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BY

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A DISSERTATION

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in
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LIST OF SYMBOLS

C	Personal Consumption Expenditure in Nominal Terms
e_C	Error Term of Consumption Equation in Model 1
e_H	Error Term of Human Capital Equation in Model 1
e_I	Error Term of Investment Equation in Model 1
e_L	Error Term of Labor Equation in Model 1
e_{RD}	Error Term of R & D Equation in Model 1
e_X	Error Term of Export Equation in Model 1
H	Human Capital in Real Terms
I	Investment Expenditures in Nominal Terms
K	Capital (non-human) in Real Terms
L	Labor Hours
M	Imports of Goods and Services in Nominal Terms
P	A Vector of Output Prices
Q	Gross National Product
P_C	A Divisia Price Index of Consumption
P_I	A Divisia Price Index of Investment
P_M	A Divisia Price Index of Imports
P_X	A Divisia Price Index of Exports
R_D	Research and Development in Real Terms
t	Time
V_C	Error Term of Consumption Equation in Model 2
V_H	Error Term of Human Capital Equation in Model 2

V_I	Error Term of Investment Equation in Model 2
V_L	Error Term of Labor Equation in Model 2
V_{RD}	Error Term of R & D Equation in Model 2
V_X	Error Term of Exports Equation in Model 2
W_H	Price of Human Capital
W_K	Price of Capital
W_L	Price of Labor
W_{RD}	Price of R & D
X	Exports of Goods and Services in Nominal Terms
x	A Vector of Domestic Factor Endowments
Y	A Vector of Outputs
ε	Own and Cross Price Elasticities of Outputs and Inputs
θ	Elasticity of Transformation
ψ	Elasticity of Intensity
σ	Elasticity of Substitution (Complementarity)

ABSTRACT

ESTIMATION OF UNITED STATES IMPORT DEMAND AND EXPORT SUPPLY IN A MULTI-INPUT MULTI-OUTPUT MODEL, USING HUMAN CAPITAL AND R & D AS FACTORS OF PRODUCTION

by

EVANGELOS N. CHAROS

University of New Hampshire, December, 1984

Traditionally the estimation of the import and export functions has been done by specifying either linear or loglinear functions of some income and relative price variables then using, usually, ordinary least squares technique. This procedure is subject to a wide range of criticisms due to its lack of theoretical foundation and because of its implicit assumptions. In this thesis import and export functions will be derived within a more general theoretical framework first introduced by Samuelson and investigated empirically by Foley and Sidrauski in their treatment of the production side of the economy. This more general framework was also used by Diewert in his study of the functional forms for profit and transformation functions, and by Kohli in his study of the foreign sector of the Canadian economy.

A framework similar to that of Kohli is used to estimate the structure of U.S. foreign trade. We depart, however, from Kohli by adding human capital and R & D as inputs to the model. Even though human capital and R & D have been considered as factors

affecting trade flows by Keesing, Gruber, Metha and Vernon and have been also considered as inputs in the production side of the economy, they have not yet been incorporated as inputs in a multi-input, multi-output profit function in which imports and exports are explicitly considered.

The scope of this thesis is to eradicate this omission and to use a translog profit function to estimate all input-output own and cross price elasticities as well as elasticities of transformation, complementarity and intensity for the United States economy when imports, human capital, R & D, non-human capital and labor are used as inputs, and exports, consumption and investment as outputs.

CHAPTER I

INTRODUCTION

The thesis is divided into eight chapters as follows:

CHAPTER I, which is the introduction chapter, outlines the organization of the study.

CHAPTER II traces the major theories of international trade since Adam Smith. The classifications of Classical Theory, Neoclassical Heckscher-Ohlin Theory and Modern Theories are the same employed by Chipman in his articles entitled "A Survey of the Theory of International Trade: Part 1 and Part 2 (1965)".

CHAPTER III consists of a number of sections, Section 1 outlines some of the previous empirical studies of import and export functions as well as the explanatory variables used in these studies. Section 2 deals with the critique of the empirical studies and finally Section 3 reviews elasticities of substitution between imports (exports) from (to) different countries from a cross section of articles.

CHAPTER IV takes a historical look at human capital and research and development along with the ways to measure these variables. The second part of this chapter outlines Eisner's data, these being the data used in our study.

CHAPTER V contains the general description of the model, the functional form and estimation technique for the translog profit function, and the elasticity matrices to be estimated.

CHAPTER VI shows the specific model estimated and the results of the estimation.

CHAPTER VII is divided into two sections. The first section consists of tables of elasticities and the second section consists of the interpretations of these elasticities.

CHAPTER VIII is the summary and conclusion chapter where there is a summary of the study and conclusions are made based on the findings.

CHAPTER II

THEORETICAL STUDIES

Following Chipman's classification we can divide the theories of international trade into three major categories:

1. Classical Theory
2. Neoclassical Heckscher-Ohlin Theory
3. Modern Theories

The purpose of doing so is to outline the evolution of the theories of trade from Adam Smith to present, show the highlights of these theories, discuss their flows and show the neglect for the human capital and R & D variables.

It will also be shown that these missing variables have been considered, separately, to be important variables in understanding trade behavior, thus laying the theoretical foundations for including them in the empirical model.

One of the major categories of trade is the Modern Theories category, but not all of the modern theories will be discussed in this chapter. Special attention will be given to Keesing's study of the affect of human capital and Gruber's, Metha's and Vernon's study of the affect of research and development on trade flows. Other theories discussed are the Trade Cycle Model and Linder's Hypothesis.

Classical Theory

The classical theory stems from Adam Smith in the eighteenth century. Before Adam Smith the mercantilist school of thought was of the belief that the proper trade policy for a nation would be one which discouraged imports and encouraged exports. This notion was based on the assumption that the total wealth of the world was fixed; thus any trade between nations where a nation imported more goods than it exported abroad would loose gold and silver in paying for these goods, and in so doing would lower its stock of wealth.

Adam Smith's efforts to refute the mercantilists' arguments for restricting free trade by demonstrating the potential gains from unimpeded trade, gave us the first systematic analysis of the causes of international trade. Smith's theory which came to be known as the Absolute Advantage Hypothesis postulates that two nations can increase their combined output if each specializes in producing the goods in which it is most efficient and then engages in trade with the other nation. Both countries will be better off, in terms of the quantity of goods available for consumption, as they trade and thus divide up the additional output obtained through specialization.

Smith did demonstrate the potential gains from specialization and trade but left many questions unanswered. Foremost among those questions was: What if a nation did not possess an absolute advantage in the production of any commodity? In what manner would such a country engage in trade? This question was addressed by Ricardo.

David Ricardo, with his theory of comparative advantage, demonstrated that a basis for trade existed, as did the potential for gains from trade, even if one of the trading nations did not possess an absolute advantage in the production of any commodity. According to the comparative advantage theory, each country will concentrate on the production of those goods that it can produce relatively more cheaply than other countries and that the equilibrium terms of trade will be determined by international supply and demand relations so as to provide the basis for the division of the gains from trade among the participating nations.

Ricardo is credited with having been the first economist to recognize the importance of differences in relative or, as he called it, comparative costs as the basis of international trade. He made the following assumptions:

(1) The real variables of the economic system are determined independently of the monetary system. This assumption is often referred to as the neutrality of money. Basically it means that the real and monetary variables of the system are determined independently of each other. The only function that money performs is to set the absolute price level.

(2) All prices are truly flexible and are determined under conditions of perfect competition.

(3) The total amount of each factor of production is fixed for any one country.

(4) International immobility of factors.

(5) Technology available to the producers of the same product within one country is the same.

(6) Tastes are given.

(7) Income distribution patterns are given.

(8) No barriers to trade in the form of costs of transportation, information, and communication.

(9) Full utilization of all productive resources.

(10) Validity of the labor theory of value.

Several economists have attempted to test the validity of the elementary form of the comparative cost theory. The most important attempts were made by MacDougall (1951), Stern (1962), and Balassa (1963) and all of them worked with data for the United States and the United Kingdom.

All three investigations tried to test the validity of the labor theory of value as the main determinant of international trade. According to this theory, differences in the productivity of labor will result in differences in the cost of production of various commodities which in turn affect the pretrade prices for these commodities. If a country has relatively low prices for a commodity, it will tend to export this commodity.

The testing of this hypothesis entails a number of problems. One such problem is the inability to observe the pretrade prices that would prevail under conditions of autarky. A second problem is the tariffs and transport costs that exist in the real world; a third difficulty arises in the availability of export performance data.

Because of the first problem, empirical studies tested directly the hypothesis that the country that has a relative high productivity of labor in the production of a commodity will tend to export this commodity. Because of the second problem, the empirical studies concentrated on the export performance of the two countries investigated, in third markets. The third problem was taken care of more easily than the previous two because value of exports is quantity times price. As both countries are able to obtain the same price in the world market, price indices could be constructed.

The Ricardian theory predicts that the country whose productivity of labor is higher than that of the other country in the production of a certain commodity would capture the whole export market of this commodity. MacDougall used 1937 data for the United States and the United Kingdom and found that in those commodities where the United States labor productivity is the highest (relative to that of the United Kingdom), the United States will capture the largest share of the export market. As the relative advantage of the United States falls, the export share also falls. MacDougall found that no country succeeded in capturing the whole export market as a result of a small comparative cost advantage, but he found that high productivity of labor was strongly correlated with a superior export performance.

Stern who used 1950 and 1959 data and Balassa who used 1950 data, confirmed and amplified the conclusions reached by MacDougall. They also found that other factors, such as capital cost per unit of output, did not significantly influence export performance.

Bhagwati (1964), however, casts doubt on these seemingly convincing studies. Using a somewhat more sophisticated technique he found that linear regressions of export price ratios (United States/ United Kingdom) on labor productivity ratios yielded no significant regression coefficients. Similarly, regressions of unit labor costs on export price ratios for the same two countries yielded no significant results. The strong positive results of MacDougall, Balassa and Stern regarding the usefulness of the classical theory of comparative costs were looked upon with caution and new theories about international trade were born.

Neoclassical Heckscher-Ohlin Theory

The factor proportions theory can be stated quite simply: a country exports those commodities that intensively use the productive factors that are relatively abundant in the country, as compared with the relative abundance of these factors in the rest of the world.

The factor proportions theory stems from a trade model based on the following assumptions:

(1) Identical production functions for each commodity in all countries and qualitatively identical productive factors throughout the world.

(2) Production under conditions of constant returns to scale for all goods and diminishing marginal productivity for each factor.

(3) Uniform ordering of the relative factor ratios used in producing all commodities at all possible factor price ratios.

(4) Identical consumption patterns (meaning that all goods are consumed in the same proportions) amound countries at any given set of international commodity prices.

(5) Perfect markets, free trade, no transport costs and complete international immobility of productive factors.

Empirical tests have failed to support the factor proportions theory in a convincing way. One of the most widely publicized empirical tests was undertaken by Wassily Leontief (1953). On the basis of the Heckscher-Ohlin theory one can predict that a country will tend to export the commodity that is relatively (to the other commodity) intensive in the relative (to the other country) abundant factor.

To test this prediction Leontief used a 1947 input-output table for the United States. The table gave detailed information on the capital and labor requirements for the production of any commodity group. Leontief had to resort to the United States import competing industries to estimate the capital and labor requirements for the production of a given batch of imports rather than using the corresponding requirements in the country of origin as a basis for comparison. This procedure was legitimate since one of the assumptions of the Heckscher-Ohlin model is identical production functions. Leontief excluded products such as coffee, tea and jute that were not produced in the United States. He also excluded service industries that did not enter into international trade, such as trucking, railroad transportation, warehousing, retail trade, banking and so on.

Leontief then computed the capital and labor requirements for the production of 1 million dollars worth of United States exports and import competing commodities. The results are summarized in Table 2.1.

TABLE 2.1

DOMESTIC CAPITAL AND LABOR REQUIREMENTS
FOR PRODUCTION OF $1 MILLION U.S. EXPORTS
AND IMPORTS

	Exports	Imports
Capital (1947 Prices)	$2,550,780	$3,091,339
Labor (man-years)	182	170
Capital per man-year	$14,010	$18,180

Since the United States is the most capital abundant country in the world the Heckscher-Ohlin theory predicts that the United States will tend to export commodities that are intensive in her abundant factor, capital, while importing relatively labor intensive goods. The Leonteif results contradicted this prediction, because the United States was shown to export commodities that use only $13,991 of capital per man-year of labor, while importing commodities that required $18,184 of capital per man-year. These statistics seem to indicate that the Heckscher-Ohlin theory does not yield satisfactory predictions about the direction of trade in this particular case.

Bharadwaj (1962) found that India tends to export labor intensive goods and import capital intensive goods. But when trading with the United States, India is found to export capital-intensive commodities to the United States while importing labor intensive commodities in return.

A study by Wahl (1961) found that Canadian exports are capital intensive and imports, labor intensive. Since most of Canada's trade is with the United States, this is again contrary to what would be expected on the basis of pure theory.

Two studies that support the Heckscher-Ohlin theory are one by Tatemoto and Ichimura (1959) investigating the trade relations between Japan and the United States and another by Stolper and Roskamp (1961) investigating imports and exports of East Germany and Eastern Europe.

Modern Theories of International Trade

Modern theories of international trade have attempted to reconcile the difference between theory and reality by bringing some new explanatory variables into the analysis.

Keesing (1966), for example, stresses that the quality of labor, as measured by skill and educational levels, differs markedly within and among countries. Furthermore, skill requirements vary considerably among traded commodities. Since these differences influence the commodity composition of a country's trade, investigators such as Keesing suggested abandoning the Heckscher-Ohlin theory of only two factor approach (capital and labor), in favor of a factor-proportions approach that distinguishes among different types of labor on the basis of skill levels. Under this factor classification system, the United States economy is relatively abundant in skilled labor which would imply that the production of United States exports would require relatively greater amounts of skilled labor than the production of goods that compete with imports.

Keesing divided occupations into eight catagories, as shown in Table 2.2, with the greatest skill requirements represented in category I and the least in category VIII (as identified in the "source note" to Table 2.2). The contribution of each category to the total labor required to produce exports is shown in percentage terms for a number of countries. Such countries as India and Japan tend to specialize in producing commodities using comparatively large amounts of unskilled labor and import commodities requiring large amounts of skilled labor.

Keesing's study suggests that the Heckscher-Ohlin predictions of trade patterns, based on factor endowments, may prove valid after all if more than two factors of production are considered, the missing factor is human capital. The role of human capital in determining trade patterns not only help to explain the Leontief paradox, but also provided the basis for some of the more recent theories of international trade.

