambda_{12}|\,(\sigma_D+\sigma_S)}$$

$$(7.37) \qquad (\hat{w}-\hat{r}) = \frac{-\ (\hat{L}-\hat{K})}{|\theta_{12}|\,|\lambda_{12}|\,(\sigma_D+\sigma_S)}$$

$$(7.38) \qquad (\hat{p}_1-\hat{p}_2) = \frac{-\ (\hat{L}-\hat{K})}{|\lambda_{12}|\,(\sigma_D+\sigma_S)}$$

We are now prepared to discuss the differences in scope for Rybczynski type output effects in a model where prices change following changes in exogenous variables, as in the simulation model, compared to in a model with no price changes, as in the Heckscher-Ohlin model (for most of the cases we have analysed).

We take the case of an increase in the capital stock, i.e. $\hat{K} > 0$ and $\hat{L} = 0$. Consider (7.36). The difference in the rates of output changes is determined by a) price elasticities of demand, σ_D (but not by income elasticities, because of our assumption of homotheticity), b) factor proportions differences, as given by $|\lambda_{12}|$, and c) elasticities of substitution through σ_S. In a two-good, two-factor Heckscher-Ohlin model only factor proportions differences would have mattered; (7.36) then becomes:

$$(7.39) \qquad (\hat{X}_1-\hat{X}_2) = \frac{(\hat{L}-\hat{K})}{|\lambda_{12}|} \ .$$

For $K_1/L_1 > K_2/L_2$ we have that $|\lambda_{12}| < 0$, and, hence, $(\hat{X}_1-\hat{X}_2) >$ > 0. But in a closed economy, factor and goods prices will change following a change in factor endowments. Assume that $K_1/L_1 > K_2/L_2$ so that the determinants $|\lambda_{12}| < 0$, $|\theta_{12}| < 0$. Then we have, from (7.38) and (7.37), $(\hat{p}_1-\hat{p}_2) < 0$ and $(\hat{w}-\hat{r}) > 0$.

The rise in the wage-rental ratio will diminish the Rybczynski effect, because it will give rise to substitution in production. This is best seen from equation (7.32). A big change in the wage-rental ratio, big elasticities of substitution, shown through δ_L and δ_K, and a small difference in capital intensity, $|\lambda_{12}|$, serve to dampen the Rybczynski output effect of a change in factor endowments.

However, under our assumption that demand is homothetic we find that the primary Rybczynski effect is stronger than the secondary effects on output induced by price changes.

Non-homothetic demand may strengthen or attenuate this result, depending on whether the income elasticity for good 1 is greater or smaller than the income elasticity for good 2. With non-homothetic demand (7.36) becomes

$$(7.39) \qquad (\hat{X}_1-\hat{X}_2) = \frac{(\hat{L}-\hat{K})\ \sigma_D}{|\lambda_{12}|(\sigma_D+\sigma_S)} + \frac{\sigma_S(\eta_{1Y}-\eta_{2Y})\hat{Y}}{(\sigma_D+\sigma_S)}$$

A second term is now added to the right-hand-side of (7.36). Assuming that national income increases following an increase in capital, i.e. $\hat{Y} > 0$, the term is positive or negative according as $\eta_{1Y} \gtrless \eta_{2Y}$.

Note that the relation between goods prices and factor prices is not altered by letting the goods prices be endogenous instead of exogenous as in the Heckscher-Ohlin model. Equation (7.33) is identical to the corresponding equation in the standard two-good, two-factor Heckscher-Ohlin model.

The model exercise shows that in a closed economy demand can serve to prevent extreme reallocations following changes in exogenous variables, such as factor endowments. This brings us back to the question asked at the outset: What reasons do we have to expect that the Heckscher-Ohlin model in chapter 6 and the simulation model will yield the same qualitative results for the same changes in exogenous variables?

Assume that we increase the supply of capital in a many-good, two-factor model with endogenous prices. Also, assume that there is no possibility for substitution in production. The increase in capital can in principle be absorbed by an infinite number of reallocations. For example, the most capital intensive sector may expand while all other sectors contract or some sectors in the middle range of capital intensities may expand while both more and less capital intensive sectors contract.

The actual reallocation will however not be stochastic, but will be determined by the demand system. Assume that demand is *homothetic* and *symmetric* in the sense that all goods have the same own-price elasticites and that all cross-price elasticities are the same, i.e.

$$\eta_{iY} = 1 \qquad i = 1,\ldots, n$$

$$\eta_{ii} = \eta_1 \qquad i = 1,\ldots, n$$

$$\eta_{ij} = \eta_2 \qquad i = 1,\ldots,n;\ j = 1,\ldots,n;\ i \neq j.$$

The many-good, two-factor model corresponding to the model described by (7.23)-(7.31), assuming no technical change and no substitution in production, can now be written as

$$(7.40) \qquad \sum_{i=1}^{n} \lambda_{Li}\hat{X}_i = \hat{L}$$

$$(7.41) \qquad \sum_{i=1}^{n} \lambda_{Ki}\hat{X}_i = \hat{K}$$

$$(7.42) \qquad \theta_{Li}\hat{w} + \theta_{Ki}\hat{r} = \hat{p}_i \qquad i=1,\ldots,n$$

$$(7.43) \qquad \hat{D}_i = \sum_{j=1}^{n} \eta_{ij}\hat{p}_j + \hat{Y} \qquad i=1,\ldots,n$$

$$(7.44) \qquad \hat{Y} = \theta_L(\hat{w}+\hat{L}) + \theta_K(\hat{r}+\hat{K})$$

$$(7.45) \qquad \hat{X}_i = \hat{D}_i \qquad i=1,\ldots,n$$

There are 3n + 3 equations to solve for the rates of change in n prices p_i, n outputs X_i, n demands D_i, the wage rate w, the rental rate r and national income Y. Equations (7.40)-(7.45) can be manipulated to yield the following relations:

$$(7.46) \qquad (\hat{w}-\hat{r}) = \frac{(\hat{L}-\hat{K})}{\left(\eta_1-\eta_2\right)\left(\sum_{i=1}^{n} \lambda_i \theta_{Li}\right)}$$

$$(7.47) \qquad (\hat{p}_i-\hat{p}_j) = (\theta_{Li}-\theta_{Lj})(\hat{w}-\hat{r}) \qquad i=1,\dots,n \quad j=1,\dots,n \quad i \neq j$$

$$(7.48) \qquad (\hat{X}_i-\hat{X}_j) = (\eta_1-\eta_2)(\hat{p}_i-\hat{p}_j) \qquad i=1,\dots,n \quad j=1,\dots,n \quad i \neq j$$

Assume now that there is an increase in capital but that the supply of labor is constant, i.e. $\hat{K} > 0$ and $\hat{L} = 0$. From (7.46) we have that the wage-rental ratio must increase following the change in factor endowments. The term $(\eta_1-\eta_2)$ is negative, since the uniform own-price elasticity of demand η_1 is assumed to be negative and the uniform cross-price elasticity η_2 positive.

Consider next (7.47). A given rise in the wage-rental ratio will lower (raise) relative costs of production for capital (labor) intensive goods. The fall (rise) in production costs is larger the more capital (labor) intensive production is, as shown by the term $(\theta_{Li}-\theta_{Lj})$. Costs are equal to prices. We have the result that when capital intensities are ranked as

$$\theta_{K1} > \theta_{K2} > \dots > \theta_{Kn},$$

the price rates of change will be ranked as

$$\hat{p}_1 < \hat{p}_2 < \dots < \hat{p}_n.$$

Consider now (7.48). The difference in rates of change of outputs is proportional to the difference in their price rates of change. Since the latter difference is dependent on capital intensities as shown above we have the result that the output rates of change are ranked as

$$\hat{x}_1 > \hat{x}_2 > \dots > \hat{x}_n.$$

Hence, we argue that under a certain degree of symmetry in demand and substitution and with income elasticities close to unity we can expect a positive correlation between the ranking of capital intensities and the ranking of the rates of output change in the simulation model when capital is increased (and a negative correlation when labor is increased). In addition, the ranking of the rates of change of prices will be negatively correlated with the ranking according to capital intensity when capital is increased (and positively correlated when labor is increased).

Are the conditions about price and income elasticities of demand and elasticities of substitution met by the simulation model? Let us first consider elasticities of substitution. All sectors produce value-added by Cobb-Douglas production functions, see equation (7.2). Hence, the elasticity of substitution between capital and labor is constant and equal to unity in value-added as well as in intermediate inputs. The condition about *symmetry* in substitution is thereby fulfilled. (Accordingly, there will be no factor intensity reversals.) On the other hand, the scope for substitution is considerable; substitution between labor and capital takes place at the same rate as factor prices change. *This property of the simulation model can be expected to neutralize a substantial part of the Rybczynski output effects.*

Next, we consider the demand system. Demand for domestically produced goods is composed of private (household) demand, public demand, investment demand, and export demand. Public demand is held constant, except in one simulation, where we study the effects of an expansion of public output and demand. Investment demand is also determined exogenously (as a function of the exogenously determined capital stock), and the composition of the investment good is fixed. Export demand is determined by the ratio between the Swedish production cost and the world market price, a price elasticity term, and exogenously given growth rates. The price elasticities and the growth rates differ substantially between export functions, so that export demand is not characterized by symmetry and homotheticity. The private demand system, on the other hand, is nearly homothetic in that the marginal consumption propensities are close to unity for all consumption goods, and the matrix converting sector-classified outputs into consumption goods has fixed coefficients, see (7.5) and (7.6). Also, Stone's linear expenditure system has the property that relative price changes only reallocate consumption *via* income changes, i.e. via the marginal consumption propensities. In other words, the private consumption pattern in the simulation model is fairly rigid.