Gruber, Mehta, and Vernon (1967) in their paper entitled "The R&D Factor in International Trade and International Investment of United States Industries" echoed another modern theory of international trade which emphasizes, as a major casual factor influencing the commodity pattern of trade, differences in technological knowledge among countries. Thus the assumption of identical production functions throughout the world for each commodity is dropped. Differences in expenditures on research and development (R&D) activities per dollar of output are usually used to indicate differences in levels of technological knowledge. According to Gruber, Mehta, and Vernon this difference is an important consideration in the explanation of the U.S. trade pattern. The U.S. devotes considerably more resources than any other country to search for new and better products and productive methods. Productive lines in which United States research and development expenditures are especially large, and presumably have the highest payoffs, are those products in which the share of United States exports in world market is the highest. And, borrowing from Gruber, Mehta, and Vernon "All roads lead to a link between export performance and R&D". This is indicated by Table 2.3, which provides a simple set of data typical of the evidence which relates research effort by United States industry to United States trade performance in 1962.

TABLE 2.2

Labor Requirements by Skill Class to Produce 1962 Exports of Fourteen Countries, Using 1960 U.S. Skill Combinations, for Forty-Six Manufacturing Industries Including Natural-Resource Processing

Country	Man Years per Billion Dollars of Exports	Percentage Distribution of Labor Requirements by Skill Class							
		I	II	III	IV	V	VI	VII	VIII
U.S.	48,194	5.02	2.89	2.74	4.85	8.38	14.96	15.73	45.42
Canada	34,881	4.17	2.33	2.43	4.76	5.39	16.45	14.70	49.76
U.K.	49,833	3.77	2.29	2.36	4.79	7.20	15.01	14.91	49.68
Austria	52,954	2.76	1.76	1.91	4.15	5.71	15.97	12.87	54.87
Belgium	48,611	2.83	1.71	1.98	3.86	4.67	17.35	12.75	54.85
France	49,381	3.15	1.92	2.15	4.58	5.28	15.55	14.14	53.24
Germany	50,459	3.89	2.48	2.33	4.69	8.44	15.84	14.54	47.79
Italy	52,304	2.75	1.75	1.97	4.33	4.32	12.78	13.24	58.86
Netherlands	44,519	3.62	2.39	2.31	4.65	5.04	15.62	14.50	51.87
Sweden	49,984	3.53	2.34	2.23	4.41	8.92	18.87	13.73	45.96
Switzerland	54,971	3.50	2.39	2.18	5.29	7.76	12.66	15.65	50.56
Japan	57,842	2.48	1.66	1.78	3.96	4.56	15.15	12.04	58.38
Hong Kong	74,304	0.69	0.49	1.13	3.75	1.34	8.48	10.39	73.73
India	66,517	0.71	0.58	1.06	3.47	1.33	11.13	9.62	72.09

Source: Donald B. Keesing, "Labor Skills and Comparative Advantage", American Economic Review, 56 (May 1966) 249-58 (Table 1). (Reprinted with permission).

Skill Classes are:

I. Scientists and Engineers
II. Technicians and Draftsmen
III. Other Professionals
IV. Managers
V. Machinists, Electricians and Tool and Diemakers
VI. Other Skilled Manual Workers
VII. Clerical Workers
VIII. Unskilled and Semiskilled Workers

TABLE 2.3

Research Effort and World Trade Performance by United States Industries, 1962

INDUSTRY NAME [a] AND SIC NUMBER	RESEARCH EFFORT: Total R & D Expenditures as Percentage of Sales (R_1)	RESEARCH EFFORT: Scientists and Engineers in R & D as a Percentage of Total Employment (R_2)	EXPORT PERFORMANCE: Exports as Percentage of Sales (E_1)	EXPORT PERFORMANCE: Excess of Exports over imports as Percentage of Sales (E_2)
Transportation (37)	10.0	3.4	5.5	4.1
Aircraft (372)	27.2	6.9	8.4	7.6
Transportation (other than aircraft((...)	2.8	1.0	4.2	2.6
Electrical machinery (36)	7.3	3.6	4.1	2.9
Instruments (38)	7.1	3.4	6.7	3.2
Chemicals (28)	3.9	4.1	6.2	4.5
Drugs (283)	4.4	6.6	6.0	4.8
Chemicals (other than drugs) (...)	3.8	3.7	6.2	4.4
Machines (non-electrical) (35)	3.2	1.4	13.3	11.4
Rubber and plastic (30)	1.4	0.5	2.0	1.3
Stone, clay, and glass (32)	1.1	b	1.9	-0.2
Petroleum and coal (29)	0.9	1.8	1.2	-0.8
Fabricated metal (34)	0.8	0.4	2.1	0.7
Primary metal (33)	0.6	0.5	3.1	-1.8
Nonferrous metal (333)	0.8	0.5	4.2	-4.7
Ferrous metal (...)	0.5	0.4	2.5	-0.2
Leather (31)	0.6	0.1	1.7	-3.4
Printing and publishing (27)	0.6	0.2	1.7	1.1
Tobacco (21)	0.3	0.2	2.2	2.1
Food (20)	0.2	0.3	0.9	-1.2
Textile (22)	0.2	0.3	3.4	-1.1
Furniture and fixtures (25)	0.1	0.2	0.7	b
Lumber and wood (24)	0.1	b	2.0	-6.2
Paper (26)	0.1	0.3	2.1	-3.5
Apparel (23)	0.1	b	0.7	-2.1
All 19 industries:	2.0	1.1	3.2	0.6
5 industries with highest research effort	6.3	3.2	7.2	5.2
14 other industries	0.5	0.4	1.8	-1.1

[a] Industries arranged in descending order of research effort, defined by R & D expenditures as a percentage of sales.

[b] Less than 0.05 per cent.

R_1 and R_2 are the research effort measures and E_1 and E_2 are the export performance measures. It can be seen that there is a positive measure between total R&D expenditures as percentage of sales (R_1) and scientists and engineers in R&D as a percentage of total employment (R_2) and a positive correlation between exports as percentage of sales (E_1) and excess of exports over imports as percentage of sales (E_2) (between R_1 and R_2 and between E_1 and E_2). The five industries with the greatest research effort are also the five industries with the most favorable trade position.

Another modern theory of international trade is the Trade Cycle Model. The model claims that many products go through a trade cycle. Initially an exporter, a country loses its export markets and finally becomes an importer of the product. This theory was developed to aid the business executive in decision making about his products since the detailed problems facing him are not accounted in the previous theories of international trade.

Even though Linder (1961) is credited with this next theory of international trade, the origins of the theory can be traced to Frankel (1943) who in his paper "Industrialization of Agricultural Countries and the Possibilities of A New International Division of Labour" wrote:

> A country with a large internal market for low quality goods is more likely to compete successfully in countries with a demand for similar goods than one whose internal markets are mainly in goods of higher quality, because less adaptation of production processes to export requirements will be needed in the former case. Japan's success (in foreign trade) was greatly due to the low purchasing power of the population in the European colonies and semicolonies.

Linder departs from the Heckscher-Ohlin theory of trade in manufactured goods by assuming not only that production functions are not identical in all countries but also that consumer preferences differ among countries. Differences in production functions among countries are in the form of similar but not identical products and differences in tastes are associated with differences in per capita income.

According to Linder, firms within a country are primarily oriented toward producing goods for which there is a large home market. This determines the set of goods these firms will have to offer when they begin to export. The logical foreign markets for such exports are countries with similar tastes. The basket of goods demanded within an economy and the quality of these goods, depends largely on the country's per capita income and its state of development. If an exporting country is highly industrialized, it is likely to find promising markets in other countries with similar preferences. That is in other industrialized countries rather than in less-developed countries. Thus it is not surprising that the majority of world trade occurs among the industrialized countries.

The Linder hypothesis, in addition to helping to explain a given pattern of world trade, offers some insight into changing trade patterns as well. As per capita income grows within a country its residents will be able to afford a larger quantity of goods offered on world markets, and their tastes tend to move closer to those in the more advanced economies. As a result both the volume and the characteristics of foreign goods demanded by this country will change. Thus the very process of economic growth and development can affect the volume and composition of world trade by affecting the demand preferences of trading nations.

A number of empirical studies were undertaken for the verification of Linder's hypothesis. In fact, Linder (1961) himself has tried to provide some empirical evidence in support of his thesis. He has constructed a trade matrix giving the data for the trade intensities and per capita income. Linder noted that highest trade intensities were found near the diagonal of the trade matrix. Hence, he concluded that countries with per capita income closest to any country have longer propensity to import from that country. Bhagwati (1964) pointed out that this test is not generally recognized as completely satisfactory. Gruber (1967) found some evidence in support of Linder's Hypothesis for EEC countries, but much confidence cannot be placed in his results as he did not conduct any statistical test to verify the hypothesis. Fortune (1971), using a cross-section multiple regression analysis, claimed that his results provide some support in favor of the hypothesis. His test remains inconclusive for the following reasons:

(A) The coefficients of determination for almost all the countries are generally poor. They range from 0.01 for United Kingdom to 0.41 for Germany.

(B) He has adopted the absolute difference in per capita income among countries as a measure of the similarity in internal demand structures. This measure being completely inadequate and misleading since it gives the same weight to both positive and negative differences. Obviously any two countries which have the opposite signs in the difference in per capita income in relation to a third country, but the equal magnitude in the absolute value, cannot be said to have the similar internal demand structures.

(C) Only eight out of twenty-one countries have the correct sign and significant coefficient of income differences. In contrast to this, distance is found to be significant in eleven countries, out of which in seven countries the coefficient of income differences is not significant at all. One would suspect that whatever explanatory power his regressions have is due to the inclusion of distance as a variable.

(D) His study is based upon cross-section data for one year. Nonetheless, international trade flows are subject to the influence of a number of factors such as business cycles, fluctuations of exchange rates, international inflation, energy supplies, and so on. Consequently, any cross-section analysis cannot be expected to provide conclusive evidence for a test of the Linder Hypothesis as there is no sufficient time for adjustment to these short run random disturbances.

Sailors, Qureshi and Cross (1973) have attempted to verify Linder's Hypothesis with the help of rank coefficient of correlation. They have also used the absolute value of per capita income differences and cross-section data. Thus, their study becomes subject to the same shortcomings as that of Fortune. Furthermore, the reported coefficients of correlation are not high and only nine out of thirty-one countries provide significant correlation at the five percent level.

Ahmad and Simos (1979) suggested an alternative test to the Linder Hypothesis which is free from the shortcomings mentioned above. Their study differs from the previous studies in the following important ways:

(A) They used time-series data, thus taking into account the long-run behavior of trade flows.

(B) The ratio of per capita income of two trading countries has been used as a measure of similarity in demand structures.

(C) Unlike Sailor, Qureshi, and Cross they have used regression analysis instead of correlation analysis.

(D) They have estimated the elasticity of exports (imports) with respect to change in per capita income ratio, thus their results have far reaching policy implications.

(E) They have conducted tests for various categories of manufactured products.

The results of this study were of overwhelming support in favor of the Linder Hypothesis and Ahmad and Simos state:

> "In view of these results, the LH cannot be considered a supplementary hypothesis in the explanation of trade patterns as it has been claimed by Fortune (1971, p. 317). Instead, the LH should be regarded as a major thesis providing the rationale of international trade patterns in manufactures."

In concluding this section the following observations can be made:

(A) The international trade theory over the years has been tested, retested and scrutinized.

(B) The classical theory and the neoclassical theory even though the nucleus of the modern theories of international trade themselves are not able to explain accurately trade flows.

(C) Human Capital and Research and Development were shown separately to be important missing variables in understanding trade behavior.

(D) Despite the theoretical and empirical support of the above missing variables, no model has been developed so far incorporating both of them as explanatory variables, and as we shall see in the next section the methods of estimation of export and import function that are found in the literature are subject to a number of limitations.

In the next chapter we will deal with previous empirical studies of import and export functions which have attempted to quantify the theories of trade as presented above.

CHAPTER III

Previous Empirical Studies of Import and Export Functions

In the previous chapter we outlined the Theories of Trade, while in this chapter we will deal with the empirical aspect of these theories. For this reason CHAPTER III was divided into three sections. The first section discusses the functional forms of import demand and export supply functions used in empirical estimation. A special emphasis is given to the explanatory variables used, which include National Income, GNP, Prices, Lagged Variables, Dummy Variables, Credit, etc. The second section deals with the critique of the empirical studies, particularly with Orcutt objections as well as a rebuttal of these objections. The last section reviews elasticities of substitution between imports, exports, to and from different coutries, and it reports the actual size of these elasticities from a cross-section of studies.

Usually there are two kinds of misspecifications that may occur in the process of constructing a mathematical relationship. The first is when relevent variables are omitted from the equations and the second is when irrelevant variables are added to the equations. This creates what is often referred to as "the gap between theory and empirical analysis". These kind of problems are also discussed in this chapter so as to give an overview of the limitations of empirical studies.

Functional Forms of Import Demand and Export Supply Functions

Import and export functions, traditionally, have been specified as either linear or loglinear functions of income and relative price. The parameters were estimated by the method of least squares.

A popular form for the import demand function was:

$$M = f\left(\frac{Yd}{Pd} ; \frac{Pm}{Pd}\right) \qquad 3.1$$

where M is the quantity of imports demanded,

Yd is nominal domestic income,

Pd is domestic price index, and

Pm is price of imports.

If all imported and domestic goods are consumer goods, conventional consumer theory suggests the quantity of imports individual i demands is:

$$\begin{aligned} M_1^i &= d_1^i(Y_d^i, Pm, Pd) \\ M_2^i &= d_2^i(Y_d^i, Pm, Pd) \\ &\vdots \\ M_n^i &= d_n^i(Y_d^i, Pm, Pd) \end{aligned} \qquad 3.2$$

where Y_d^i is individual i's disposable income

Pm is the price vector of the imported goods

Pd is the price vector of the domestic goods

If both imports and domestic goods can be aggregated, and if one further aggregates over all individuals, Equation 3.2 becomes:

$$M = D\ (Yd, Pm, Pd) \qquad 3.2'$$

Assuming the absence of money illusion, Equation 3.2´becomes:

$$M = D\left(\frac{Yd}{Pd}, \frac{Pm}{Pd}, 1\right) = f\left(\frac{Yd}{Pd}, \frac{Pm}{Pd}\right) \qquad 3.3$$

and the form of Equation 3.1 is established.

In linear terms Equation 3.1 can be represented as:

$$M = a + b\left(\frac{Yd}{Pd}\right) + C\left(\frac{Pm}{Pd}\right) + u \qquad 3.4$$

b and c are respectively the income and the price propensity to import and u is the error term. The error term has the usual properties. It reflects other minor influences; it is assumed to be normally distributed, with zero means and constant variances, and uncorrelated with the explanatory variables.

The loglinear equation of 3.1 can be specified as follows:

$$\ln M = \alpha + \beta \ln\left(\frac{Yd}{Pd}\right) + \gamma \ln\left(\frac{Pm}{Pd}\right) + v \qquad 3.5$$

where β and γ are the income and the price elasticity of imports respectively, and v is the error term.