The most important components of demand for domestically produced goods for the question under discussion are export demand and private demand (considering that public demand is exogenous and fixed). Inspection of the parameters in the export functions and consideration of the size of export demand relative to private demand leads us to conclude that the combined export and private demand is fairly stable with respect to income changes and also with respect to price changes.

Finally, in this discussion of the basic trade theorems in a many-sector, two-factor model with endogenous prices, we must also mention the Heckscher-Ohlin theorem. If factor prices are equalized between countries, technology is the same, and demand is homothetic and identical, the Heckscher-Ohlin theorem still holds, see e.g. Melvin [1968] and Bhagwati [1972]. A stronger version of the theorem holds when technology is the same and prices are *not* equalized. Then *all* exported goods are more capital (labor) intensive than *all* imported goods. This proposition is due to Jones [1956] as corrected by Bhagwati [1972].

7.4 SIMULATION RESULTS

In principle, the simulations repeat the comparative statics experiments of the last chapter. The starting point is the Swedish economy as described by the simulation model in 1966.[1] Exogenous changes are put to the model one by one, and new sets of prices, allocations and trade patterns are obtained. The exogenous changes constitute the actual changes in factor supplies, public sector output, technology (in a certain sense) and tariffs during the periods 1959-66 and 1966-74. Prices, allocations and trade patterns in 1959 and 1974 for the different simulations are then compared to simulated "actual" values in those years and to the actual values in 1966. The intention is to find and, if possible, to estimate the strength of the Rybczynski type effects discussed in chapter 6.

Five simulations have been made for each of the two periods 1959-66 and 1966-74. They are labelled *standard, endowment, public sector, technology* and *tariff* respectively. The standard simulation is a simulation of the actual economic development between 1959 and 1966 and between 1966 and 1974. Changes in factor endowments, public production (consumption), technology and tariffs have been assigned their actual values.[2]

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[1] An obvious alternative to taking 1966 as the starting year would be to use 1959. The simulations would then describe the *ceteris paribus* effects of the various exogenous developments for the whole period 1959-74, instead of for two, shorter periods. The year 1959 was not chosen as a base year for two reasons. The first is that the 1959 input-output coefficients represent an "extreme" point for the intermediate input-output technology of the period 1959-74. The coefficients for 1966 are likely to represent some average technology. The second reason is simply that there does not exist a suitable input-output table for 1959.

[2] Accounted for in the *Appendix*.

In the other simulations only one kind of change is allowed.[1] In the endowment simulation the capital and labor endowments in 1966 have been replaced by the endowments in 1959 and 1974, respectively. In the public sector simulation the actual output values of seven different public services in 1959 and 1974 have been replaced by the output values in 1966. This experiment corresponds to the experiment of a shift in taste towards non--traded goods in the Heckscher-Ohlin model in chapter 6. In the technology simulation we find new solutions for the model when there has been technical change (total factor productivity change) for seven years, 1959-1966, and eight years, 1966-1974. Finally, in the tariff simulation we let the tariff rates take on the values in 1959 and 1974 respectively, and obtain new solutions for prices, outputs, trade, income, and other endogenous variables.

Before presenting and commenting on the simulation results it is necessary to discuss a more basic result, which dominates the other results. It concerns the similarity in factor proportions between sectors and the consequences of this similarity for the simulations. This is done in section 7.4.1. Section 7.4.2 deals with the price effects in the various simulations. Sections 7.4.3-6 contain presentations and discussions of the effects on aggregate income, domestic demand, allocation of production and trade, respectively.

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[1] This is not strictly true; exports and imports are allowed to grow at their exogenously given residual rates in all simulations. An alternative would have been to have zero growth except in the standard simulations, and to add a sixth simulation to establish the *ceteris paribus* effects of exogenous residual growth in exports and imports. This alternative was not chosen because of the difficulty of interpretation of exogenous residual growth as an independent explanatory variable.

7.4.1 *Factor proportions differences*

The present analysis rests on *differences in factor proportions*. Before turning to the simulation results we record the factor proportions of the 30 sectors in the MSG-model to see if the particular ordering of capital intensities in it is the same as in the Heckscher-Ohlin model. Consider *table 7.1*:

Table 7.1 Capital-labor ratios[1]

Sector		
1	Agriculture	2.33
2	Forestry	1.70
3	Mining	2.85
4	Import-sheltered food manufacturing	2.33
5	Import-competing food manufacturing	2.23
6	Beverage and tobacco	2.23
7	Textiles and clothing	1.50
8	Wood and wood products	1.86
9	Printing and publishing	2.85
10	Rubber	1.86
11	Chemicals	2.45
12	Petroleum	2.03
13	Non-metallic minerals	2.13
14	Iron and steel	1.78
15	Engineering	1.78
16	Ships	1.86
17	Other manufacturing	1.56
18	Electricity, gas and water	5.25
19	Construction	2.23
20	Commerce	1.86
21	Transport	2.13
22	Housing	11.50
23	Private services	3.00
24	Defense	2.33
25	Judicial services	3.00
26	Education	4.00
27	Health	1.86
28	Social services	1.63
29	Road construction and maintenance	1.86
30	Administration and other services	3.00

[1] Returns to capital/returns to labor, in terms of total requirements of capital and labor.

Observe that the capital-labor ratios in *table 7.1* correspond to κ_1 in chapter 3, except that instead of being based on direct requirements, here the ratios are based on total requirements of capital and labor.[1] Because all production functions are Cobb-Douglas, the ratios will be constant over time; the rate of change of the ratio between the quantity of capital and the quantity of labor is equal to the rate of change of the wage rental ratio in all sectors.

The differences in capital intensities are rather *small*. They are smaller than those recorded in chapter 3 measured in standard deviations. This is expected: in chapter 3 the capital-labor ratios are for *value-added* and here they are for *total* (direct-and-indirect) factor inputs. The ratios for total inputs tend to be more equal than the ratios for direct inputs. The reason is that sectors which are very capital intensive or very labor intensive in terms of direct inputs have intermediate inputs which are less extreme in capital or labor intensities.

Relatively small factor proportions differences mean that the transformation surface of the economy is relatively flat. A flat transformation surface produces strong Rybczynski effects; the small factor intensity differences are "compensated" for by large output changes. Thus, we should expect relatively strong Rybczynski effects in the simulations. This would be true if there were no price changes to take into account. If price changes follow other, exogenous, changes, such as in factor endowments, there will be substitution between factors of production which counteracts the Rybczynski output changes. The flatter the transformation

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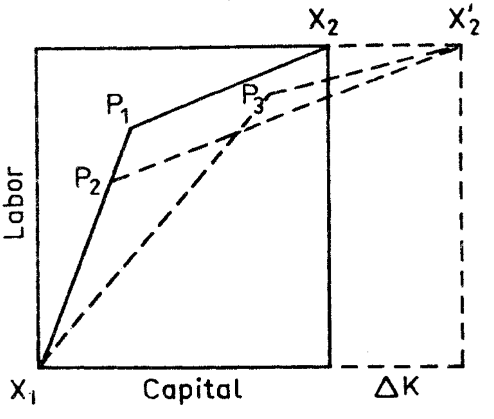
1

$$\kappa_1 = \frac{R^K K_i + R^H H_i}{wL} .$$

surface, the larger are the output movements induced by substitution.[1] The box diagram below serves to illustrate the point:

Figure 7.2



An increase in the capital stock, ΔK, leads to a big expansion of good X_2, from X_2P_1 to $X_2'P_2$, and a big contraction of good X_1, from X_1P_1 to X_2P_2. This reallocation is greater the more similar is the slope of X_1P_1 to that of X_2P_1 (or $X_2'P_2$), i.e. the flatter is the transformation curve. However, in the MSG-model an increase in capital will lead to a fall in the price of capital. As both sectors now rearrange production to employ relatively more capital, good X_1 will again expand and good X_2 contract. The extent of this countereffect of course depends on elasticities of substitution.

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[1] Cf. the discussion in section 7.3, and in particular equation (7.36). When the transformation surface is flat, even small tariff changes may have sizeable effects on resource allocation. The potential importance of small tariff changes has been pointed out by Melvin [1968].

Hence, although capital intensities are similar between sectors and, accordingly, the transformation surface of the economy seems to be relatively flat, we do not expect pronounced Rybczynski effects.

A second observation which can be made about the observed factor proportions is that the public sector as a whole, which plays the role of the non-traded good of chapter 6, is as capital intensive as the aggregate private, tradable sector. The public and private sectors both have weighted average capital-labor ratios of 2.33 in 1966.

There are important consequences of equal factor proportions in the private and public sectors. It will be recalled that an expansion of the non-traded sector in the analysis of chapter 6 resulted in a lower capital intensity of the tradables sector. This was achieved by a contraction of the capital intensive exportable and an expansion of the labor intensive importable good. As a result of decreased specialization in the tradables sector less goods were exported and imported as a proportion of GNP. These effects of changes in the relative size of non-traded, public goods only occur when there is a difference in factor proportions between the non--traded and the tradables sector. We will return to necessary modifications of the results of the Heckscher-Ohlin analysis when presenting the simulation results below.

7.4.2 *Prices*

Consider first the movement of *factor prices:*

Table 7.2 Wage-rental ratios

Wage-rental ratio in 1966 = *0.84* = 5.50 SK per hour/6.55 SK per year per 100 SK of capital

Simulation	*1959*	*1974*
Standard	0.62	1.06
Endowment	0.60	1.07
Public sector	0.83	0.81
Technology	0.88	0.80
Tariff	0.83	0.81

Note that the wage-rental ratio increases substantially in the standard simulation. The rate of change over the whole period 1959-74 is 3.6 per cent per year. It is slightly higher for the first subperiod 1959-66 than for the second subperiod 1966-74. Note also that the wage-rental ratio rises at an even higher rate in the endowment simulation, in both subperiods. In contrast, the wage-rental ratio is more or less constant or falling in the other simulations. Hence, we conclude that the increased wage-rental ratio from 1959 to 1974 is entirely caused by an increasingly capital intensive factor endowment.

The effect of expanding the public sector is to raise the wage-rental ratio very slightly, from 0.83 to 0.84, in the first period and to lower it somewhat in the second period. These small changes are caused by demand changes only. We can conclude that demand changes are not sufficiently biased towards capital or labor intensive goods to alter the wage-rental ratio significantly.

Technical change has a significant effect on relative factor prices: the wage-rental ratio is lowered in an equal degree in both subperiods. In the framework of the Heckscher--Ohlin model a higher rate of technical change in labor intensive importables than in capital intensive exportables results in a fall in the wage-rental ratio, cf. equations (6.33) and (6.34). The reason is that relatively more labor is "released" by technical progress than capital. This results in a potential excess supply of labor, which leads to a fall in the wage-rental ratio. The potential excess supply of labor is then taken care of by substitution of labor for capital in production. It appears that the rates of change in total factor productivity in the simulation model are such that more labor is saved than capital, which sets off the same chain of effects as in the Heckscher-Ohlin model, one of which is a fall in the wage-rental ratio.

Tariff reductions on the labor intensive import good result in a lower wage-rental ratio in the Heckscher-Ohlin framework of chapter 6, cf. equations (6.33) and (6.34). Here, the results are ambiguous. The wage rate is slightly increased in the first subperiod and then decreased in the second subperiod. We can therefore do no more than conclude that tariff reductions have had an insignificant effect on relative factor prices. The ambiguous results are consistent with our finding in chapter 5, that there exists no significant correlation between tariff rates and sectoral capital intensities.

Next, we turn to domestic *production costs*. The production cost is the major component of *prices* on commodities. We wish to determine how much relative costs change following the different exogenous changes made. Consider the standard deviations of the different sets of production costs in *table 7.3:*

Table 7.3 Production cost variability in the private sector

Standard deviations of unweighted costs, means within parenthesis.
All costs in 1966 equal to unity.

Simulation	*1959*	*1974*
Standard	0.06 (1.02)	0.06 (0.99)
Endowment	0.03 (1.00)	0.03 (1.01)
Public sector	0.02 (0.98)	0.02 (1.03)
Technology	0.06 (1.00)	0.07 (1.00)
Tariff	0.02 (0.99)	0.02 (1.03)

There is quite little variability in costs in 1959 and 1974 in all simulations. Relative costs can change in two ways, cf. equations (6.19)-(6.21). One way is through technical change at different rates between sectors. The other way is through differences in capital intensities, when factor prices change for some exogenous reason. Apparently factor price movements, although they are substantial in the endowment simulation, have almost no effect. The explanation is that the different sectors have similar capital-labor ratios. Technical change has a somewhat greater effect on relative costs, since the rates of change differ significantly between sectors.[1]

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[1] The stronger influence of technical change on cost changes is confirmed by the following regression results:

$$C_{59}/C_{66} = \beta_o + \beta_1(K/L) + \beta_2\lambda + \varepsilon$$

$$= \underset{(10.11)}{0.68} + \underset{(4.10)}{0.36(K/L)} + \underset{(7.49)}{2.85\,\lambda} \qquad \bar{R}^2 = 0.71$$

$$C_{74}/C_{66} = \underset{(14.25)}{1.30} - \underset{(2.68)}{0.31(K/L)} - \underset{(5.63)}{2.90\,\lambda} \qquad \bar{R}^2 = 0.57$$

All coefficients have expected signs. The coefficients λ for technical change in value-added are highly significant at the 5 per cent level. Clearly, the effect of technical change on prices is quite strong, while the effect of factor proportions is weak.

7.4.3 *GNP*

Not surprisingly, increases in factor endowments and technical progress are the major sources of growth, according to the simulations. Consider *table 7.4*:

Table 7.4 GNP changes

	GNP_t / GNP_{1966}		
Simulation	*1959*	*1974*	Yearly growth rate, per cent
Standard	0.73	1.29	3.9
Endowment	0.80	1.18	2.6
Public sector	0.98	1.02	0.3
Technology	0.89	1.14	1.7
Tariff	0.98	1.03	0.3

The change in the level of GNP in the standard simulation is equivalent to a yearly growth of 3.9 per cent. Factor accumulation is the most important source of GNP growth, and technical progress ranks second, significantly below factor accumulation but still important. As can be seen, tariff reductions contributed somewhat to growth, as did reallocation of resources from the private to the public sector. The explanation for the increase in GNP of this reallocation is probably that factors are more productive in the public than in the private sector.

7.4.4 *Private demand*

In view of quite small changes in relative costs and also in prices (not shown above), and considering that income elasticities are fairly similar, it is expected that the pattern of private demand is stable. The simulated patterns are shown in *table 7.5*:

Table 7.5 Patterns of private demand

Percentage shares

Goods*	1959					1966	1974				
	S	E	P	Te	Ta		S	E	P	Te	Ta
1	25	25	23	25	24	23	21	21	24	21	22
2	7	7	9	7	8	9	10	10	8	10	9
3	8	8	9	8	9	9	10	10	9	10	10
4	5	5	4	5	4	4	4	4	4	4	4
5	6	5	5	6	5	5	4	4	5	4	5
6	22	22	18	22	19	19	16	16	20	16	18
7	14	14	16	14	15	16	16	16	15	16	16
8	5	5	6	5	5	6	6	6	5	6	6
9	4	4	5	4	5	5	6	6	5	6	5
10	4	4	6	4	5	5	6	6	5	6	6

* 1 = Food
2 = Beverage, tobacco
3 = Clothes
4 = Entertainment
5 = Personal hygiene
6 = Housing
7 = Transportation
8 = Leisure
9 = Furniture, etc.
10 = Other

By looking at the three S columns (S = standard simulation) one can see the simulated development over time of the consumption pattern. Clear trends are visible. For example, major items such as food and housing have decreasing shares of private consumption. Nevertheless, changes are relatively small. The demand pattern in the endowment (E) and technology (Te) simulations are virtually identical to that of the standard simulation in each subperiod. The pattern is more or less constant, compared to 1966, in the public sector (P) and tariff (Ta) simulations.

From *table 7.5* we infer that demand for private goods and services has not been the cause of large reallocations in the economy. Furthermore, it seems that the derived demand for capital and labor from private consumption has not changed in a way so that factor prices have changed much. This conclusion is supported by the fact that factor proportions are similar in the consumption goods. Similar factor proportions and a stable consumption pattern mean that the derived demand for factors of production is stable as well, and not shifting substantially towards one of the factors.

7.4.5 *Allocation*

The focus of attention in chapter 6, where the effects of some stylized facts of growth were analyzed, and here, where the effects of similar exogenous changes are studied in a different model, is on allocation. The question now is: can the same effects be observed in the simulation as in the Heckscher-Ohlin model?

The Rybczynski effects in the Heckscher-Ohlin model are essentially adjustments in resource allocation to accommodate changes in factor endowments, which are necessary to maintain required full employment of resources. The effects are easy to define and identify in a model with only two traded commodities (and two factors). Even when other influences are present on resource allocation, such as factor substitution, we can separate them from the pure Rybczynski effects (cf. equation (7.32)).