Similarly, the export function can be written as:

$$X = g\left(\frac{Yw}{Pw}, \frac{Px}{Pw}\right) \qquad 3.6$$

where X is the quantity of exports supplied,

Yw is the gross world product,

Pw is world price index, and

Px is price of exports

and the linear equation can be written as:

$$X = a_1 + b_1\left(\frac{Yw}{Pw}\right) + C_1\left(\frac{Px}{Pw}\right) + u_1 \qquad 3.7$$

and the loglinear equation can be written as:

$$\ln X = \alpha_1 + \beta_1 \ln\left(\frac{Yw}{Pw}\right) + \gamma_1 \ln\left(\frac{Px}{Pw}\right) + v_1 \qquad 3.8$$

If imports are composed of non-finished goods which enter the production process along with domestic inputs, an equation similar to 3.1 can be derived from production theory if there exists a homothetic aggregate production function and aggregation over imports as well as over domestic inputs is possible. In this case Yd should be redefined as output and Pd as the rental price of domestic inputs. An equation similar to 3.6 could also be derived for exports of non-finished goods.

Since imports are generally composed of both finished and non-finished goods, the common procedure is to take for the income variable some proxy for both output and disposable income such as GNP. The wholesale price index is often used as the domestic price variable. When import functions for various commodity groups are estimated, the standard method consists of trying, for each equation, a number of different income and domestic price variables. In many instances, a variety of supplementary explanatory variables, not accounted for in the basic theory, are added to the model. Leamer and Stern (1970) have summarized the other variables used as: dummy variables for unusual periods and for seasonal variation, lagged variables, foreign exchange reserves, and credit.

A Historical Outlook of Explanatory Variables

National Income. Tinbergen (1946), Kubinski (1950), DeVries (1951), Adler, Schlesinger and Van Westerborg (1952) were among the first to estimate import demand and export supply income elasticities. Johnson (1962), Houthakker and Magee (1969) and Pourmoghim (1978), to mention a few, followed.

In studying the relationship between the growth rate of real income and the growth rate of real exports and imports there are two theories to be considered: The Keynesian Theory and the Pure Theory of International Trade.

The Keynesian Theory argues that the income parameter in the structural imports demand function with fixed prices is positive where the Pure Theory argues that the relationship between the growth of real income brought about by economic development, and the growth of real imports demand the exports supply is not necessarily positive, it could be negative. Most of the empirical research has supported the Keynesian model expectations. In particular, Houthakker and Magee (1969) found that the income elasticity of demand for imports and exports for 15 countries were highly significant and positive and most of them were between one and two. (See Table 3.1.)

Positive signs of the parameter associated with income were found also by Pourmoghim, who studied the foreign sector of 13 developing countries. Johnson (1962) argued that the effect of growth on demand for imports is the combined result of its effects on consumption demand and domestic supply. If the two move in opposite directions, the net effect could be either positive or negative.

TABLE 3.1

HOUTHAKKER & MAGEE ESTIMATES

Income and Price Elasticities for Total Exports and Imports of Countries (Annual Data, 1951-66)

IMPORTS			EXPORTS	
Income Elasticity	Price Elasticity	Country	Income Elasticity	Price Elasticity
1.68	-1.03	United States	.99	-1.51
1.20	-1.46	Canada	1.41	- .59
1.45	- .21*	United Kingdom	1.00	-1.24
1.23	- .72	Japan	3.55	- .80
1.85	- .24*	Germany	2.08	-1.25
2.19	- .13*	Italy	2.68	-1.12
1.89	.23*	Netherlands	1.88	- .82*
1.66	.17*	France	1.53	-2.27
1.94	-1.02	Belgium-Luxembourg	1.87	.42*
.91	- .52*	South Africa	.88	-2.41
1.42	- .79*	Sweden	1.75	.67*
.90	.83*	Australia	1.16	- .17*
2.05	- .84*	Switzerland	1.47	- .58
1.31	-1.66	Denmark	1.69	- .56*
1.40	- .78	Norway	1.59	.20*

*These coefficients were significant at the 95% level.
Source: Houthakker H.S., and Magee, S.P., "Income and Price Elasticities on World Trade," Review of Economics and Statistics, May 1969, pp 11-125.

Indeed, if imports take place to fill a gap between home demand and home supply, the income elasticity of imports can be calculated by the following model where D, S, and M denote respectively domestic demand, domestic supply and imports:

$$D = D(Y)$$

$$S = S(Y)$$

$$M = D - S \qquad 3.9$$

Taking the derivative of Equation 3.9 with respect to Y (national income) and substituting, we can derive the income elasticity of demand for imports (ε_{my}).

$$\varepsilon_{my} = \frac{dM}{dY}\frac{Y}{M} = \frac{Y}{M}\left(\frac{dD}{dY} - \frac{dS}{dY}\right) = \frac{D}{M}\varepsilon_{DY} - \frac{S}{M}\varepsilon_{SY}$$

$$\varepsilon_{my} < o \text{ when } \frac{D}{S} < \frac{\varepsilon_{SY}}{\varepsilon_{DY}}$$

Thus, when the domestic demand and supply elasticities are of the same sign, in order to have a negative income elasticity of demand for imports, the value of the domestic supply elasticity must be sufficiently higher than the domestic demand elasticity so that their ratio exceeds the ratio of demand to domestic supply.

Khan (1974) studied the import demand and export supply function of 15 developing countries. He found that seven of them had income elasticities for demand of imports positive and significant, five of them were positive and insignificant and three of them were negative and insignificant. Magee (1975) argued that the reasons for the negative import-income elasticities at the aggregate level were due to misspecification of import demand functions and failure to distinguish cyclical and secular elasticities in trade studies.

Khan and Ross (1975) did study the import demand functions of 14 developed countries in an attempt to distinguish between cyclical and trend influences on the quantity of imports. They found that the potential real income elasticities for U.S. and United Kingdom were positive and significant, where the income elasticities of the estimates of Canada, France, Japan and Switzerland were negative and significant. The remaining cases were insignificant.

Other income elasticities were calculated by Ball and Marwah (1962) who used Equation 3.4 to estimate the United States import functions, imports being divided into six commodity groups. They used quarterly data for the period 1948-58 with all right-hand variables being lagged one quarter. For the income variable they chose either GNP net of government wages and salary disbursement or disposable income. The income elasticity was 0.91 for total imports and was between 0.49 to 2.47 for the six categories.

Kemp (1962) also estimated the linear functional form for twelve groups of imports to Canada for the period 1926-1955. The total import income elasticity was 0.96.

Price Elasticities. Marshall (1923), originated the estimation of import and export price elasticities in his discussion about the possibility of a devaluation causing a deterioration rather than an improvement in the balance of payments. The above studies, in addition to the income elasticities, did estimate import and export elasticities as well.

Many empirical studies, especially those using interwar data, found very low estimates for the price elasticities of demand for imports and exports. Many economists have been hesitant to accept these estimates at their face value, arguing that the price elasticity of imports should be substantially higher than the price elasticity of either domestic demand or domestic supply. Again, if we assume that imports take place to fill a gap between home demand and home supply, the price elasticity of imports can be calculated from the following model where D, S, and M denote respectively domestic demand, domestic supply and imports:

$$D = D(P)$$
$$S = S(P) \qquad 3.10$$
$$M = D-S$$

the price elasticity of imports can be expressed as:

$$\varepsilon_m = \frac{dM}{dP}\frac{P}{M} = \frac{P}{M}\left(\frac{dD}{dP} - \frac{dS}{dP}\right) = \frac{D}{M}\varepsilon_D - \frac{S}{M}\varepsilon_S \qquad 3.11$$

Thus, one would expect ε_m to be considerably larger, in absolute terms, than both ε_D and ε_S. There is, however, a substantial difference between the model underlying Equation 3.11 and those which are made implicit in deriving Equation 3.3. In all empirical studies traded goods were assumed to be non-perfect substitutes for domestic goods while in 3.10, traded goods are identical to the home produced good.

Ball and Marwah (1962) in their estimates for the United States import functions used the wholesale price index for the domestic price variable except for the equation for food products where they preferred a food consumer price index, they found the price elasticity of total imports to be -0.51. The price elasticity ranged from -0.26 to -3.50 for the six commodity groups, when the total exports were disaggregated.

Houthakker and Magee (1969) estimated loglinear equations for imports and exports of 26 countries. Their income variable was GNP and the wholesale price index was used as the domestic price variable. Most price elasticities had the right sign, but were in general smaller than one. For the United States they found an import elasticity of -0.54 and an export price elasticity of 1.51. For Canada, the price elasticities were -1.46 (imports) and -0.59 (exports). Houthakker and Magee next estimated U.S. imports and exports by country using additional variables such as the price of a country's exports relative to the price of U.S. total imports and vice-versa. In order to obtain long-run estimates of the elasticities, they estimated a flow adjustment model the optimal amount of which is determined by Equation 3.5. Finally, they estimated U.S. imports by commodity class for which the price elasticities ranged from -0.18 to -4.05.

Kemp (1962) also estimated the linear functional form for twelve groups of imports for Canada for the period 1926-1955. Most of the estimated price elasticities had the correct sign, but all of them were less than 2 in absolute value. For total imports the price elasticity was -0.93.

Rhomberg (1964) used Equation 3.4 for both imports and exports in a macro model for the Canadian economy. He also used dummy variables and an investment proxy as an explanatory variable. The price elasticities that he obtained were of the order of -2 for exports and -1 for imports.

Adams (1969), Samuelson (1973), Khan (1975), Kohli (1978) had similar findings. Akhtar (1980) estimated income and price elasticities of total imports for industrial countries based on quarterly data for 1970-1976 and annual data for 1952-76. The estimated income elasticities ranged from about 1.3 for Japan to around 2.5 for the United States, United Kingdom and Germany. The price elasticities estimates ranged between 0 and -0.7, and are significant for most countries. Akhtar's estimates are significant at the 0.001 level while the others are only significant at the 0.01 level.

Lagged Variables. Although income in the current period may have some impact on current imports, it is reasonable to assume that income in several previous periods may also exert a significant influence. Similarly, it can be argued that other variables such as relative prices may affect imports in a manner which implies some lag in the process of actual imports being adjusted to the desired or equilibrium level of imports. A typical equation is the following:

$$M_t = \alpha_0 Y_t + \alpha_1 Y_{t-1} + \alpha_2 Y_{t-2} + \alpha_3 Y_{t-3} + \ldots + \alpha_n Y_{t-n} + u_t \qquad 3.12$$

where $\alpha_0 \ldots \alpha_n$ represents the coefficients describing the relative influence of current and past Y on the current level of M and u is an error term.

Koyck and Almon are the two major approaches to the problem of lags. Koyck (1954) suggests that the coefficients are assumed to decline in the form of a geometric progression. This implies that $\alpha_i = bk^i$ where b is a scale factor, k lies between zero and one, and i = o,1,2,...n. Equation 3.12 becomes as follows:

$$M_t = bY_t + bk\, Y_{t-1} + bk^2 Y_{t-2} + \ldots + u_t \qquad 3.13$$

On the other hand Almon (1965) assumed that the weights on the lagged independent variables take the shape of a polynomial curve. By varying the degree of the polynomial, it is possible to estimate and compare a wide range of weight patterns. The general relationship involved in the Almon approach is the form:

$$M_t = \sum_{i=0}^{n-1} W_i\, Y_{t-1} + u_t$$

where M is imports

Y is income

n is the number of periods over which the distributed lag extends

The lag coefficients W_i, are assumed to lie on a polynomial of degree P where $P \leq n$.

Magee (1975) assumed that the lags in response of supply and demand were longer with respect to price than they were with respect to income. Thus it is a matter of importance to estimate the nature of the lags inherent in the adjustment process.

Deane and Lumsden (1972) in their study of New Zealand's imports found that lags are sufficiently long to warrant careful consideration by policy makers.

Dummy Variables. Rhomberg (1964) used seasonal dummy variables in his macro model for the Canadian economy. Deane and Lumsden (1967) used five dummy variables in their model for New Zealand's imports to account for changes in official monetary policy. Deane and Lumsden (1972) used them to pick up unusual movement in other current payments. In short, the dummy variable is a simple and useful method of introducing into a regression analysis information contained in variables that are not conventionally measured on a numerical scale. The dummy variable can be used by researchers in order to see the effects upon imports of unusual occurances such as strikes, natural disasters, wars, changes in tariffs, and so forth.

Credit. Credit as an explanatory variable is meant to indicate the availability on terms at which credit is provided for the financing of imports. Such a variable will play an important role especially in linking the current and capital accounts of the balance of payments. Increasing interest in the capital account will surely provide a stimulus to increased examination of the effect of credits on imports and exports (Leamer and Stern, 1970).

El-Sharif (1979) in his study of the monetary sector of Libya considered the credit extended to importers by the banking sector to be one of the explanatory variables in the import demand equation. He assumed that the level of imports is related positively to the level of credit available to finance importers. He found that this variable enhanced the explanatory power of the import demand equation.

Other Variables. In a number of international trade models Mundell (1968), Dornbusch (1971), and Johnson (1972), the bond markets and the money markets were also considered as part of the model. These studies attempted to show the relationship between the growth of income, trade, and the balance of payments. It is assumed that, in a small country producing a single good, if expenditures exceed output, the country has an excess demand for goods and a trade-balance deficit, and in this case, there must be an excess flow of supply in the bond and money market, implying a gap between desired and actual stocks in those markets (Johnson, 1967). Other variables such as non-traded items, world-wide effects variables and capacity-utilization have also been considered.

Other studies have incorporated exchange rates in the analysis of trade flows. Hemphill (1974) proposed on import-exchange equation as a substitute for the standard imports equation, and he estimated it for eight developing countries excluding the oil exploiting countries. He found that the foreign exchange reserves did not show a strong response.

Critique of Empirical Studies

The purpose of this section is the review of some of the main problems associated with the estimation and specification of foreign trade equations. Usually there are two kinds of misspecifications that may occur in the process of constructing a mathematical relationship. The first is when relevant variables are omitted from the equations and the second is when irrelevant variables are added to the equations.

These problems may occur because in theory certain assumptions are specified and behavior of the variables in deduced through logic, while in empirical studies, the deal is with the quantifiable variables only. This creates what is often referred to as "the gap between theory and empirical analysis." A researcher may omit some important variables because they are non-quantifiable, difficult to find data for them, difficult to include them in the equation, or impossible to be measured or observed. In international trade, trade restrictions and export promotional activities are examples of such conditions. At the same time, a researcher may try to add some other variables that might be proxies of omitted variables, and this practice may not be as accurate as it should be. Thus, in reality, a perfectly specified model is never assured. According to Pindyck and Rubinfield (1976) the term "specification error" covers any type of error in specification, but it is used to mean errors in specification of the independent variables.