Full employment of resources is required in the simulation model as well. Hence, Rybczynski effects, i.e. reallocation of resources at constant prices to fulfill the full employment restriction, are expected to be present also in the simulation model. However, as there now are more goods than factors it cannot be determined precisely which goods will expand and which will contract. For example, it is not certain that the most capital intensive commodity will be produced in greater quantity following an addition to the economy's capital stock.

However, we also argued in section 7.3 that with a certain degree of symmetry in substitution and demand, and with nearly homothetic demand, we expect the rates of output change to be ranked as are the capital-labor ratios. As a test of the degree to which Rybczynski type reallocation is occurring we have calculated the *rank correlation between sectorial output changes and sectorial capital intensities*. Rank correlation coefficients are presented in *table 7.6*:

Table 7.6 Rank correlation between output changes and capital intensities in the private sector

	Spearman rank correlation coefficients	
Simulation	*1959*	*1974*
Standard	0.184	-0.063
Endowment	0.125	0.074
Public sector	-0.218	0.210
Technology	-0.154	0.046
Tariff	-0.208	0.146

Factor endowment simulation

In the Heckscher-Ohlin model the effects of changes in the factor endowment are clear. An increase in the aggregate capital-labor ratio causes the capital intensive exportable to expand and the labor intensive importable to contract, cf. section 6.5. The output movement is more pronounced than the factor movement in proportional terms. Behind the reallocation of production are conflicting Rybczynski effects: one direct effect from the change in factor endowments and one indirect effect via the change in non-traded goods output. This direct effect should be present also in the MSG-model. The indirect effect, on the other hand, is eliminated, as public sector output is held constant in the endowment simulation. (The effects of the expansion of the non-traded, public sector are instead analyzed separately in the public sector simulation.)

Because of the way in which the Heckscher-Ohlin model is specified there are no price changes following a change in factor endowments. Resources are reallocated solely as a result of the change in factor supplies. That is, however, not the case in the MSG-model. There, as we have seen, the given change in factor endowments causes factor and commodity prices to move, and as a result there will be secondary effects on resource allocation. An increase in the aggregate capital-labor ratio and, consequently, in the wage-rental ratio makes exportables contract, while the primary effect of the higher capital-labor ratio works in the other direction.

The simulation results in *table 7.6* do not indicate that the Rybczynski effects are strong; there is no significant correlation between output changes and capital-labor ratios. The correlation coefficients are expected to be positive for the late period and negative for the early. As can be seen, the sign for the early period is instead positive.

Public sector simulation

The share of total factor supplies being used by the non-traded sector is of importance in the Heckscher-Ohlin model, because factor proportions between the tradable and the non-traded sector differ. When the share is changed, so are factor proportions in the tradables sector. If, as was the case in chapter 6, the non-traded sector is relatively capital intensive and expands, production of capital intensive goods in the tradables sector must contract and labor intensive goods expand, cf. equations (6.41b) and (6.42b).

In contrast to the Heckscher-Ohlin model factor proportions do not differ in the MSG model between the private, largely tradable sector and the non-traded public sector. Hence, Rybczynski effects based on factor proportions differences as described are eliminated, when the public sector is made to expand and to command a larger share of labor and capital.

Also, incentives to substitute capital for labor, or vice versa, are weak, since factor prices change insignificantly in this simulation. Therefore, we do not expect any significant Rybczynski effects.

A look at *table 7.6* shows that the correlation between output movements and capital intensity is low and in fact not significant, although it is stronger than in all other simulations.

Technical change simulation

Technical change can affect resource allocation in a number of different ways, as was demonstrated in chapter 6. The allocation effects in the Heckscher-Ohlin model depend on whether or not the technical change is biased and on differences in rates of change between sectors.

The simulation is a case of Hicks-neutral technical change. The rates differ considerably between sectors and in a way which results in a small but significant fall in the wage-rental ratio. It is this change in relative factor prices which is one source of possible reallocation in the private sector, cf. equations (6.41) and (6.42). The expected result is an expansion of exportables and contraction of importables as producers substitute labor for capital. Another source, a change in the non-traded sector output, is eliminated here, because public consumption and production is held constant. The third and final source is the difference in rates; exportables can therefore be expected to grow more rapidly than importables.

The results in *table 7.6* again give no conclusive evidence of the expected changes. The correlation between output changes and capital intensities is insignificant (although with expected signs).

The tariff simulation

In the Heckscher-Ohlin model tariff reductions influence resource allocation via changes in the non-traded output and factor prices, cf. section 6.8. A reduction in the domestic price of the labor intensive importable results in a fall of the relative price of labor (the Stolper-Samuelson effect).

The simulation, which is based on the actual but rather small tariff reductions, holds practically none of the causes for a reallocation in the private sector. Non-traded output is held constant and there is no significant change in factor prices. Consequently, we expect insignificant changes in the allocation of resources. The correlation coefficients in *table 7.6* between the rank order of output changes and capital intensities are not significant.

7.4.6 *Trade*

The simulations give two sets of results for trade which are of particular interest. One set is the changes in aggregate trade shares, an aspect which received much attention in the Heckscher-Ohlin model. The other set is the capital intensity of exports and imports, and how it changes over time.

We have assumed, on the basis of other evidence (cf. chapter 5), that exports are more capital intensive than imports, i.e. that Sweden has a comparative advantage in capital intensive goods. This assumption is weakly confirmed by the weighted average capital-labor ratio of exports and imports in 1966, but not by the corresponding ratios for 1959 and 1974:

Table 7.7 The weighted average capital-labor ratios of exports (E) and imports (M)
1966: exports 2.27, imports 1.94

Simulation	*1959*	*1974*
	E-M	*E-M*
Standard	1.94 - 2.03	1.94 - 1.94
Endowment	1.63 - 1.63	1.63 - 1.94
Public sector	1.94 - 2.03	1.94 - 2.03
Technology	2.13 - 2.03	1.94 - 2.03
Tariff	1.94 - 2.03	1.94 - 2.03

In all simulations but one exports and imports are of practically the same capital intensity. Thus, the results give no support to the factor proportions explanation of trade.

The explanations for the equal factor proportions in exports and imports are probably that, *first*, factor proportions are similar among tradables, and, *second*, that intra-industry trade is dominant. Both explanations tend to give a similar factor content in exports and imports.

Next, we turn to the changes in trade shares:

Table 7.8 Trade shares

Export value/GNP

1966: 0.20

Simulation	*1959*	*1974*
Standard	0.17	0.29
Endowment	0.15	0.32
Public sector	0.18	0.27
Technology	0.18	0.30
Tariff	0.17	0.30

The recorded trade share increases are, in contrast to the case in the Heckscher-Ohlin model, *not* a result of Rybczynski type reallocations, or due to substitution of labor for capital. Even the public sector simulation, which is not expected to yield a higher trade share, does so. The explanation is found in the exogenous growth of exports and imports. Apparently, this factor explains most of the trade share increase.

Still, it remains to explain why the factor endowment simulation gives a higher rate of increase than in the other simulations. We expect the substantial rise in the capital-labor ratio to have particularly strong Rybczynski effects. But to infer that the difference recorded here depends on such effects is not justified on the basis of the results in section 7.4.5 above. There, no Rybczynski effects were shown in the endowment simulation.

7.5 COMMENTS AND CONCLUSIONS

The simulations show no certain effects of changes in factor endowments, public consumption, technology, and tariffs on allocation and trade of the kind obtained in the Heckscher-Ohlin model. This gives rise to some questions: To what extent do the differences in results depend on differences between the models? To what extent do they depend on differences in empirical content? What conclusions can be drawn about Heckscher-Ohlin theory as a tool for empirical research?

In view of the sizable increase in the economy's capital stock relative to its labor supply it is somewhat surprising that capital intensive activities have not expanded more than labor intensive activities. An important difference between the comparative statics exercise and the endowment simulation is that factor prices are kept constant in the Heckscher-Ohlin model and change in the simulation. The wage-rental ratio rises and causes substitution of capital for labor. It was shown in section 7.3 how this tends to raise labor intensive production, thus neutralizing the Rybczynski effects of the increased capital-labor ratio. It seems to be the case that most of the increased capital supply has been absorbed in the way of substitution in production rather than by reallocation of resources in the simulation.

The wage-rental ratio moves also in the simulation with Hicks-neutral technical progress as the exogenous change. Here, the wage rate falls and sets off substitution of labor for capital. We expect capital intensive goods to expand in relation to labor intensive goods. The correlation between rates of change and capital intensities is of expected sign in both periods, but not significant.

The public sector causes Rybczynski output effects in the Heckscher-Ohlin model because its capital intensity differs from that of the tradables sector. Such a difference does not exist in the simulation model, and, hence, no reallocation effects are expected. (The signs of the correlations in *table 7.6* indicate a relative, but insignificant gain for capital intensive sectors.) Thus, in contrast to the endowment and technology simulations we can explain the results of the public sector simulation by differences in empirical content relative to the Heckscher-Ohlin model, rather than by different specifications of the two models.

Finally, the tariff simulation also produces insignificant results. A tariff reduction in the Heckscher-Ohlin model on the labor intensive importable good lowers the wage rate. The wage-rental ratio is only slightly changed in the simulation. This is expected; tariff cuts are rather small, they are made in most sectors and capital-labor ratios are similar. There is no distinct group of labor intensive, importable sectors. Therefore, there is no cause for reallocation and the reallocation registered in correlation coefficients is not significant. The tariff simulation is a second case where the main reason for different results between the simulation and the corresponding analysis in the Heckscher-Ohlin model probably lies in empirical differences (factor intensity differentials and intra-industry trade) rather than in model differences.

With no significant Rybczynski effects in resource allocation it is expected that trade changes are not those predicted by the Heckscher-Ohlin model. But, in addition to this explanation trade in the simulation model has another character than in the Heckscher-Ohlin model, which in itself is a sufficient explanation. Most sectors have intra-industry trade, and in many sectors trade is more or less balanced, i.e. exports are of the same magnitude as imports. In addition, capital intensities are rather similar. As a result, we find that the factor content of aggregate exports and imports is approximately the same in all simulations. In other words, the factor proportions theory of trade does not seem to be very relevant in this case. In the Heckscher-Ohlin model *all* trade is explained by differences in factor proportions.

There is an important qualification to the conclusion that factor proportions theory explains little of Sweden's trade during the period under study. The conclusion is based on the assumption that goods with the same sector classification are homogeneous with respect to their factor intensity. This may be wrong. A disaggregation may show that significant differences in factor intensity exist within each sector, and that there is a systematic difference between exported and imported goods. However, attempts to rescue the factor proportions explanation of trade by looking at disaggregated trade flows have not been successful as was pointed out in chapter 5.

Apparently, the attempt to gain more knowledge about the working of a standard MSG-model by using Heckscher-Ohlin theory as a tool has met with very little success. One important reason for the limited usefulness of the theory has been clear from the outset: the central theorems lose much power when the number of goods exceed the number of factors. The simulations have made clear that the small-country assumption usually made in traditional trade analysis is crucial in the empirical application. When prices on traded goods are endogenous and influenced by domestic demand and supply conditions, other influences on resource allocation than factor proportions gain importance. Although Rybczynski effects are present, they are offset or dominated by the effects on allocation of substitution in production and by domestic demand. This seems particularly to be the case in the endowment simulation. Substitution is a substitute for reallocation as adjustment to changing factor proportions, and domestic demand serves to conserve the existing allocation.

Although the kind of mechanisms which are central in traditional trade models seem to be relatively unimportant empirically, at least in our case, the simulations give some valuable indications about economic development in Sweden from 1959 to 1974 (although we must keep in mind that relatively little effort has been spent to estimate parameters in the model). Not surprisingly, the substantial increase in the wage rate relative to the reward to capital is attributable to a substantially higher capital-labor ratio. Technical progress has had the opposite effect on the wage-rental ratio, while the effects of public sector expansion and tariff reductions are small and uncertain. No Stolper-Samuelson effect on factor returns has been detected. The relative cost structure is mostly affected by technical change. Factor endowment changes have less influence on relative costs because factor intensities are similar. (This similarity is by itself an important information given by the simulation model.) Finally, the results of the simulations indicate that factor accumulation is a more important source of growth in GNP than technical change.

APPENDIX

The appendix gives sources for the values on exogenous variables and parameters used in the simulations. The order of presentation follows that of the lists of variables and parameters in section 7.2.

Data on labor supply in terms of man-hours, net investments and current account surpluses (deficits) are from national accounts statistics, SM N 1975:98 and Appendix 2, 3, and 5.

The capital stock data were imputed in the way described in section 7.2.1. Physical capital stock data are from SM N 1975:98, Appendix 2.

Disaggregated data on public sector consumption and output were supplied by the Ministry of Economic Affairs (Ekonomidepartementet).

World market prices on imports and exports were taken from preliminary estimates of import and export functions at the National Bureau of Economic Research (Konjunkturinstitutet) and from data supplied by Lars Bergman.

The Ministry of Economic Affairs supplied data on indirect tax and tariff rates for the relevant period and sector classification. More correctly, the ratios between tariff receipts and import value (exclusive of tariffs) were taken as tariff rates. They are shown in *table 5.8*.

The input-output table for 1966 was supplied by the Ministry of Economic Affairs.

As distribution parameters α_i in the Cobb-Douglas production functions we simply used the actual functional shares of capital in value-added in 1966, according to the input-output table.

Rates of technical change are those shown in *table 3.5*, except that the average level has been raised so that no sector has a negative rate. In other words, the relative structure is preserved. Also, we have set the rate in all public sectors equal to zero.

The rate of depreciation of capital was determined by the ratio between the value of aggregate depreciation of physical capital according to the national accounts (SM N 1975:98, Appendix 4) and the aggregate composite capital stock. The same rate of depreciation applies to all sectors.

In the export and import functions the parameters for residual growth of exports and imports were obtained from time series data from the Ministry of Economic Affairs. The rates of change of world trade in the export functions and the price elasticities in the export and import functions were in part supplied by Lars Bergman and in part by the National Bureau for Economic Research (unpublished and preliminary estimates).

Finally, a matrix with fixed coefficients converting sectoral outputs into consumption goods was constructed on the basis of a similar matrix obtained from Lars Bergman. The marginal propensities in the consumption functions are from Dahlman and Klevmarken [1971].

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CHAPTER 8: THE RYBCZYNSKI THEOREM IN A MODEL WITH NON-TRADED GOODS AND INDECOMPOSABLE INTER-INDUSTRY FLOWS*

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8.1. INTRODUCTION AND SUMMARY

According to the Rybczynski [1955] theorem, applied to the standard two-country, two-good, two-factor model, an increase in one factor will result in an absolute rise in the output of the commodity which is relatively intensive in the increased factor, and to an absolute fall in the output of the other commodity. The generalization of the theorem by Jones [1965] states that "if factor endowments expand at different rates, the commodity intensive in the use of the fastest growing factor expands at a greater rate than either factor, and the other commodity grows (if at all) at a slower rate than either factor." The application of Jones' version of the theorem to a model with three goods, one of which is non-traded, two factors and indecomposable inter-industry flows is studied here. The introduction of inter-industry flows makes necessary a distinction between *net* and *gross* Rybczynski output effects and also between direct and total factor intensities of commodities. It is found that a sufficient condition for the generalized Rybczynski theorem, defined in terms of total factor intensities, to hold for both net and gross outputs, net output changes being proportionately greater than gross changes, is that the net output change of the non-traded good is bounded by the factor changes. This result is compared with earlier findings and the meaning of the sufficient condition is discussed in terms of basic demand parameters.

8.2. REVIEW OF THE LITERATURE

Since Bhagwati [1964] pointed to the non-existence of *intermediate goods* as a central limitation in pure trade theory much has been done to correct this defect. It seems that Kemp [1969] in the second edition of his trade theory textbook was first to examine the Rybczynski theorem in the two-by-two-by-two trade model incorporating inter-industry flows. His conclusion was that the theorem (and the Stolper-Samuelson theorem) "emerge unscathed by the recognition of intermediate goods." His proof was faulty, but subsequently Casas

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[1972] and others demonstrated that Kemp's conclusion was right and that, furthermore, *net* output movements are magnified by the introduction of inter-industry flows. Until the contribution by Chang and Mayer [1973] no one had analyzed the Rybczynski effects on *gross* outputs in the two-good model. They proved that for fixed intermediate input coefficients (e.g., when prices are kept constant) net and gross output changes are always qualitatively the same, and that net changes must be proportionately and absolutely greater than gross changes. The recognition of Chang and Mayer of separate net and gross Rybczynski output effects seems quite important. In their words: "...each output concept can serve for quite distinct purposes; if one wants to examine the impact of an exogenous change in the production pattern of different industries in a given country, one should look at the resulting changes in gross output. This is especially relevant to the theory of effective tariff protection as well as the theory of technical change and trade. If, on the other hand, one wants to determine how an exogenous change affects the availability of a given commodity for domestic consumption and foreign trade, one observes net output changes. This is particularly relevant to problems in trade and welfare, the balance of trade, etc."