In international trade the exphasis in empirical work shifted from theoretical improvements to the mechanics of refining the estimation techniques. Orcutt (1950), in his much publicized article, "Measurement of Price Elasticities in International Trade," gave five reasons as to why the estimated price elasticities of demand obtained from many studies were downwards biased. The five reasons were the following:

(1) Simultaneous equation bias
(2) Random observation errors in the price indices
(3) The problem of aggregation
(4) Estimation of short-run rather than long-run elasticities
(5) Quantum effects.

Orcutt's five objections caused grave doubts on the usefulness of least squares procedures for the time series analysis of demand, and his views were supported by a number of authors such as Machlup (1950) and Neisser (1958). It led Neisser, for example, to declare that: "The traditional multiple regression analysis of time series... is dead." As we shall see in the next section, this conclusion was overly pessimistic because Orcutt's objections about least squares procedures are not quite as devastating as they may appear.

Orcutt's Objections, Explained and Discussed

The Simultaneous-Equation Bias. According to the theory underlying ordinary least squares regression, the estimate of the price elasticity will be unbiased only if the random deviation or error is independent of relative price variables. Assuming that import demand is an excess demand, it seems that shifts in demand curves have not, in general, been independent of shifts in supply curves. Rather, it seems that, generally, import demand and supply schedules for imports shift together. Orcutt has put it in his following statement:

> One way of dealing with (this) situation in which both the demand and supply schedules shift over time is that of incorporating the other variables influencing demand into the relation which is to be fitted to the data and thus attempt to fit a surface in several variables instead of a straight line to the data. By this means a demand surface which has not shifted materially over the historical time period studied might be obtained." (Orcutt, 1950, p. 533.)

According to this, it is argued that income and relative prices tend to move together. If real income is not included in the relationship, there will be an error in the estimated price elasticity. Even if both relative prices and real income are included there may still be a dependency between prices and the random term. Thus, the estimated elasticities will be biased because of lack of independence between relative prices and the residual.

Magee (1970) and Richardson (1972), however, found evidence that the standard techniques for eliminating simultaneous-equation bias succeeded in increasing the price elasticities of demand. Blaming researchers who conclude that any reasonable specification that increases estimated international price elasticities of demand must be a step in the right direction, Magee said that incorrect functional form, data mining, and excessive experimentation with lags can lead to an upward rather than a downward bias in the price coefficients.

Random Observation Errors. Orcutt's second point was that when the data contained errors of measurement due to misclassification, falsification, and faulty methods of index-number construction, the effect may be to bias the coefficients toward zero (Leamer and Stern, 1970). Magee has criticized Orcutt's point by saying:

> Orcutt was right that observation errors in the own price variable will cause the own price elasticity to be biased toward zero, but only on his assumption that errors in the dependent quantity variable...are uncorrelated with the observed price and income variables. In many empirical studies, however, errors in the quantity variable are negatively correlated with the price variable. This is because the quantity indices used as the dependent variables in import demand equations are derived by deflating an error-free value series by an import price variable subject to random errors. (Magee, 1975, p. 205.)

The Problem of Aggregation. Orcutt argues that goods which have relatively low elasticities may exhibit the largest price variations, and therefore, they exert a predominant effect on the aggregative price index used in the estimation. Using such aggregative indices, may thus understate the true elasticity to the extent that goods with lower elasticities are given undue weight. In other words, a price index being a weighted average, tends to show less variation than any of its components insofar as price increases are offset against price declines. An aggregative price index is likely to be highly correlated with income. (Leamer and Stern, 1970.)

Leamer and Stern proposed a solution to this problem by saying that the price indices should be reweighted proportionally to the individual demand elasticities. This suggests that disaggregation may be desirable, but on the other hand Grunfield and Griliches (1969) argue that aggregation may sometimes decrease the specification error and thus bring some gain in accuracy. In addition, studies by Ball and Marwah (1962), DaCosta (1965), and Dutta (1964) indicate that the returns to the use of fine subcategories of data may be limited.

Time Dimension Problems. Orcutt argued that what was calculated in most studies was a short-run elasticity that would be expected to be lower than the long-run elasticity. Leamer and Stern argued that the concept of the short-run elasticity is not particularly meaningful, and, further, that ignoring the time dimension in the analysis would bias downward the estimate of long-run price elasticity (Leamer and Stern, 1970). On the other hand, Magee criticized Orcutt by saying that he was not strictly correct on the timing issue, since short-run elasticities will be larger than long-run elasticities if the purchases are made for inventories. Houthakker and Taylor (1970) found that in 28 percent of the categories for which they estimated domestic U.S. demand equations, this inventory behavior dominates.

Quantum Effects. Orcutt argues that the price elasticity of demand for large price changes will generally be higher than for small price changes. His reasons were that it takes time for habits to adjust and that the price changes must be large enough to overcome the cost of switching. Leamer and Stern agreed with Orcutt's point by saying that adjustment to large price changes is more rapid than adjustment to small changes and this will be especially true in the case of devaluation when the price changes are clearly going to be permanent and there will be no adjustment delay in anticipation of a reversal of the price change. Magee did not find much empirical support for this effect in events following the 1971 currency realignments. In the period from the end of the Korean War until 1971, annual changes in the international prices of goods traded by developed countries were modest compared to the price changes implied by 1971 currency realignment.

Goldstein and Khan (1976) studied the import demand functions for 12 industrial countries to empirically test Orcutt's proposition that the import price elasticity is a function of the size of the relative price change. They found no evidence that either the price elasticity of demand for imports varied with the size of the relative price changes, or that importers adjust any faster when faced with larger rather than with "normal" relative price changes.

As we have seen from the above arguments, a consensus seems to have emerged in more recent years that the least-squares approach could still be used for many empirical studies.

This thesis does not directly deal with Orcutt's objections. There are, however, a number of other reasons why the traditional method to estimate price elasticities is not satisfactory. The advantages of the approach which will be employed is presented in a later section. Finally, the estimation would be much more efficient if instead of estimating isolated import and export functions, one estimated the whole system simultaneously.

Estimation of Elasticities of Substitution Between Imports (Exports) from (To) Different Countries

The estimation of elasticities of substitution between imports or exports is often viewed as an alternative way of estimating price elasticities. Assuming a production function with commodities $x_1, \ldots . x_n$ for arguments, the Allen-Hicks elasticity of substitution along an isocurve can be defined as:

$$\sigma_{ij} = \partial \ln (X_i/X_j) \;/\; \partial \ln (\partial X_j/\partial X_i)$$

Since in competitive equilibrium,

$$\frac{P_i}{P_j} = \frac{\partial X_j}{\partial X_i}$$

the elasticity of substitution for movements along a two-dimensional isocurve can be written as:

$$\sigma_{ij} = \partial \ln (X_i/X_j) \;/\; \partial \ln (P_i/P_j)$$

In empirical studies, the function which has almost invariably been estimated is the logarithmic form:

$$\ln (X_1/X_2) = \alpha + \beta \ln (P_1/P_2) + u$$

where X_1 and X_2 are import (export) quantities of similar commodities, but from (to) different countries or regions; P_1 and P_2 are their respective prices and β is the estimated elasticity of substitution which, we should note, is frequently assumed to be constant.

Zelder (1958) compared manufactured exports of the United Kingdom with those of the United States, dividing them into 27 groups and 12 sub-groups. He logarithmically regressed both x_1/x_2 on P_1/P_2 and P_1/P_2 on x_1/x_2 over the period of 1921-1938 and he calculated the elasticity of substitution as the geometric average of the two values he obtained. All estimates were between -1.2 and -12.8, but for total manufactures his estimate was positive. He blamed this result on aggregation errors and the different composition of exports of the two countries.

Zelder then categorized the elasticities obtained into two groups:

(a) Devaluation elasticities of substitution
(b) Non-devaluation elasticities of substitution.

The first category is the case when the prices of all of a country's exports move together, that is there is no or little substitution between exports of one country. The second category is the case when all prices but one are held constant.

Kaliski (1958) criticized Zelder's study on the grounds that the estimates of the elasticities of substitution are only efficient and unbiased if all cross elasticities of demand for the two country's exports of the same good as well as the income elasticities are equal, in which case it becomes impossible to distinguish devaluation from non-devaluation elasticities.

Stern (1962) also raised questions, on the theoretical validity of the relative price changes used in quantitative studies of the estimations of elasticity of substitution (in the international trade) of competing countries. In criticizing Zelder's study he concluded that the price data used by Zelder reflected the outcome of the operation of market forces, but did not reveal the impact price differentials which are needed to compute the time elasticity of substitution.

Kreinen (1967) estimated elasticities of substitution for a number of industrial countries for three groups of manufacturers: chemicals, machinery and transport equipment, and other manufacturers. The elasticity of substitution of chemicals was about -1.6; machinery and transport equipment, -1.72, and other manufacturers had an elasticity of -4.50. He also estimated the elasticity of substitution for all manufacturers and he found it to be -2.6.

Surprisingly, only a few authors attempted to give vigorous interpretation to the elasticities they had estimated, although the problems of estimating elasticities of substitution and the implications of the particular forms have been discussed extensively by Morrisset (1953) and by Goldberger (1967).

Selected Studies, Reporting Elasticities of Substitution Price and Input Elasticities

In this section of the thesis we review some price and input elasticities along with elasticities of substitution as reported by other studies on similar variables as the ones investigated in our thesis. Even though a meaningful comparison of our estimates and these estimates cannot be made, due to differences in assumptions, data, and empirical estimation techniques, these estimates provide a context or setting within which our estimates can be appreciated, evaluated, or understood.

Hudson and Jorgenson (1974) in their paper, "U.S. Energy Policy and Economic Growth, 1975-2000," presented a new approach to the quantitative analysis of U.S. energy policy, based on an integration of econometric modeling and input-output analysis. They incorporated a new methodology for asserting the impact of economic policy on both demand and supply for energy within a complete econometric model of the U.S. economy. The model consisted of production models for nine industrial sectors, a model for consumer demand and a macro-econometric growth model for the U.S. economy. They first projected economic activity and energy utilization for the period 1975-2000 under the assumption of no change in energy policy and then they designed a tax program for stimulating energy conservation and reducing dependence on imported sources of energy. Among their estimates was the elasticity of substitution between capital and labor which they found to be 1.09, indicating substitutability between these factors of production. They also found the estimates of:

$$\varepsilon_{LL} = -0.45$$

$$\varepsilon_{KK} = -0.42$$

$$\varepsilon_{LK} = 0.14$$

$$\varepsilon_{KL} = 0.29$$

Where ε_{ih} measures the percent change in the quantity of input i due to percent change in the price of input j, ε_{ii} is the own elasticity.

Humphrey and Moroney (1975) presented estimates of partial elasticities of substitution among reproducible capital, labor, and an input aggregate of natural resource products. They tested two hypotheses: a) whether natural resource products are strictly complementary in production with either capital or labor and b) whether resource products are less substitutable with capital than with labor. Among their finding the elasticity of substitution between capital and labor for various product groups ranged from 0.37 to 36.75.

Berndt and Wood (1975) in an attempt to characterize more completely the structure of technology in United States manufacturing, analyzing the period 1947-1971, tried to provide evidence on the possibilities for substitution between energy and nonenergy inputs. They reported the elasticity of substitution of capital and labor to be 1.01. Also, their findings included the following elasticities:

ε_{LL} which ranged from -0.45 to -0.46

ε_{KK} which ranged from -0.44 to -.050

ε_{LK} which ranged from 0.05 to 0.06 and

ε_{KL} which ranged from 0.26 to 0.30.

Griffin and Gregory (1976) applied tanslog methodology to pooled international data for manufacturing in investigating the generality of Hudson-Jorgenson (1974) and Berndt-Wood (1975) results. They found the elasticity of substitution between capital and labor for the U.S. to be 0.06. Also they found among other elasticities for the U.S.:

ε_{LL} to be -0.12

ε_{KK} to be -0.18

ε_{LK} to be 0.1

ε_{KL} to be 0.5

Dennis and Smith (1978) presented the results of an evaluation of the role of real cash balances as a factor input for 11 two digit SIC code industries over the period 1952-73. Using a four factor translog cost function for each industry along with duality theory they estimated the partial elasticities of substitution and the elasticities of demand for all factors. Their overall findings supported the neoclassical model for modeling the firm's demand for money. For our purposes their estimation of the elasticity of substitution between capital and labor was reported to range from 0.04 to 3.52.

Kohli (1978) in his modeling of the substitution possibilities between Canadian imports, exports and domestic inputs or outputs derived import demand and export supply functions from a representation of the technology that is similar to Samuelson's GNP function. He then estimated these functions simultaneously with the demand and supply functions of the domestic factors. He reported the following findings for the period 1949 to 1972:

ε_{LL} ranged from -0.319 to -0.373

ε_{KK} ranged from -0.738 to -0.802

ε_{LK} ranged from 0.319 to 0.373

ε_{KL} ranged from 0.738 to 0.802

ε_{II} ranged from 1.456 to 1.898

ε_{CC} ranged from 0.293 to 0.308

ε_{IC} ranged from -0.998 to -1.264

ε_{CI} ranged from -0.360 to -0.372

ε_{MM} ranged from -0.902 to -0.993

ε_{MC} ranged from -0.255 to -0.434

ε_{XX} ranged from 1.476 to 2.213

ε_{XI} ranged from -0.445 to -0.722.

Simos and Roddy (1980) using a multi-input multi-output model, investigated the economic influences that contribute to the technological development of the U.S. private domestic economy for the period 1929 to 1969. Among their findings the following elasticities were reported:

ε_{LL} ranged from -0.580 to -0.661

ε_{KK} ranged from -3.183 to -4.275

ε_{LK} ranged from 2.115 to 2.830

ε_{KL} ranged from 0.612 to 0.711

ε_{II} ranged from 0.488 to 1.160

ε_{CC} ranged from 0.252 to 0.280

ε_{IC} ranged from -0.252 to -0.289

ε_{CI} ranged from -0.471 to -1.160

Simos (1981) in his study of the influence that investment in human capital has had on the technological development of the United

States during the twentieth centruy, reports the elasticity of substitution between capital and labor to range from 1.157 to 2.012.

Again Simos (1981) using a translog production function and data from the United States private sector over the period 1929-1972 investigated the theoretical debate whether real money balances are an original factor input or a catalyst with a role similar to technological innovation. Among his reported estimates was the elasticity of substitution between capital and labor which ranged from 1.351 to 2.504 and the following elasticities:

ε_{LL} which ranged from -0.454 to -0.892

ε_{KK} which ranged from -0.971 to -1.652

ε_{LK} which ranged from 0.475 to 0.992

ε_{KL} which ranged from 0.844 to 1.470.