Concurrent with the increasing interest in the literature for different kinds of intermediate goods is the interest for *non-traded goods*. Seminal examinations of pure trade theory within the framework of a model with three goods, one of which is non-traded, and two factors were done by Komiya [1967] and Ethier [1972]. Komiya showed, among other things, that the Rybczynski theorem remains valid, barring inferiority in consumption. Ethier's treatment of the theorem is more penetrating and wider in scope than Komiya's in that he allows *both* factors to change and to change in the same direction, and investigates under what conditions Rybczynski's original theorem and generalized versions of it hold in this case. Ethier's additional results are (i) "... there exists a number θ such that ... the output of that good which is more intensive to the relatively increased factor will increase relative to the output of the other traded good, provided that $\hat{K}<\hat{L}$ and $\hat{K}<\theta\hat{L}$ or that $\hat{K}>\hat{L}$ and $\hat{K}>\theta\hat{L}$" ($\hat{K}$ and $\hat{L}$ denote relative changes in capital and labor respectively), (ii) "An increase of K/L will always increase the output of the capital intensive traded good relative to that of the labor intensive traded good, and vice-versa, if and only if either the marginal propensity to consume the non-traded good (m) equals the average propensity (c), or the capital intensity of the non-traded good equals the economywide capital intensity" (results (i) and (ii) are generalizations of Komiya's theorem, but still weaker than a Jones' generalization since output movements of tradables need not bound factor movements), (iii) Jones' generalized theorem holds if $\hat{K}\gtrless 0\gtrless\hat{L}$ and the changes in non-traded good consumption and total income are close to zero (by continuity arguments), and (iv) if demand is redefined as *per capita* demand and is a function of all prices and *per capita* income, then Jones' generalization holds if $0\leq m/c\leq 1/a$ (a is capital's distributive share). Results (i)–(iii) require that $0\leq m\leq 1$.

Ray [1972] was first to examine the Rybczynski theorem in a model with both intermediate and non-traded goods. In a model with decomposable inter-industry flows he demonstrated that (i) Jones' generalized theorem, defined in terms of total factor intensities, holds for both net and gross outputs when the non-traded good is a pure intermediate, (ii) the Komiya result holds for net and gross outputs when the non-traded good is finally consumed, if the marginal propensity to consume the non-traded good lies between zero and unity, and (iii) the tradable labor intensive net and gross outputs increase relatively to the tradable capital intensive net and gross outputs as labor increases relatively to capital, if the marginal and average propensities to consume the non-traded good are equal (corresponds to part of Ethier's result (ii) and thus is weaker than Jones' generalization).

We are going to extend earlier work in two respects. First, we establish a sufficient condition for the Jones' generalized Rybczynski theorem to hold in the three good model which is more general than Ethier's results (iii) and (iv) above. Second, the implications for the theorem of complete indecomposable inter-industry flows are explored.

8. 3. THE MODEL

There are two traded goods, 1 and 2, and one non-traded good, N. The two primary factors are capital, K, and labor, L. Each production activity uses both primary factors and the two other commodities as inputs.[2] Production functions exhibit constant returns to scale and diminishing returns to changing factor proportions. We assume perfectly competitive product and factor markets and full employment of the primary factors. Also, it is assumed that for the price and factor supply configurations considered all three goods are produced.

From the equilibrium zero profit conditions we have that

$$a_{L1}w + a_{K1}r + a_{21}P_2 + a_{N1}P_N = P_1 \tag{1}$$

$$a_{L2}w + a_{K2}r + a_{12}P_1 + a_{N2}P_N = P_2 \tag{2}$$

$$a_{LN}w + a_{KN}r + a_{1N}P_1 + a_{2N}P_2 = P_N \tag{3}$$

where a_{ij} symbolizes the direct input of primary factor or intermediate good i per unit of good j, w is the wage rate, r is the rental price of capital, and P_i denotes the price of commodity i.

The prices of the two tradables are assumed to be world market determined. This leaves us with a system of three equations in three unknowns, w, r and, P_N. Hence, once prices on traded goods are given, then factor returns and the price of the non-traded good are determined, independently of domestic demand conditions.

The gross and net full employment conditions are

$$a_{L1}x_1 + a_{L2}x_2 + a_{LN}x_N = L \tag{4}$$

[2] Own direct inputs are netted out for convenience.

(5) $$a_{K1}x_1 + a_{K2}x_2 + a_{KN}x_N = K$$

and

(6) $$A_{L1}y_1 + A_{L2}y_2 + A_{LN}y_N = L$$

(7) $$A_{K1}y_1 + A_{K2}y_2 + A_{KN}y_N = K$$

where x_i denotes gross and y_i net output of the respective commodity, and A_{ij} symbolizes total input of primary factor i per unit of net output of good j. The A_{ij}'s are given from the standard input-output relation

$$\begin{pmatrix} A_{L1} & A_{L2} & A_{LN} \\ A_{K1} & A_{K2} & A_{KN} \end{pmatrix} = \begin{pmatrix} a_{L1} & a_{L2} & a_{LN} \\ a_{K1} & a_{K2} & a_{KN} \end{pmatrix} \times \begin{pmatrix} 1 & -a_{12} & -a_{1N} \\ -a_{21} & 1 & -a_{2N} \\ -a_{N1} & -a_{N2} & 1 \end{pmatrix}^{-1} .$$

The input coefficients are functions of all input prices at the given state of technology, i.e.,

(8) $$a_{i1} = a_{i1}(w, r, P_2, P_N) \qquad i = L, K, 2, N$$

(9) $$a_{i2} = a_{i2}(w, r, P_1, P_N) \qquad i = L, K, 1, N$$

(10) $$a_{iN} = a_{iN}(w, r, P_1, P_2) \qquad i = L, K, 1, 2.$$

Each input coefficient is homogeneous of degree zero in all its arguments since we have assumed that production functions are linear homogeneous in all inputs.

The generalized Rybczynski theorem is stated in terms of relative rates of change. Therefore, equations (1)-(7) are converted into[3]

(1.1) $$\theta_{L1}\hat{w} + \theta_{K1}\hat{r} + \theta_{21}\hat{P}_2 + \theta_{N1}\hat{P}_N = \hat{P}_1$$

(2.1) $$\theta_{L2}\hat{w} + \theta_{K2}\hat{r} + \theta_{12}\hat{P}_1 + \theta_{N2}\hat{P}_N = \hat{P}_2$$

(3.1) $$\theta_{LN}\hat{w} + \theta_{KN}\hat{r} + \theta_{1N}\hat{P}_1 + \theta_{2N}\hat{P}_2 = \hat{P}_N$$

(4.1) $$\lambda_{L1}\hat{x}_1 + \lambda_{L2}\hat{x}_2 + \lambda_{LN}\hat{x}_N = \hat{L} - (\lambda_{L1}\hat{a}_{L1} + \lambda_{L2}\hat{a}_{L2} + \lambda_{LN}\hat{a}_{LN})$$

(5.1) $$\lambda_{K1}\hat{x}_1 + \lambda_{K2}\hat{x}_2 + \lambda_{KN}\hat{x}_N = \hat{K} - (\lambda_{K1}\hat{a}_{K1} + \lambda_{K2}\hat{a}_{K2} + \lambda_{KN}\hat{a}_{KN})$$

(6.1) $$\beta_{L1}\hat{y}_1 + \beta_{L2}\hat{y}_2 + \beta_{LN}\hat{y}_N = \hat{L} - (\beta_{L1}\hat{A}_{L1} + \beta_{L2}\hat{A}_{L2} + \beta_{LN}\hat{A}_{LN})$$

(7.1) $$\beta_{K1}\hat{y}_1 + \beta_{K2}\hat{y}_2 + \beta_{KN}\hat{y}_N = \hat{K} - (\beta_{K1}\hat{A}_{K1} + \beta_{K2}\hat{A}_{K2} + \beta_{KN}\hat{A}_{KN}).$$

Above, a circumflex (^) denotes relative rate of change, as for instance $\hat{w} = dw/w$ and $\hat{P}_2 = dP/P$. The symbol θ_{ij} stands for the direct distributive share

It should be pointed out that the first-order cost minimization conditions have been used in deriving equations (1.1)-(3.1), namely that

$$\theta_{L1}\hat{a}_{L1} + \theta_{K1}\hat{a}_{K1} + \theta_{21}\hat{a}_{21} + \theta_{N1}\hat{a}_{N1} = 0$$
$$\theta_{L2}\hat{a}_{L2} + \theta_{K2}\hat{a}_{K2} + \theta_{12}\hat{a}_{12} + \theta_{N2}\hat{a}_{N2} = 0$$
$$\theta_{LN}\hat{a}_{LN} + \theta_{KN}\hat{a}_{KN} + \theta_{1N}\hat{a}_{1N} + \theta_{2N}\hat{a}_{2N} = 0.$$

of input i in output j; λ_{ij} is the proportion of input i used directly in output j; β_{ij} denotes the proportion of primary factor supply i used totally in output j. As examples, $\theta_{K1}=a_{K1}r/P_1$, $\theta_{N1}=a_{N1}P_N/P_1$, $\lambda_{L1}=a_{L1}x_1/L$, and $\beta_{K2}=A_{K2}y_2/K$.

8.4. RYBCZYNSKI OUTPUT EFFECTS

Using the notation introduced above, Jones' generalized version of the Rybczynski theorem applied to net as well as gross outputs can be stated as:

$$\hat{y}_1 \gtrless \hat{K} \gtrless \hat{L} \gtrless \hat{y}_2,\ \hat{x}_1 \gtrless \hat{K} \gtrless \hat{L} \gtrless \hat{x}_2 \quad \text{as} \quad K_1 \gtrless K_2$$

where K_i denotes *total* factor intensity: $K_1=A_{K1}/A_{L1}$ and $K_2=A_{K2}/A_{L2}$. We are going to investigate under what condition(s) the generalized theorem still applies to the tradable outputs 1 and 2 in the presence of a third, non-traded good, good N, and indecomposable inter-industry flows.