The purpose of this chapter was threefold. One was to review the functional forms of empirical studies along with the explanatory variables used in the literature; the second purpose was to outline some of the usual objections that econometricians face when dealing with empirical studies and the third was to report various elasticities of substitution from different studies which pretty much support our argument of the neglect of human capital and R & D.

None of the studies attempted to find the effects of human capital and research and development on either the foreign or the domestic sector of the U.S. economy (using a sophisticated macro model), even though both factors are seen in the literature as major components affecting trade flows, which is precisely the contribution of this thesis.

In the next chapter we will discuss both human capital and research and development and we will also take a look at Eisner's data which we will use in our empirical analysis.

CHAPTER IV

HUMAN CAPITAL AND RESEARCH AND DEVELOPMENT

A Historical Look at Human Capital

> Although it is obvious that people acquire useful skills and knowledge, it is not obvious that these skills and knowledge are a form of capital, that this capital is in substantial part a product of deliberate investment, that it has grown in western societies at a much faster rate than conventional (nonhuman) capital, and that its growth may well be the most distinctive feature of the economic system. It has been widely observed that increases in national output have been large compared with the increases of demand, man-hours, and physical reproducible capital. Investment in human capital is probably the major explanation for this difference. (Theodore W. Schultz, 1961)

Human capital is defined as an individual's productive skills, talents and knowledge. It is not a new concept. Well known names in the history of economics such as Petty, Smith, Say, Senior, List, Von Thunen, Roscher, Bagehot, Ernst Engel, Sidgwick, Walras and Fisher had considered human beings or their acquired skills as capital. Even in ancient Greece Plato indicated the benefits of a trained citizenry: "What I assert is that every man who is going to be good at any pursuit must practice that special pursuit from infancy....Besides this, they ought to have elementary instruction in all necessary subjects, the carpenter for instance, being taught the use of rule and measure".

Despite its importance, for several years, economists were reluctant to consider human beings as an input within the "capital" framework. It was felt that an individual's acquired traits cannot be measured apart from the individual, which necessarily involves assigning a monetary value to human beings. But since in our society men do not own other men it is easy to see why economists have been reluctant to assign such values. A further reason why many present day economists have neglected undertaking a study of human capital is the difficulty of measuring human capital formation.

According to Schultz (1959), investment by human beings in human beings may seem without substance when compared with investments in physical plant and equipment. In addition, the productive role of outlays on human beings cannot easily be separated from current consumption characteristics of the outlays.

Finally, some economists have neglected human capital because of the conventional restriction on the concept of capital. Marshall (1930) argued that capital should include only those classes of wealth which are commonly bought and sold in the market place. This had the effect of excluding all investment that becomes an integral part of a human being.

In recent years the concept of human capital has gained increasing attention for the following reasons:

1) the cost of rearing and educating human beings is a real cost,

2) the product of their labor adds to the national wealth,

3) an expenditure on a human being which increases his productivity will, ceteris paribus, increase national wealth,

4) to demonstrate the power and prestige of a nation,

5) to determine the economic effects of education, health service investment and migration,

6) to propose tax schemes thought to be more equitable than existing ones,

7) to determine the total cost of war,

8) to awaken the public to the need for life and health conservation and the significance of the economic life of an individual to his family and country,

9) to aid courts and conpensation boards in making fair decisions in cases dealing with compensation for personal injury and death.

Several early writers attempted to estimate the economic value of human life. Basically, two methods were utilized to do this:

A) the cost of production, and

B) the capitalized-earnings procedures

although other methods appeared from time to time.

Sir William Petty in 1691 asserted that because the true wealth of the nation (Great Britain) is unknown, the existing method of taxation is unjust. He then attempted to ascertain the total wealth of the nation, by estimating the value of the stock of nonhuman wealth, which included such things as land, houses, shipping, cattle, money and miscellaneous goods in the country. These items however, according to Petty, did not include the total wealth of a nation because the value of labor, which is the father of wealth, is excluded.

> "Labour, is the Father and active principle of Wealth, as Lands are the Mother".
>
> (Sir William Petty, 1699)

Since neither of the pair should be omitted from national wealth estimates he attempted to estimate the value of the population. However to add the value of a stock of people to that of a stock of property requires a common unit of measure; and since non-human wealth is normally estimated in monetary terms, Petty chose to determine the money value of the population.

Petty's method was to estimate the total income of labor indirectly as the residue after deducting property income from national income. His method made no allowance for the cost of maintenance of works before capitalization. In spite of these limitations, his capitalized gross earning procedure (including living expenses) gives a close approximation for determining the capital value of a nation's population.

William Farr (1853) was the first to try to find the capital value of a man. His method of valuing human beings was to calculate the present value of a typical individual's net future earnings (that is his future earnings minus his personal living expenses), allowance being made for deaths in accordance with a life table. His calculations proceeded in the following manner.

From an English mortality table he found the number of persons who were alive from birth through every year of age of a century. If, for example, one thousand babies were born in a year X he found the number alive at ages X + 1, X + 2,...100. He then estimated the average annual earnings of the work force at the ages of X to X + 100. He assumed that the earnings were zero at very young ages and zero at very old ages. He also denoted these earnings was W_X. He also assumed P_X to be the number per thousand in the mortality table living through the yearx, thus $W_X P_X$ is the total earnings in the age group x. Then

$$\sum_{x=100}^{0} (W_X P_X) = W_0 \qquad \text{where} \quad X = 100, 99, 98, \ldots.0$$

is the aggregate earnings of the generation at birth W_0. If D_0 is a given number of births and Q_0 is the total number of individuals living at all ages when W_0/Q_0 is the annual percapita earnings of the entire generation of individuals and that W_0/D_0 equals the total per-capita earnings of individuals from birth to the end of their lives.

He also assumed that:

$$\sum_{x=100}^{0} (Y_x P_x) = Y_0$$

where Y_0 is the total cost of maintenance of the entire generation.

Y_x is maintenance cost at age x. Farr called the difference between earnings and maintenance cost "profits".

Thus $\frac{W_0 - Y_0}{Q_0}$ is the annual profit per capita and $\frac{W_0 - Y_0}{D_0}$ is the average aggregate gain over the life of each individual.

Farr's basic procedure is still used today by those interested in estimating the value of human beings. According to Dublin and Lotka (1946) "Farr's method remains to this day the fundamental standard on which any sound estimate of the value of a man...must be based...".

Theodor Wittstein and Ernst Engel in the eighteen hundreds and Dublin and Lotka (1930) were among the many early economists who attempted to quantify human capital. Later articles include the works by Schultz (1961), Kendrick (1976) and Robert Eisner (1981).

Schultz in his paper "Rise in the Capital Stock Represented by Education in the United States, 1900-1957" argues that the stock of human capital formed by investment in education must be dealt with in a measurable way because of its significance to economic growth. Measurement of the stock of education embodied in the population and labor force can be approximated by estimating the real cost of a year of schooling that includes income foregone as well as direct educational costs. Based upon Schultz's real cost measure, the stock of education embodied in the labor force increased twice as fast from 1900 to 1957 as did the stock of physical capital.

TABLE 4.1

Changes in the Stock of Education Measured by Costs and the Stock of Reproducible Nonhuman Wealth in the United States, 1900-1957

Year	Cost of Constant School Years Weighted by Composition (in 1956 prices in dollars)	Cost of Educational Stock Population 14 Years and Older (billions)	Cost of Educational Stock Labor Force 14 Years and Older (billions)	Stock of Reproducible Nonhuman Wealth (Billions)	Percent Col 4 is of Col 5
1	2	3	4	5	6
1900	$540	$114	$ 63	$ 282	22
1910	563	168	94	403	23
1920	586	227	127	526	24
1930	614	328	180	735	24
1940	650	465	248	756	33
1950	690	656	359	969	37
1957	723	848	535	1,270	42
1967 (1900 = 100)	134	744	849	450	191

Kendrick (1976) summarizes the sources and methods of capital formation in his book "The Formation and Stocks of Total Capital" by dividing current dollar gross investment series into two categories: tangible and intangible. The tangible investment is subdivided into its own two categories: tangible nonhuman investment and tangible human capital.

Kendrick assumed tangible human capital to consist of the portion of personal consumption expenditures allocated to rearing children to working age, that is, age fourteen, corresponding to the official United States labor force definition at the time the estimates were made (working age now being sixteen). All rearing costs were considered financed by the personal sector.

Estimates of average annual costs per child were by age groupings, based on surveys of family consumption patterns. Basically the

BEA (Bureau of Economic Analysis) personal consumption expenditures by category were used. Some items were left out, either because they were included elsewhere, such as expenditures on education. Population was divided into age groups, and the corresponding proportions of personal consumption expenditures were assigned to each group. For the estimates of personal consumption expenditures prior to 1929 Kendrick relied upon studies by Dewhurst, Kuznet and Gallman. Kendrick did not include the opportunity costs of parent's time devoted to rearing since, with the exception of schoolwork, in his study he had not undertaken imputations for unpaid work.

Kendrick also divided intangible investment into two categories as well. Intangible nonhuman investment (R&D) which will be discussed in the next section and intangible human investment which will be discussed here. Kendrick used education and training for intangible human investment, and he disaggregated it into five expenditure series:

A) Formal

B) Informal

C) Special

D) Employee training

E) Mobility.

For formal education costs for the personal sector he used BEA's personal consumption expenditures on private education and research, plus his own estimates of the net rental for this sector's educational plant and equipment. Students' expenditures on supplies and rentals of books and equipment were estimated as a percentage of imputed student compensation (opportunity costs). Government sector-financed formal education expenditures were obtained again by BEA and they were data on federal, state and local purchases for education and for veterans' education and training. Then gross public education structure and equipment rentals were added, with public educational capital derived from public construction figures and educational capital outlays estimated by the U.S. Department of Health, Education and Welfare (HEW).

Informal educational outlays by the government sector were estimated from BEA data as the total purchases for state and local libraries and recreation, the Library of Congress, and the Smithsonian Institution. Personal sector informal education consists of parts of consumer costs for radio, TV, records, books, periodicals, libraries, museums, etc. Business and institutional expenditures on public education were estimated as percentages of media advertising expenditures, based on Machlup's proportional allocations to intellectual and practical topics of media time and space.

Special (religious) education expenditures were derived from BEA totals in the religious activity expenditures personal sector. The allocation to religious education uses a ratio based on numbers of students in Sunday school times expenditures per pupil, with a portion of imputed interest on plant and equipment of religious organization added. Military education and training is estimated from government expenditure series.

Employee training was estimated separately for each sector. Several cost components were included. The cost of initial nonproductive time was estimated by converting nonproductive hours of employees and supervisors to standard hours. The occupational standard hours were weighted by occupational distributions of employment, and training time was derived as a proportion of annual hours worked, applied to annual compensation of new hires.

Training hours were based on personnel journal data, and occupational distribution of workers and average annual hours worked, were based on BLS (U.S. Bureau of Labor and Statistics) data. Government new hire rates were obtained from the U.S. Civil Service Commission, new hire rates for the private sector wer obtained from BLS and employee compensation rates were obtained from BEA. Along with the initial training time lost, additional time lost was considered as a percentage of the initial training time. Non-wage production costs were also taken into account. Formal training costs for the business sector were considered the number of trainers by type of training multiplied by the cost per employee. Statistics about the number of trainees by type of training were based on a U.S. Department of Labor survey, where the costs per employee statistics were based on a sample survey. The direct costs of formal training of federal government employees were estimated from Civil Service Commission data, where the state and local costs were considered as percentages of federal costs.

One half of the expenditures on medical, health and safety objectives were considered as investment, and the other half as maintenance that does not increase future productivity capacity. The personal sector's expenditures on health and medical care were based primarily on BEA estimates. The business sectors outlays for in-plant medical care were derived from HEW estimates and safety costs were based on Brookings Institution estimates of expenditures for safety programs. The government sector expenditures on health, sanitation and medical care consisted of the BEA estimates of total federal, state and local outlays on goods and services for health and hospitals, sanitation and veterans' hospital and medical care.

Finally the last category of mobility costs included job search and hiring, frictional unemployment, and migration costs. Job search costs were considered to be incurred by persons and were included in BEA's personal consumption expenditures. The business sector was also considered to have costs linked to job changes. A cost estimate per new hire was multiplied by the number of new hires derived from BLS data. Hiring costs were estimated along the same lines for the government sector, using government new hire rates. Using frictional unemployment rate of 3 percent of the labor force Kendrick considered the frictional unemployment costs of the personal sector to be the product of the frictionally unemployed and the average annual wages and salaries.

The last component of mobility costs, the migration costs, is the outlay linked to work-oriented travel and moving of household items. Kendrick used cost per mile estimates for each of these categories, applied to an estimate average mileage of work-oriented travel and moving for interstate and interstate migration. The number of migrants was based on Census Bureau data, adjusted for work-oriented migration. One half of the estimated moving and travel costs was charged to the personal sector and the other half to the business and government sectors in proportion to the number of persons employed by each. International migration was also considered, and estimates for this kind of government investment were used to evaluate the administrative costs of the Immigration and Naturalization Service.

After the estimation of the current dollar gross investment series, Kendrick used price indexes for deflating the various categories of investment to obtain real investment estimates on the basis of which the associated real stocks were estimated. The price deflators that he used for tangible human investment and intangible human investment were as follows: for human tangibles, rearing cost estimates were made directly in constant dollars, most of the categories were either available in constant dollars from BEA or deflators were constructed from the underlying BLS consumer price indexes. For human intangibles, personal sector formal education costs in constant dollars were estimated directly, by the same method as used for the current dollar estimates.

Associated costs were deflated by a composite index including transportation and supply costs. For constant dollar foregone earnings of students, average compensation was held at the 1958 level. Organized education and training outlays for the government sector were deflated by BEA's implicit price deflator for state and local purchases of goods and services. The same deflator was used for the government's sector informal education expenditures. Direct outlays on libraries and museums were deflated by a BEA deflator for religious and welfare outlays. The deflator for institutional and business public education costs was based on the cost of the various media per person reached. Religious education expenditures were deflated by the BEA deflator for religious and welfare activity. Military education costs were deflated by the BEA deflator for federal government purchases of goods and services. For training costs all compensation was converted into 1958 dollars by an index of average compensation adjusted for quality change. For the personal and business sectors, non-wage training costs were deflated using BEA's private fixed nonresidential investment price deflator, where for the government sector, non-wage training costs were deflated by the price deflator for government purchases of goods and services. For business sector training costs a composite index including the compensation deflator and the nonresidential private fixed investment deflator was used.

Turning to medical care costs, deflators for both personal and business sectors came from the American Medical Association. The BEA's price index for government purchases of goods and services was used to deflate government expenditures on health, sanitation and medical care.

In the area of mobility costs, job search costs in the personal sector were estimated by the implicit BEA price deflator corresponding to the personal consumption expenditures category used to get the costs. A composite index was applied for business sector hiring costs, based on BEA's average industry labor compensation adjusted for quality changes. The same index was used for frictional unemployment costs other than governmental. For government sector hiring costs, frictional unemployment costs and immigration costs were deflated by the price index of government purchases of goods and services. For moving costs the BLS transportation services price index was used and for travel costs a composite price index for costs of owner operated and other transportation charges was created.

Kendrick's next step was to develop capital stocks. In order to estimate the stock of tangible human capital, Kendrick added the average constant dollar rearing costs per child up to age fourteen and multiplied the cumulative cost by the number of persons in each cohort up to age ninety-five plus, thus accounting automatically for retirement. Summing the total real costs for all cohorts each year yielded the annual real gross tangible capital estimates.

Depreciation was caluclated by the declining-balance formula. Real gross and net human stocks were revalued to current prices by the implicit deflator for rearing costs.

For intangible human stocks with its three categories of education, general training and health expenditures, the stock accumulation and depreciation method was used. Kendrick first estimated the average annual real expenditures per head by single age groups up to age ninety-five, then accumulated per capita lifetime expenditures for each cohort for each year covered in the stock calculation, then multiplied this by the number of persons in each age group each year and summed across age groups. Basic population figures by single years of age were obtained from the Bureau of the Census.

For formal education, whether financed by the personal or government sector, constant dollar direct costs are broken down into elementary, secondary, higher and other education, and allocated to age groups within these educational levels. Informal education follows the same general procedure.

For the government sector military training costs are split between specific and general training. Specific training was added over the period of active and reserve duty where general training was spread over the total male population, with different ages receiving different weights. Employee training is divided into the same categories, with specific training costs included in stock for the average duration of job tenure, and general training costs allocated to age groups according to the estimated age distribution of employment, developed from labor force participation rates, with a deduction for unemployment.

While all of the medical and health investment financed by the personal and government sectors was allocated by age groups, business sector investment was only partly treated that way. One half of the investment outlays of the business sector were considered general investment and were accumulated as a stock, as in the case of other human categories. The other half was assumed to be specific investment yielding benefits only as long as an employee stays with the original firm.

Medical, health, and safety outlays had to be allocated among age groups as a basis for cumulative real per capita outlays from which gross stocks were calculated. As to mobility stocks, lives were considered different for each cost category and since these costs were estimated only for a fraction of persons in a group, life was estimated as the reciprocal of the percentage of people in the group. Changes in the yearly percentages were taken into account. Hiring cost lives was considered to be the reciprocal of new hiring rates; frictional unemployment cost lives was based on layoff rates; and moving and travel costs used the ratios of work-oriented migrants to the labor force.

Net capital stocks embodied in humans was derived by depreciating investment units from maturation ages through the age seventy-five. This was done for each investment unit and each age. The net stock for those people who die before age seventy-five were dropped out at the time of death.

Double declining balance switched to straight line depreciation was used, constructed in such a manner as to approximate depreciation factors published by the Internal Revenue Service. Depreciation reflecting the decline in the lifetime earning capacity of the human capital, of rearing and medical costs was started at age eighteen, education and training, at age twenty-eight.

Discounted future earnings curves were obtained from a U.S. Census Bureau study which assumed a 3 percent productivity increase and discount rates of 8 to 10 percent per year. This study indicated appreciation in value of individuals through the late twenties and a pattern of decline thereafter that seemed to be approximated by Kendrick's method of declining balance switched to straight line depreciation methods.

Robert Eisner (1978, 1980, 1981) also estimated human capital. A detailed investigation of his approach and his findings will be discussed in a later chapter of this thesis, since his data is employed in our empirical estimations.

Among other economists who have done theoretical and empirical research on human capital are: Becker(1964) and Mincer (1974), who have focused on general equilibrium analysis and the distribution of earnings in the context of human wealth; Friedman (1959) and Simos and Triantis (1982), who have utilized the concept of human wealth in their studies of consumption and the demand for money. Now we shall turn our attention to the other component of intangible capital, research and development.

From the above it can be seen that a number of economists have devoted a lot of time and effort in the study of human capital because of its importance on a theoritical basis and its importance for empirical analysis as well. Now we shall turn our attention to the other component of intangible capital, research and development, where the various definitions of R & D will be disucssed and various methods of estimating it will be outlined.

A Look at R & D

The National Science Foundation, the chief source of research and development estimates in recent years, uses the following definitions for the three major components of R&D:

1) Basic research "in which the primary aim of the investigator is a fuller knowledge or understanding of the subject rather than a practical application thereof".

2) Applied research which is "directed toward practical application of knowledge".

3) Development which is "systematic use of scientific knowledge directed toward the production of useful materials, devices, systems or methods, including design and development of prototypes and processes".

The pool of productive knowledge and know-how drawn on by producers is the capital resulting from R&D, which is measured at cost revalued to constant and current prices. Basic research results in accumulation of knowledge which continues to be drawn upon through the ages. But the applied research and productive knowledge and know-how developed through engineering has a finite life and is eventually supplanted by new applied research and related development.

Different researchers may classify the report data using somewhat different criteria. Nevertheless, the NSF categories are broadly useful for analytical purposes. Usually basic research as well as related development activities are counted as investment with the cost of the currently non-productive research being borne by that which has an economic payoff.

The real cost of R&D may be regarded as an input, resulting in an output of knowledge, some of which may be incorporated in designs, prototypes, etc. The R&D output itself becomes an input in the further investment process, where the ideas become practical products for both the producer and the consumer and these new methods, and systems expand the economy's capability of producing income.

Kendrick (1976) used the following method in estimating intangible nonhuman investment (R&D): measured R&D includes only the formal activities of the various sectors; informal inventive activities of isolated inventors are not included, being unimportant due to the spread and expansion of the industrial laboratories. He also uses the National Science Foundation estimates of R&D outlays for the period from 1953 onward, which are broken down into basic research and applied research and development.

Capital stock calculations for basic research are kept fairly simple. Annual constant dollar expenditures are added without regard to length of time needed for completion and without regard to obsolescence.

Even though R&D was basically neglected in the literature, sporadic studies can be found in researchers attempts to tie R&D and economic growth. Brown and Conrad (1967) employed research and development along with education as inputs to the CES production function, and using pooled time series and cross-sectional observations for a limited group of manufacturing industries in the United States for the 1950's, they tried to measure the influence of these variables on labor productivity. Their findings supported the notion that the inputs of education and research have a relatively longer impact on productivity in the durable group of goods rather than the nondurable group.

Griliches (1980) investigated the possibility of a link between R&D and the slow-down in productivity growth in manufacturing in the late seventies for the United States. His finding implied a longer effect of R&D on the slow-down with the effect coming not so much from the slow-down in R&D as from the collapse in the productivity of R&D.

Griliches himself was not convinced that the recent productivity slow-down could be blamed primarily on the R&D slow-down. One reason was the inability of economists to measure the spillover effects of R&D within and across industries. Another reason was the negative way that past and current R&D is valued in the national accounts when it is spent on social activities such as health and environment. His final reason was based on R&D's chancy and fickle process. Griliches argued that even though R&D may run into a dry spell, this does not imply that current expenditures may not have future returns or there are no major productivity gains already on the drawing board. Thus he blamed his lack of findings as reflecting data difficulties and the turmoil of the times.

Another study by Terleckyj (1980) reviews some of the past research and theoretical discussions on the many problems surrounding the concept and measurement of technological change and suggests an approach for constructing systematic data which would permit a better focus on technological change than the data now available. Among the things he states that the R&D data tell us are the following five propositions:

1) Technical change can be induced and that productivity increases can be induced by means of R&D based technological innovations.

2) Returns to R&D investment both social and private are appreciably higher than returns from fixed capital investment.

3) Research and Development act as capital when expenditures are treated as investments and an R&D capital stock is derived, more stable estimates of research and development effects are obtained than when R&D expenditures are used in such estimations and assumed to be instantaneously depreciated.

4) Government financed industrial R&D has a very different effect on private productivity growth and on technological change in industry than does privately financed R&D.

5) There is considerable uncertainty regarding the estimated magnitudes of economic relationships involving R&D. Specifically, the rates of return to research and development and the rate of depreciation of R&D capital have not been estimated directly.

Finally the most relevant study for our thesis was that of Keesing who used R&D as an explanatory variable in the estimation of import and export functions. R&D estimates will be obtained from Eisner, whose estimation and measurement techniques will be discussed in the following section.

Eisner's Data Description

The national accounts published by the Bureau of Economic Analysis (BEA), while they are considered as the best available measures of the progress of the economy as a whole, and of overwhelming value in economic analysis and the formation of policy, have been criticized as incomplete measures of consumption and capital accumulation. A number of economists, Richard and Nancy Ruggles (1970), Juster (1966), Nordhaus and Tobin (1972), Kendrick (1976), McElroy (1970), and Robert Eisner (1978, 1979, 1980), have contributed and suggested new methods for measures of these accounts.

Eisner's work is comprehensive. He utilizes the same framework as the one used by BEA with the following extensions and revisions:

1) Eisner defines consumption as the total of household purchases of nondurable consumption goods and services and all production of other consumption services whether by enterprises, government or households, whether sold in the market or not.

2) Measuring capital accumulation as the total of acquisitions of capital throughout the economy rather than in the business sector alone, and including intangibles as well as tangible investment.

3) Adding to income, product and capital accumulation the net reevaluations - capital gains set of increases in the general price level - on tangible capital.

4) Adding new imputations of consumption and capital accumulation where they are not affected in market transactions, most prominently in unpaid housework and education.

5) Treating expenses related to work and much of government output as intermediate while counting much of media services now purchased by business as consumption transferred to households.

Using the above extensions and revisions of the conventional BEA accounts, by borrowing from the work of the above mentioned economists, and with the help of Emily R. Simons, Paul J. Pieper, and Steven Bender of Northwestern University, Eisner built a set of extended accounts for business for the years 1946-76 for the U.S. economy.

In addition to a national income and product account, Eisner offers separate sector accounts for business, non-profit institutions, government enterprises, government and households. Debits in the national accounts are the sum of the individual sectors and net income originating in the rest of the world. Total gross product is subdivided into comsumption, gross domestic capital accumulation, net foreign investment and net transfer payments to foreigners.

Credits of the business sector display the Bureau of Economic Analysis (BEA) gross domestic product for business and various additions and subtractions relating to differences between BEA and Eisner's Total Incomes System of Accounts (TISA), in definitions of the business sector and of intermediate product. He places the net space rent of owner occupied nonfarm dwellings in households and the rental value of buildings owned and occupied by non-profit organizations in the non-profit sector. He also separates government enterprise product from business, adds subsidies to credits instead of subtracting them from debits or charges against gross national product and adds an estimate for "expense account items of consumption", which is put in debits as an additional imputation in labor income.

BEA treats business investment in research and development along with media support as intermediate products, where Eisner includes them in the final output. According to him, business investment in research and development is a component of intangible investment and an addition to business income, where media support involves an addition to consumption, in the form of entertainment and other services of television and radio broadcasting and newspapers and magazines included in business transfers on the debit side of the account.

BEA treats all goods and services purchased by government as final product where Eisner includes a major amount of government product, primarily military and policy services as intermediate in the output of other sectors. In fact, there is a rough correspondence between his estimates of intermediate product finished by government and the indirect taxes which may be thought of as paying for them. Thus, in each sector he nets intermediate product from government against indirect taxes. The output of police services, to give an example, is treated in the same way when it is provided by local governments and essentially paid for by taxes, as it would be if it were provided by a private protection agency. In both cases TISA counts the output only once, as it is produced, and not again as part of value added of the business of the other sector receiving it.

For nonprofit institutions, output plus intermediate product transmitted from government is allocated among consumption and capital accumulation. Government enterprise product and income is allocated among sales, transfers of consumption and investment, and accumulation in the form of net revaluations.

In allocating the credits of government income and product, Eisner first assigned output to government functions on the basis of compensation of employees and other changes against product. This output plus the associated value of intermediate product received by government from other sectors was then distributed among the other sectors and among consumption, capital accumulation and intermediate product.

In the household sector he included the capital services of durables and semi-durables, imputed interest and capital accumulation, and of inventories. He imputed the value of labor services in households on the basis of estimated time devoted to household labor and the mean compensation per employee for domestic service. He also imputed opportunity costs for students' time, borrowing from Kendrick's work. All of these imputed values were credited to investment in education and training. On the basis of time devoted, some of non-market household product as also allocated to investment in child rearing, adding this to Kendrick's market expenses for child rearing investment.

The total output of Eisner's study, allocated on the credit side of the account, in many cases, depends upon the imputations of income and other changes of the debit size thus deviating substantially from the conventional accounts.

Going at the national income and product, labor income consists of compensation of employees, which is the sum of corresponding items in individual sectors and the rest of the world and it is taken from BEA National Income and Product accounts, and several imputations, from all of which expenses related to work are subtracted. Expense account items of consumption, opportunity costs of students, and unpaid household work are all net additions to national income and product. The opportunity costs of the self employed which involve a reallocation, are netted out of net operating surplus.

Expenses related to work, which are subtracted to arrive at labor income, comprise transportation costs for getting to and from jobs.

Net imputed interest in the business sector does not affect total income because it is subtracted from corporate profits and private noncorporate income in arriving at the net operating surplus. Imputation of interest in the other sectors does represent however a net addition to income and product, except for the interest in equity in owner occupied nonfarm housing, which reduces rental income or such housing. Government and consumer interest paid are both included in TISA accounts, but they do not affect total income and product in the household and government sectors since the interest component in these sectors is gross imputed interest, against which they are charged.

Net revaluations presented in the accounts are restricted to tangible capital, that is, land, owner-occupied housing, all other structures and equipment, consumer durables and semidurables and inventories. Eisner departs from Kendrick, who counts child rearing as investment in tangible human capital. He classifies all human capital as well as investment in research and development as intangible capital.

It is also assumed that all research and development capital, wherever produced, is used in the business sector and that all human capital, wherever produced, is used in the household sector. The return to intangible capital is then assumed to be reflected in business and labor income. Intangible capital consumption is subtracted from income originating in the business and household sectors to arrive at what is called "net income originating" which is analagous to "income originating" in the other sectors.

Nonincome charges against gross national product include media support and uncompensated factor services. Media support are under business transfer payments and uncompensated factor services include the services of volunteers in nonprofit institutions and the difference between what might have had to be paid for military draftees in a free market and their actual remuneration by government. A similar imputation for under payment to jurors is included under the "other" category.