It should be stressed, before we continue, that factor intensities are defined in terms of *total* coefficients. Much of the earlier literature of generalizing the standard trade theorems to incorporate intermediate inputs is concerned with the conditions under which direct and total intensities are qualitatively equal. It is well known that if the theorems are stated in terms of direct intensities and there is a third, pure intermediate commodity, then limiting restrictions need to be imposed to ensure the standard results, see e.g., Ray, and Batra and Casas [1973]. The reason is that relative direct and total factor intensities need not be qualitatively the same in the presence of a third, intermediate good. However, this aspect of the problem does not interest us here; we only deal with total factor intensities.

First, we turn to Rybczynski *net* output effects and prove the following theorem:

THEOREM 1. *If, in a model with three finally consumed goods, one of which is non-traded, and indecomposable inter-industry flows, the factor movements bound the movement of the net output of the non-traded good, i.e.,* $\hat{K}\gtrless\hat{y}_N\gtrless\hat{L}$, ***then net output movements of the tradable goods always bound factor movements in such a way that*** $\hat{y}_1\gtrless\hat{K}\gtrless\hat{L}\gtrless\hat{y}_2$ *as* $K_1\gtrless K_2$.

PROOF. Using equations (6.1) and (7.1) and the identity $\hat{Y}_N\equiv\hat{Y}_N$ set up the equation system

$$\begin{matrix} \beta_{K1} & \beta_{K2} & \beta_{KN} \\ \beta_{L1} & \beta_{L2} & \beta_{LN} \\ 0 & 0 & 1 \end{matrix} \quad \begin{matrix} \hat{y}_1 \\ \hat{y}_2 \\ \hat{y}_N \end{matrix} \quad = \quad \begin{matrix} \hat{K} \\ \hat{L} \\ \hat{y}_N \end{matrix}$$

and solve for the difference $(\hat{y}_1-\hat{y}_2)$, making use of $\sum\beta_{Kj}=1$ and $\sum\beta_{Lj}=1$ $(j=1, 2, N)$, to obtain

(11)
$$(\beta_{K1}\beta_{L2} - \beta_{K2}\beta_{L1})(\hat{y}_1 - \hat{y}_2) = (\hat{K} - \hat{y}_N)(1 - \beta_{LN}) + (\hat{y}_N - \hat{L})(1 - \beta_{KN}).$$

The right hand side of the equation is positive or negative as $\hat{K} \gtrless \hat{L}$ by the restrictions $\hat{K} \gtrless \hat{y}_N \gtrless \hat{L}$ and $0 < \beta_{iN} < 1$ $(i = K, L)$. On the left hand side, the determinant $(\beta_{K1}\beta_{L2} - \beta_{K2}\beta_{L1}) = (y_1\ y_2/K\ L)(A_{K1}A_{L2} - A_{K2}A_{L1})$ is positive or negative as $K_1 \gtrless K_2$. It follows that the sign of $(\hat{y}_1 - \hat{y}_2)$ is determined for a given factor change and assumption about relative factor intensities. That net output movements bound factor movements follows from equations (6.1) and (7.1), which give factor movements as weighted averages of net output movements, and from the restriction $\hat{K} \gtrless \hat{y}_N \gtrless \hat{L}$.

Thus, it is seen in the net output case that a sufficient condition for Jones' generalized Rybczynski theorem to hold when a third, non-traded good is added is a restriction on the marginal propensity of consumption, $\hat{K} \gtrless \hat{y} \gtrless \hat{L}$. Furthermore, the introduction of inter-industry flows makes no difference at all except requiring that the theorem is stated in terms of total (direct and indirect) factor requirements. All this is hardly surprising since what we have done is to ensure that the three-good model with inter-industry flows has essentially the same properties as the standard two-good model without inter-industry flows.

Next, we turn to Rybczynski *gross* output effects:

THEOREM 2. *If, in a model with three finally consumed goods, one of which is non-traded, and indecomposable inter-industry flows, the factor movements bound the movement of the net output of the non-traded good, i.e.,* $\hat{K} \gtrless \hat{y}_N \gtrless \hat{L}$, *then gross output movements of the tradable goods always bound factor movements in such a way that* $\hat{x}_1 \gtrless \hat{K} \gtrless \hat{L} \gtrless \hat{x}_2$ *as* $K_1 \gtrless K_2$.

COROLLARY. *If* $\hat{K} \gtrless \hat{y}_N \gtrless \hat{L}$, *then* $\hat{x}_1 \gtrless x_N \gtrless \hat{x}_2$ *as* $K_1 \gtrless K_2$, *i.e., tradable gross output movements always bound the gross output movement of the non-traded good.*

PROOF. Set up the equation system

$$\begin{vmatrix} \lambda_{K1} & \lambda_{K2} & \lambda_{KN} \\ \lambda_{L1} & \lambda_{L2} & \lambda_{LN} \\ -\alpha_{N1} & -\alpha_{N2} & \alpha_{NN} \end{vmatrix} \begin{vmatrix} \hat{x}_1 \\ \hat{x}_2 \\ \hat{x}_N \end{vmatrix} = \begin{vmatrix} \hat{K} \\ \hat{L} \\ \hat{y}_N \end{vmatrix}$$

where the first two rows are equations (4.1) and (5.1) respectively and the third row is formed from the input-output identity $x_N \equiv y_N + a_{N1}x_1 + a_{N2}x_2$. It is easily shown that $-\alpha_{N1} - \alpha_{N2} + \alpha_{NN} = 1$, where $\alpha_{N1} = a_{N1}x_1/y_N$, $\alpha_{N2} = a_{N2}x_2/y_N$, and $\alpha_{NN} = x_N/y_N$. Thus, all rows in the coefficient matrix sum to unity. Using this fact the system is solved for the differences $(\hat{x}_1 - \hat{x}_2)$, $(\hat{x}_1 - \hat{x}_N)$, and $(\hat{x}_2 - \hat{x}_N)$ to obtain

(12) $$|\lambda|(\hat{x}_1 - \hat{x}_2) = (\hat{K} - \hat{y}_N)(\alpha_{NN} - \lambda_{LN}) + (\hat{y}_N - \hat{L})(\alpha_{NN} - \lambda_{KN})$$

$$(13)\qquad |\lambda|(\hat{x}_1-\hat{x}_N)=(\hat{K}-\hat{y}_N)(\lambda_{L2}+\lambda_{LN})+(\hat{y}_N-\hat{L})(\lambda_{K2}+\lambda_{LN})$$

$$(14)\qquad |\lambda|(\hat{x}_N-\hat{x}_2)=(\hat{K}-\hat{y}_N)(\lambda_{L1}+\alpha_{N1})+(\hat{y}_N-\hat{L})(\lambda_{K1}+\alpha_{N1})$$

where $|\lambda|$ is the determinant of the coefficient matrix and can be written as

$$|\lambda|=\prod_{j\in M}x_j/\prod_{i\in R}z_i\begin{vmatrix}a_{K1} & a_{K2} & a_{KN}\\ a_{L1} & a_{L2} & a_{LN}\\ -a_{N1} & -a_{N2} & 1\end{vmatrix}\qquad \begin{matrix}M=\{1,2,N\}\\ R=\{K,L,N\}\\ z_K=K,\ z_L=L,\ z_N=y_N\end{matrix}$$

from which it is seen that

$$\text{sign}\,|\lambda|=\text{sign}\begin{vmatrix}a_{K1} & a_{K2} & a_{KN}\\ a_{L1} & a_{L2} & a_{LN}\\ -a_{N1} & -a_{N2} & 1\end{vmatrix}.$$

The sign of the determinant on the right hand side is given from the equation system

$$\begin{matrix}A_{K1} & A_{K2} & A_{KN}\\ A_{L1} & A_{L2} & A_{LN}\\ 0 & 0 & 1\end{matrix}=\begin{matrix}a_{K1} & a_{K2} & a_{KN}\\ a_{L1} & a_{L2} & a_{LN}\\ -a_{N1} & -a_{N2} & 1\end{matrix}\times\begin{matrix}1 & -a_{12} & -a_{1N}\\ -a_{21} & 1 & -a_{2N}\\ -a_{N1} & -a_{N2} & 1\end{matrix}^{-1}$$

$$A'=B'\times[I-a]^{-1}$$

which is the regular input-output relation with a third row added in the total and primary input coefficient matrices respectively. Taking determinants of the system we know that $\det[I-a]^{-1}>0$ by the Hawkins-Simon conditions and sign det $A'\gtrless 0$ as $K_1\gtrless K_2$. Hence, sign det $B'=\text{sign}\,|\lambda|\gtrless 0$ as $K_1\gtrless K_2$. Going back to equations (12), (13), and (14) it is clear that the right hand sides are positive or negative as $\hat{K}\gtrless\hat{L}$. It then follows that for $\hat{K}>\hat{L}$ we have $\hat{x}_1\gtrless\hat{x}_2$, $\hat{x}_1\gtrless\hat{x}_N$, and $\hat{x}_N\gtrless\hat{x}_2$ as $K_1\gtrless K_2$, and conversely for $\hat{K}<\hat{L}$. It is seen that gross output movements of tradables always bound gross non-traded output movements. From equations (4.1) and (5.1) we have factor movements as weighted averages of gross output movements. Hence, factor movements are always bounded by gross output movements of the two tradable goods.

It is interesting to note that the critical factor intensities for this result are those involving the direct plus indirect-through-the-non-traded-good-only factor inputs.[4] To see this, multiply out determinant B', the sign-determining element of $|\lambda|$, to get $a_{K1}a_{L2}-a_{L1}a_{KN}a_{N2}-a_{K2}a_{LN}a_{N1}+a_{L2}a_{KN}a_{N1}+a_{K1}a_{LN}a_{N2}-a_{L1}a_{K2}$. Apparently, if one tradable is more capital intensive than the other in direct-and-indirect-through-the-non-traded-good factor inputs it is so also in terms of total, direct and indirect, inputs. Primary factor inputs through inputs of the other

[4] This observation plus the proof of Theorem 3 below is due to Rodney Falvey.

tradable good cannot reverse the factor intensity ranking. This relation between the direct-plus-indirect-through-the-non-traded-good factor intensity and the total factor intensity corresponds to the relation between direct and total factor intensities in the two-good model with indecomposable inter-industry flows; there, direct and total intensities must be the same; see e.g., Casas.

Ray proved the generalized theorem for gross outputs for the special case of $y_N=0$, when inter-industry flows are decomposable. A proof when flows are indecomposable is essentially the same as above, replacing the equation in the third row of the equation system by $(-a_{N1}x_1/x_N)\hat{x}_1+(-a_{N2}x_2/x_N)\hat{x}_2+\hat{x}_N=0$.

THEOREM 3. *If factor movements bound the net output movements of the non-traded good, i.e.,* $\hat{K}\gtrless\hat{y}_N\gtrless\hat{L}$, *then net output movements will bound gross output movements so that* $\hat{y}_1\gtrless\hat{x}_1\gtrless\hat{x}_2\gtrless\hat{y}_2$ *as* $K_1\gtrless K_2$.

PROOF. We have the following input-output identities:

(15) $$y_1 = x_1 - a_{12}x_2 - a_{1N}x_N$$

(16) $$y_2 = x_2 - a_{21}x_1 - a_{2N}x_N$$

(17) $$y_N = x_N - a_{N1}x_1 - a_{N2}x_2.$$

Substituting for x_N from equation (17) in equations (15) and (16) yields:

(15.1) $$y_1 = (1 - a_{1N}a_{N1})x_1 - (a_{12} + a_{1N}a_{N2})x_2 - a_{1N}y_N$$

(16.2) $$y_2 = -(a_{21} + a_{2N}a_{N1})x_1 + (1 - a_{2N}a_{N2})x_2 - a_{2N}y_N.$$

Transforming (15.1) and (16.1) into rates of change gives

(15.2) $$\hat{y}_1 = \phi_{11}\hat{x}_1 - \phi_{12}\hat{x}_2 - \phi_{1N}\hat{y}_N$$

(16.2) $$\hat{y}_2 = -\phi_{21}\hat{x}_1 + \phi_{22}\hat{x}_2 - \phi_{2N}\hat{y}_N$$

where $\phi_{ij}>0$ for all i, j $(i=1, 2;\ j=1, 2, N)$ and $\phi_{11}-\phi_{12}-\phi_{1N}=1$, $-\phi_{21}+\phi_{22}-\phi_{2N}=1$.

Since $\hat{x}_1\gtrless\hat{y}_N\gtrless\hat{x}_2$ we can derive the inequalities

(15.3) $$\hat{y}_1 \gtrless (\phi_{11} - \phi_{12} - \phi_{1N})\hat{x}_1 = \hat{x}_1$$

(16.3) $$\hat{y}_2 \gtrless (-\phi_{21} + \phi_{22} - \phi_{2N})\hat{x}_2 = \hat{x}_2.$$

Therefore, applying Theorem 1, 2 and 3 we have

$$\hat{y}_1 \gtrless \hat{x}_1 \gtrless \hat{K} \gtrless \hat{y}_N \gtrless \hat{L} \gtrless \hat{x}_2 \gtrless \hat{y}_2 \quad \text{as} \quad K_1 \gtrless K_2.$$

8.5. COMPARISON WITH EARLIER RESULTS

The condition that net output changes of the non-traded good be bounded by factor changes is *sufficient* to ensure Jones' generalized Rybczynski output changes for both net and gross outputs. Since the generalized Rybczynski theorem is about relative changes and their order of magnitude it is natural to find the sufficient condition to be in this format also. On the other hand, one may find the condition somewhat meaningless as long as it is not related to basic demand parameters such as propensities to consume or elasticities. We will conclude by relating our result to basic parameters, at the same time comparing it with results of earlier writers.

The condition $\hat{K} \gtrless \hat{p}_N \gtrless \hat{L}$ is equivalent to

$$\frac{\hat{K}}{\hat{I}} \gtrless \frac{m}{c} \gtrless \frac{\hat{L}}{\hat{I}}$$

where, as before, c and m are average and marginal propensities to consume the non-traded good respectively, and $\hat{I}$ denotes relatire change in total income. It is clarifying to recognize three different cases:

(1) *$\hat{K}$ and $\hat{L}$ are of the same sign.* Clearly, in this case m is always positive, and could be greater than unity in value. Ethier (result (ii)) and Ray (result (iii)) showed that if $m = c$ then the intensive factor good will increase relative to the extensive factor good. Thus, they failed to realize that this condition is sufficient for a Jones generalized result, not merely a generalization of Komiya's result.[5] In fact, the condition $m = c$ gives generalized output effects for *all* $\hat{K}$ and $\hat{L}$.

(2) *$\hat{K}$ or $\hat{L}$ is equal to zero.* This is the case originally explored by Rybczynski and by Komiya. Here also m is always positive, as seen from the condition above, and could be greater than unity in value.

(3) *$\hat{K}$ and $\hat{L}$ are of opposite sign.* This case permits $m < 0$ as well as $m > |1|$. In particular, it includes Ethier's sufficient condition for fully generalized output effects, $m = 0$ and $\hat{I} = 0$ (result (iii)).

It should be pointed out that there exist conditions which suffice to give generalized Komiya effects (corresponding to Ethier's result (ii) and Ray's result (iii)) and which do not fulfill the restriction $\hat{K} \gtrless \hat{p}_N \gtrless \hat{L}$. One such condition is Ethier's, that the capital intensity of the non-traded good should equal the economy-wide intensity. However, in this paper the focus has been on conditions for fully generalized Rybczynski effects in the three-good trade model with indecomposable inter-industry flows, for both net and gross outputs. Previously only two such conditions were known, and for a model without inter-industry flows, namely Ethier's conditions $m = 0$ and $\hat{I} = 0$, and $0 \leq m \leq 1/a$ when income and demand are *per capita*, both more restrictive than our condition.

Chang and Mayer demonstrated that net output movements are more pro-

[5] It is possible to bring out the generalized Rybczynski effects in Ethier's equations (10). Using the facts that condition $\gamma = 1$ $(m/c = 1)$ implies $(\alpha_{11} - \alpha_{21})/(\alpha_{12} + \alpha_{22}) = 1$ and that the coefficients of $\hat{x}_1$ and $\hat{x}_2$ sum to unity equations (10) can be put in determinant solution format:

$$\frac{|h_2 l_1 - h_1 l_2|}{l_3 a(h_1 + h_2) + (1 - h_3 a)(l_1 + l_2)} (\hat{x}_1 - \hat{x}_2) = \hat{L} - \hat{K}.$$

The ratio before $(\hat{x}_1 - \hat{x}_2)$ is less than unity in absolute value $(l_1 + l_2 > h_2 l_1 - h_1 l_2$ and $1 - h_3 a > 1)$ and positive or negative as good 2 is more or less capital intensive than good 1; the determinant $|h_2 l_1 - h_1 l_2|$ can be written $[(x_1 x_2)/(K\ L)](a_{K2} a_{L1} - a_{K1} a_{L2})$.

nounced than gross output movements in the two-good model. From Theorem 3 we learn that the restriction $\hat{K} \gtrless \hat{y}_s \gtrless \hat{L}$ ensures the same magnification effect in our three-good model. The effect is due to the fact that some of the gross output is used up in the production of the two other goods, both of which change at a higher or lower rate than the own net output.

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GROWTH, ALLOCATION AND TRADE IN SWEDEN

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