Capital consumption allowances for tangible business and government property were essentially taken from BEA. Capital consumption allowances for household durables were taken from unpublished tabulations of Helen Tice of the Flow of Funds section of the Federal Reserve Board. Investment in household semidurables includes expenditures for shoes and other footwear, clothing and other accessories, and semidurable home furnishings. In order to derive capital consumption on original costs a straight line depreciation with a three year life was applied. Total capital consumption was calculated by depreciating investment in constant dollars and then reflating to current or replacement cost by application of relevant price deflators. The difference between replacement costs depreciation and the original cost depreciation is the capital consumption allowances on revaluations.

Eisner in his treatment of intangible capital, used Kendrick's work. Specifically a series of gross investment in research and development, education and training, health and the market costs of child rearing were taken from Kendrick, who applied declining-balance depreciation to intangible capital. Because of the nature of discounting of future returns many assets lose little or no value, or even appreciate in the early years of their lives, Kendrick applied a variety of methods to overcome this problem, including delaying the start of depreciation of human capital and on applied research and development, and infinite lives for investment in basic research and development.

Eisner followed Kendrick on basic research and development but used underlaid twenty year straight-line depreciation for the applied portion. For human capital, he applied uniform straight-line depreciation with a fifty year life. The implicit price deflator used for intangible capital investment is Kendrick's ratio of current dollar to constant dollar aggregates of such investment.

Stocks of land, structures and equipment come from a number of sources such as BEA, John Musgrave, Helen Tice and Grace Milgram.

BEA was also used as a source for unpublished data on government enterprise capital stocks, Eisner then in turn estimated imputed interest, capital consumption and net revaluations on these stocks. BEA's practice of excluding capital stocks from government enterprise land, plant and equipment except inventories as if they were owned directly by government was also followed by Eisner.

The credit side of the national income and product accounts allocates total output among consumption, domestic capital accumulation, net foreign investment and transfers to foreigners. Net foreign investment along with transfers to foreigners were taken directly from the BEA accounts. Consumption and domestic capital accumulation are the sum of consumption and investment expenditures available from the BEA, with some reallocations, plus the additional imputations of consumption services and capital produced in households and government. Total investment in education and training, research and development, health, and sectoral allocations where available, were taken from Kendrick, and like Kendrick, Eisner counts half of health services output as consumption and half as investment.

Government intermediate product transferred to business and government enterprises is presumed to be included in the value of consumption and investment expenditures for goods produced and sold by those sectors. For government enterprises he adds an imputation of consumption and investment equal to the sum of negative surpluses and his imputed interest, which may be taken as subsidies of government enterprise output.

The contribution of households to consumption and capital accumulation was taken as the sum of household output and the intermediate product from government that went into that output. In practice all of the charges against gross household product were allocated to consumption or accumulation except a small portion of indirect taxes not related to owner occupied housing.

In imputing the production of consumption and capital in the nonprofit sector he has again added intermediate product transferred by government. So in order to calculate total consumption for the TISA accounts he has then subtracted the nonprofit compensation of employees.

Eisner in his papers admits to some statistical discrepancy in addition to that already recorded by the BEA, between total changes and credits of gross national product.

In conclusion, we have taken a historical look at Human Capital and Research and Development and the importance put to them by various economists. We have also taken a look at the description of Fisher's data and now we are ready to describe in CHAPTER V our model along with the functional form and estimation technique of the translog profit function.

CHAPTER V

THE MODEL

In this chapter a system of import and export functions consistent with some underlying behavioral assumption will be derived in an attempt to avoid some shortcomings of the traditional approach as presented in CHAPTER III. Following Kohli (1978), we assume that import and export decisions are made by profit-maximizing firms which operate under perfect competition in all commodity and factor markets. Firms chose their optimum output mix and their input requirements subject to a vector of output and input prices and the economy's fixed endowment of domestic primary factors. These domestic factors are assumed to be mobile between firms, and their rental prices are determined by their marginal product. We assume that the technology employs J non-negative domestic primary inputs (fixed in the short-run) and I variable quantities (outputs or inputs). Outputs are written as positive variable quantities and inputs as negative variable quantities. The production possibility set, T, is defined as the set of all feasible input and output combinations. Furthermore, it is assumed that the aggregate technology satisfies the following conditions: constant returns-to-scale, free disposal, non-increasing marginal rates of substitution and transformation and, for a given endowment of fixed inputs, the output of variable quantities is finite. Under these conditions the competitive equilibrium can also be characterized at any point in time as the solution to the problem of maximizing GNP subject to the technology, the endowment of domestic resources, and a vector of positive output and input prices.

The technology can thus be represented by a restricted profit function defined as follows (Diewert 1973, Samuelson, 1958):

$$\Pi\ (p;x) = \max\ [p'y;\ (x_j y)\ \varepsilon\ T,\ \ p\ \ 0]$$

Π is a real extended function and is well-defined for all vectors of positive prices p,

Y is a vector of outputs,

x is a vector of domestic factor endowments, and imports

p is an output price vector.

Under the assumptions made on T, the restricted profit function is linearly homogeneous, monotonically increasing, and concave in fixed input quantities; it is also linearly homogeneous and convex in the prices of the variable quantities and monotonically decreasing or increasing in these prices depending on whether the corresponding quantity is an input or an output (Diewert, 1973).

If the restricted profit function is differentiable at p* and x* with respect to the components of p, the derived demand and supply equations for the variable quantities can be obtained by differentiation, a result known as Hotelling's (1932) lemma:

$$\partial\Pi\ (p^*,x^*) \,/\, \partial p_i = y_i\ (p^*,x^*) \qquad i = 1.....I$$

If (p;x) is differentiable at p* and x* with respect to the components of x, then we get:

$$\partial\Pi\ (p^*,x^*) \,/\, \partial x_j = w_j\ (p^*,x^*) \qquad j = 1\ ....J$$

where w is the price vector of fixed inputs. Using this variable profit function the system of demand and supply equations can be derived and estimated jointly in determining the possibilities of substitution implied by the technology. Foley and Sidrauski (1970) employed a very similar approach in their treatment of the production side of the economy (for their investment goods supply function).

Kohli (1978) contributed further to economic theory by adapting the translog functional form for the variable profit function in estimating technology in a multi-input multi-output model for the Canadian economy. In estimating the demand and supply functions Kohli considered consumption, investment and exports as positive and capital and labor as the quantities of inputs (fixed in the short run).

This thesis follows the above underlying theory and assumptions, but departs from Kohli's model by introducing two additional variables as inputs: human capital and research and development. Thus Kohli's model becomes a special case of the mode used here.

The following assumptions were imposed:

A) It is assumed that import and export decisions are made by profit maximizing firms.

B) These profit maximizing firms operate under perfect competition both in the commodity markets and in the factor markets.

C) Imports and exports are considered respectively as inputs to, and outputs of, the technology.

D) The competitive equilibrium is the solution of maximizing GNP at any period of time, subject to the technology, the factor endowments and a vector of output prices. Thus the behavioral assumption underlying the model can be written as:

$$\max p'y \text{ subject to } (x;y) \in T.$$

where:

T is the production possibility set,
y is a vector of outputs,
x is a vector of domestic endowments and imports,
p is an output price vector.

E) The real return for inputs are assumed to be their marginal productivity.

F) It is assumed that the United States, in relative terms, is a small open economy as noted in the following table.

TABLE 5.1

FOREIGN TRADE IN GOODS AND SERVICES AS A PERCENTAGE OF GNP, 19 OECD COUNTRIES, 1929, 1938, and 1976-78 [1]

COUNTRY	1929	1938	Average 1976-78
Australia [2]	19.3	18.3	17.1
Austria	NA	17.6 [3]	35.6
Belgium	NA	28.2	56.3
Canada	29.0	24.3	26.4
Denmark	NA	26.2	33.5
France	NA	13.1	21.9
Germany	NA	16.5 [4]	26.3
Greece	NA	17.8	21.2
Iceland	NA	46.8	42.1
Ireland	NA	25.5	57.7
Italy	NA	7.6	26.8
Japan	19.4	19.7	12.3
Netherlands	NA	28.1	49.0
Norway	33.6	29.2 [5]	48.6
Portugal	NA	13.0	26.6
Sweden	NA	20.1 [6]	30.2
Switzerland	NA	17.9	35.9
United Kingdom	NA	16.9	32.2
United States	6.3	4.3	10.1
All Countries [7]	NA	20.6	32.1

[1] Percentages are based on data in current prices. Trade is defined as one-half of the sum of exports and imports of goods and services, including merchandise, non-monetary gold, freight, other transportation, travel, investment income in gross amounts received and paid, and other current public and private services.

[2] Fiscal years ending June 30.

[3] 1937

[4] 1936

[5] 1939.

[6] Based on GNP for fiscal year.

[7] Unweighted averages of percentages for all countries.

NA-Not Available.

Source: Alter Salant 1981.

Functional Form and Estimation Technique

The translog functional form will be used to estimate the variable profit function. Some economists have considered it as a production function and Christensen, Jorgenson and Lau (1971) have suggeseted it as a second order approximation to any twice continuously differentiable production or cost function. Because of its quadratic character no a priori restrictions on the value of the various elasticities of transformation are imposed.

A second order approximation at the expansion point of the variable profit function $\Pi = \Pi(p;x)$ can be obtained by the logarithmic Taylor series expansion:

$$\begin{aligned}\ln\Pi &= \ln \Pi(o) + \sum_j \partial \ln\Pi/\partial\ln P_i + \sum_j \partial \ln\Pi/\partial\ln X_j \quad \ln X_j \\ &+ 1/2 \sum_{ih}\sum (\partial^2\ln\Pi/\partial \ln P_i \partial\ln P_h) \ln P_i \ln P_h \\ &+ 1/2 \sum_{jk}\sum (\partial^2\ln\Pi/\partial\ln X_j \quad \partial\ln X_k) \ln X_j \ln X_k \\ &+ \sum_{ij}\sum (\partial^2\ln\Pi/\partial\ln P_i \quad \partial\ln X_j) \ln P_i \ln X_j\end{aligned}$$

which can be written in a more convenient form as shown by Christensen, Jorgenson and Lau (1971):

$$\begin{aligned}\ln\Pi &= \alpha_o + \Sigma\alpha_i \ln P_i + \Sigma\beta_j \ln X_j + 1/2\Sigma\Sigma\gamma_{ih} \ln P_i \ln P_h \\ &+ 1/2 \Sigma\Sigma\phi_{jk} \ln X_j \ln X_k \\ &+ \Sigma\Sigma\delta_{ij} \ln P_i \ln X_j\end{aligned}$$

where

$\gamma_{ih} = \gamma_{hi}$ and $\phi_{jk} = \phi_{kj}$

i,h = ouput
j,k = input

If the translog function is considered as a functional form per se, the equalities $\gamma_{ih} = \gamma_{hi}$ and $\phi_{jk} = \phi_{kj}$ are not necessarily satisfied, but may be imposed without any loss of generality.

By definition the variable profit function is linear homogeneous in prices; in the translog case, we must therefore have (see Diewert 1974)

(i) $\sum_i a_i = 1$

(ii) $\sum_i \gamma_{ih} = 0$

(iii) $\sum_i \delta_{ij} = 0$

In addition, if the variable profit function is also homogeneous of degree one in fixed quantities, then we must have:

(i) $\sum_j \beta_j = 1$

(ii) $\sum_j \phi_{jk} = 0$

(iii) $\sum_j \delta_{ij} = 0$

By using Hotelling's lemma (1932) we have the following:

$$S_i = P_i Y_i / \Pi = \partial \ln \Pi / \partial \ln P_i = \alpha_i + \sum_h \gamma_{ih} \ln P_h + \sum_j \delta_{ij} \ln X_j$$

where, because of the linear homgeneity of prices,

$$\sum_i S_i = 1$$

Where S_i is the share equation of output i.

The share equation of input j can be derived similarly as:

$$V_j = W_j X_j / \Pi = \partial \ln \Pi / \partial \ln X_j = \beta_j + \sum_i \delta_{ij} \ln P_i + \sum_k \phi_{jk} \ln X_k$$

and because of linear homogeneity in fixed quantities, $\sum_j V_j = 1$

The elasticities of transformation, θ, complementarity, σ and intensity, Ψ, for the translog functional form can be estimated using the following formulas:

$$\theta_{ih} = (\gamma_{ih} + S_i S_h)/(S_i S_h) \qquad i \neq h$$

$$\theta_{ii} = (\gamma_{ii} + S_i^2 - S_i) / S_i^2$$

$$\sigma_{jk} = (\phi_{jk} + V_j V_k) / (V_j V_k) \qquad j \neq k$$

$$\sigma_{kk} = (\phi_{kk} + V_k^2 - V_k) / V_k^2$$

and

$$\Psi_{ij} = (\delta_{ij} + S_i V_j) / (S_i V_j)$$

This model should improve the analysis relative to the traditional approach in the following five ways.

1) A coherent and complete system of output supply (including import demand) equations will be derived and estimated simultaneously.

2) By using a very flexible functional form, no a priori assumption on separability or on the degree of complimentarity or substitutability between goods or factors will have to be made.

3) No ad hoc assumption will have to be made in the choice of particular variables and no supplementary explanatory variable will have to be introduced without theoretical justification.

4) This framework is suited when considering the effects of changes in various government policy parameters.

5) By introducing human capital and R & D as productive factors our model brings together all the major theories of international trade.

This analysis is still, however, subject to at least two of Orcutt's limitations:

1) All output prices will be taken as exogenous. To make them endogenous would require a general equilibrium model which is beyond the scope of this thesis.

2) The aggregation problem is still present. Current econometric techniques do not allow us to disaggregate beyond ten to fifteen goods.

Additional Theoretical Concepts

In order to describe the estimated technology, familiar concepts as elasticities of transformation or price elasticities will be used.

For a production function F, the Allen (1938) partial elasticity of substitution between X_i and X_j is defined as:

$$\sigma_{ij} = (\Sigma F_h X_h \;/\; (X_i X_j) \;\; (|\bar{F}_{ij}| \;/\; \bar{F} \,)$$

Where,

$$F_h = \partial F / \partial X_h$$

$\bar{F}$ is the bordered Hessian of F

$\bar{F}_{ij}$ is the cofactor of $\partial^2 F / \partial X_i \partial X_j$ in $|\bar{F}|$

If the production function is homothetic, Uzawa (1962) has shown that the elasticity of substitution can also be written in terms of the unit cost function C(w) as:

$$\sigma_{ij} = C\, C_{ij} / C_i C_j$$

Where,

$C_i = \partial C / \partial W_i$ and

$C_{ij} = \partial^2 C / \partial W_i W_j$

Diewert (1974) extended this concept to the class of variable profit functions be defining,

(i) an elasticity of transformation between variable quantities i and h:

$$\theta_{ih} = (\partial^2 \Pi / \partial P_i \partial P_h) \;/\; (\partial \Pi / \partial P_i) \;\; (\partial \Pi / \partial P_h) \qquad i,h = 1,\ldots.I$$

(ii) an elasticity of complementarity between fixed quantities j and k:

$$\sigma_{jk} = (\partial^2 \Pi / \partial P_k \partial X_j) \;/\; (\partial \Pi / \partial P_k)\; (\partial \Pi / \partial X_j) \qquad j,k = 1,\ldots J$$

(iii) an elasticity of intensity between variable quantity i and fixed quantity j:

$$\Psi_{ij} = (\partial^2 \Pi / \partial P_i \partial X_j) \;/\; (\partial \Pi / \partial P_i)\; (\partial \Pi / \partial X_j) \qquad i = 1,\ldots I \quad j = 1,\ldots J$$

The partial price elasticities of the variable quantities can be defined as:

$$\varepsilon_{ih} = (Y_i / P_h)\; (P_h / Y_i) \qquad i,h = 1,\ldots I$$

The inverse partial price elasticities for fixed inputs are:

$$\eta_{jk} = (\partial W_j / \partial X_k)\; (X_k / W_j) \qquad j,k = 1,\ldots J$$

$$\xi_{ik} = (\partial Y_i / \partial X_k)\; (X_k / Y_j) \qquad i = 1,\ldots I \quad k = 1,\ldots I$$

$$\rho_{jh} = (W_j / P_h)\; (P_h / W_j) \qquad h = 1,\ldots I \quad j = 1,\ldots I$$

Finally, the following relation holds true:

$$\theta_{ih} = \varepsilon_{ih} / S_h = \varepsilon_{hi} / S_i$$

This is proven easily by the following transformation:

$$\theta_{ih} = ((\partial Y_i / \partial P_h)\; (P_h / Y_i)) \;/\; (Y_h \; P_h / \Pi)$$

$$=((\partial Y_h / \partial P_i)(P_i / Y_h)) \Big/ (Y_i P_i / \Pi)$$

$$= \varepsilon_{ih} / S_h$$

$$= \varepsilon_{hi} / S_i$$

Similarly:

$$\sigma_{jk} = \eta_{jk} / V_k = \eta_{jk} / V_j$$

and

$$\Psi_{ik} = \xi_{ik} / V_k = \rho_{ki} / S_i$$

Where $S_i = P_i Y_i / \Pi$ is variable output i's share of national product and $V_j = X_j W_j / \Pi$ is fixed input j's share of national product.

Stochastic Specification and Estimation Technique

All estimations have been made by computing maximum likelihood using an algorith which allows for the model to be nonlinear in the parameters Berndt, Hall, Hall and Hausman (1974). The logarithm of the likelihood function is maximized with respect to all parameters in the system and with respect to the covariance matrix Ω .

Assuming a joint normal distribution of the disturbances, we will use the likelihood ratio test to find the best estimated model. The likelihood ratio is the ratio of the likelihood maximized under the null hypothesis to the likelihood maximized under the alternative hypothesis. By taking minus twice the logarithm of this ratio we can assume it to be asymptomatically distributed and the number of degrees of freedom are equal to the number of constraints required by the null hypothesis.

We assume that the translog profit function, the translog GNP function in our case, is an exact representation of the actual technology and that any deviation of the shares S's and V's from the profit maximizing shares are random. Thus we can specify a vector of random disturbances;

$$e'_t = (e_{1t}, \ldots e_{(I+J)t}) \quad \text{such that}$$

$$\sum_{i=1}^{I} e_{it} = 0 \text{ and}$$

$$\sum_{j=I+1}^{I+J} e_{jt} = 0$$

The e's are assumed to be identically distributed normal random vectors with mean zero and covariance matrix Ω. The disturbances are thus allowed to be contemporaneously correlated since the covariance between the error term of a variable quantity share equation and the error term of a fixed quantity share equation may be non zero, but they are specified as temporally independent. Since both the S and the V shares sum up to one, Ω will be singular and two equations, one of the demand and one of the supply side may be dropped. The estimation, however, does not depend on which two equations are dropped. More details concerning the estimation technique will be presented in CHAPTER VI.

Elasticity Matrices to be Estimated

1) The substitution matrix $= \begin{bmatrix} \Sigma pp & \Sigma px \\ \Sigma xp & \Sigma xx \end{bmatrix}$

a) Σpp is the matrix of the partial elasticities of transformation between quantities i and h:

$$\theta_{ih} = \Pi \ (\partial^2 \Pi \ / \ \partial P_j \partial P_h) \ / \ (\partial \Pi / \partial P_i) \ (\partial \Pi / \partial P_h)$$

whose normalization is $\partial Y_i / \partial P_h$

θ_{ih} shows the relations between the price of h output and the quantity of i output. If $\theta_{ih} > 0$ outputs i and h are complements in production, where if $\theta_{ih} < 0$ outputs i and h are substitute in production.

b) Σxx is the matrix of the partial inverse elasticities of substitution between domestic inputs j and k:

$$\sigma_{jk} = \Pi \ (\partial^2 \Pi \ / \ \partial P_k \partial X_j) \ / \ (\partial \Pi / \partial P_k) \ (\partial \Pi / \partial X_j)$$

whose normalization is $\partial X_j / \partial X_k$

σ_{jk} shows the relations between the quantity of K input and the quantity of j input. If $\sigma_{jk} > 0$ inputs K and j are substitutes where if $\sigma_{jk} \leqslant 0$ inputs k and j are complements.

c) $\Sigma xp = \Sigma px$ is the matrix of the partial elasticities of intensity whose i and j element is

$$\Psi_{ij} = \Pi (\partial^2 \Pi / \partial P_i \, \partial X_j) \ / \ (\partial \Pi / \partial P_i) \ (\partial \Pi / \partial X_j)$$

whose normalization is $\partial X_i / \partial P_j$

Ψij shows the relationship between the price of the i output and the quantity of the j output. Comparing any two elasticities of intensity we can define if an output is say X_1 or X_2 intensive.

2) The matrix of price elasticities and input elasticities

$$E = \begin{bmatrix} Epp & Epx \\ Exp & Exx \end{bmatrix} = \begin{bmatrix} \begin{bmatrix}\text{output own/cross} \\ \text{price elasticities}\end{bmatrix} & \begin{bmatrix}\text{output-input} \\ \text{cross price elasticities}\end{bmatrix} \\ \begin{bmatrix}\text{input-output} \\ \text{cross price elas-} \\ \text{ticities}\end{bmatrix} & \begin{bmatrix}\text{input inverse own/cross} \\ \text{price elasticities}\end{bmatrix} \end{bmatrix}$$

a) Epp is a matrix of the partial price elasticities of the output supply and import demand functions, whose i and h element is

$$\varepsilon_{ih} = (\partial Y_i \;/\partial\; P_h) \;\; (P_h \;/\; Y_i)$$

which can also be written as

$$\varepsilon_{ih} = \partial \ln Y_i \;/\; \partial \ln P_h$$

ε_{ih} measures the percent change in the quantity of output i due to a percent change in the price of output j for i = j and $i \neq j$.

b) Exx is a matrix of the inverse price elasticities of the demand for domestic inputs, whose j and k element is

$$n_{jk} = (\partial W_j)(\partial X_k) \;/\; (X_k)\;(W_j)$$

which can also be written as

$$n_{jk} = \partial \ln W_j / \partial \ln X_k$$

n_{jk} measures the percent change in the price of input j due to a percent change in the quantity of the input K.

c) Epx is a matrix of the partial cross quantity elasticities whose i and k element is

$$\xi_{ik} = (\partial Y_i \;/\; \partial X_k) \;/\; (X_k) \;\; (Y_i)$$

which can also be written as

$$\xi_{ik} = \partial \ln Y_i \;\;/\; \partial \ln X_k$$

ξ_{ik} measures the percent change in the quantity of output i due to a percent change in the quantity of input k

d) Exp is a matrix of the partial cross price elasticities whose j and h element is

$$P_{jh} = (\partial W_j / \partial P_h) \Big/ (P_h / W_j)$$

which can also be written as

$$P_{jh} = \partial \ln W_j / \partial \ln P_h$$

Pjh measures the percent change in the price of input j due to a percent change in the price of output h.

The Empirical Model

$$Y = \begin{bmatrix} Y_1 \\ Y_2 \\ Y_3 \\ Y_4 \end{bmatrix} \quad \text{quantities of outputs (endogenous)}$$

where:

Y_1 = consumption goods

Y_2 = investment goods

Y_3 = exports

Y_4 = imports (this is a negative output)

$$P = \begin{bmatrix} P_1 \\ P_2 \\ P_3 \\ P_4 \end{bmatrix} \qquad P' = [P_1\ P_2\ P_3\ P_4] \quad \text{output prices (exogenous)}$$

where:

P_1 = consumption price index

P_2 = investment price index

P_3 = export price index

P_4 = import price index

where:

$$x = \begin{bmatrix} X_1 \\ X_2 \\ X_3 \\ X_4 \end{bmatrix} \quad \text{Quantities of inputs (exogenous)}$$

X_1 = labor

X_2 = human capital

X_3 = R & D

X_4 = capital

$$W = \begin{bmatrix} W_1 \\ W_2 \\ W_3 \\ W_4 \end{bmatrix} \quad \text{Prices of inputs (endogenous)}$$

where

W_1 = price of labor

W_2 = price of human capital

W_3 = price of R & D

W_4 = price of capital

$$(P;X) = \max P'Y: \ (Y;X)\ T$$

We can derive the demand equation for imports and the supply equations for Consumption, Investment and Exports from

$$\partial\Pi / \partial P_i = Y_i\ (P^*,X^*) \quad i = C,I,X,M$$

The input demand equations for Capital, Labor, R & D, and Human Capital can be derived from:

$$\partial\Pi / \partial X_j = W_j\ (P^*,X^*)$$

$$\ln \Pi = \alpha_0 + \Sigma\alpha_i \ln P_i + 1/2\, \Sigma\Sigma\, \gamma_{ih} \ln P_i \ln P_h$$
$$+ \Sigma\beta_j \ln X_j + 1/2\Sigma\Sigma\phi_{jk} \ln X_j \ln X_k$$
$$+ \Sigma\Sigma\alpha_{ij} \ln P_i \ln X_j$$

where

$i,h = 1,2,3,4$ (output)

$j,k = 1,2,3,4$ (input)

The share equations of consumption, investment, exports and imports are:

1) $\partial \ln \Pi/\partial \ln P_1 = \alpha_1 + \gamma_{11} \ln P_1 + \gamma_{12} \ln P_2 + \gamma_{13} \ln P_3 + \gamma_{14} \ln P_4 + \delta_{11} \ln X_1 + \delta_{12} \ln X_2$

$+ \delta_{13} \ln X_3 + \delta_{14} \ln X_4$

2) $\partial \ln \Pi/\partial \ln P_2 = \alpha_2 + \gamma_{21} \ln P_1 + \gamma_{22} \ln P_2 + \gamma_{23} \ln P_3 + \gamma_{24} \ln P_4 + \delta_{21} \ln X_1 + \delta_{22} \ln X_2$

$+ \delta_{23} \ln X_3 + \delta_{24} \ln X_4$

3) $\partial \ln \Pi/\partial \ln P_3 = \alpha_3 + \gamma_{31} \ln P_1 + \gamma_{32} \ln P_2 + \gamma_{33} \ln P_3 + \gamma_{34} \ln P_4 + \delta_{31} \ln X_1 + \delta_{32} \ln X_2$

$+ \delta_{33} \ln X_3 + \delta_{34} \ln X_4$

4) $\partial \ln \Pi/\partial \ln P_4 = \alpha_4 + \gamma_{41} \ln P_1 + \gamma_{42} \ln P_2 + \gamma_{43} \ln P_3 + \gamma_{44} \ln P_4 + \delta_{41} \ln X_1 + \delta_{42} \ln X_2$

$+ \delta_{43} \ln X_3 + \delta_{44} \ln X_4$

$$\partial \ln \Pi/\partial \ln P_1 + \partial \ln \Pi/\partial \ln P_2 + \partial \ln \Pi/\partial \ln P_3 + \partial \ln \Pi/\partial \ln P_4 = 1,$$

$$\Sigma\alpha_i = 1,\ \Sigma\gamma_{ih} = 0,\ \Sigma_1 \delta_{ij} = 0$$

The share equations of labor, human capital, R & D and capital are:

1) $\partial \ln \Pi/\partial \ln X_1 = \beta_1 + \phi_{11} \ln X_1 + \phi_{12} \ln X_2 + \phi \ln X_3 + \phi_{14} \ln X_4$

$+ \delta_{11} \ln P_1 + \delta_{12} \ln P_2 + \delta_{13} \ln P_3 + \delta_{14} \ln P_4$

2) $\partial \ln \Pi / \partial \ln X_2 = \beta_2 + \phi_{21} \ln X_1 + \phi_{22} \ln X_2 + \phi_{23} \ln X_3 + \phi_{24} \ln X_4$

$+ \delta_{21} \ln P_1 + \delta_{22} \ln P_2 + \delta_{23} \ln P_3 + \delta_{24} \ln P_4$

3) $\partial \ln \Pi / \partial \ln X_3 = \beta_3 + \phi_{31} \ln X_1 + \phi_{32} \ln X_2 + \phi_{33} \ln X_3 + \phi_{34} \ln X_4$

$+ \delta_{31} \ln P_1 + \delta_{32} \ln P_2 + \delta_{33} \ln P_3 + \delta_{34} \ln P_4$

4) $\partial \ln / \partial \ln X_4 = \beta_4 + \phi_{41} \ln X_1 + \phi_{42} \ln X_2 + \phi_{43} \ln X_3 + \phi_{44} \ln X_4$

$+ \delta_{41} \ln P_1 + \delta_{42} \ln P_2 + \delta_{43} \ln P_3 + \delta_{44} \ln P_4$

$$\partial \ln \Pi / \partial \ln X_1 + \partial \ln \Pi / \partial \ln X_2 + \partial \ln \Pi / \partial \ln X_3 + \partial \ln \Pi / \partial \ln X_4 = 1$$

$$\Sigma \beta_j = 1, \quad \Sigma \phi_{jk} = 0, \quad \Sigma \delta_{ij} = 0$$

In this chapter we have developed a system of import and export functions in such a way as to avoid some of the shortcomings of the traditional approach, we have indicated that the translog profit function is to be used to estimate the variable profit function we have presented the elasticity matrices to be estimated and we have expressed the empirical model in terms of share equations showing the coefficients to be estimated. In the next chapter we are to present the models estimated along with the estimates for all of the coefficients, and the standard errors of these coefficients for further statistical analysis. The highlight of the chapter is the various elasticities estimated showing the different relationships between the various inputs and outputs to human capital and research and development.

CHAPTER VI

COEFFICIENT AND ELASTICITY ESTIMATES

The theoretical model developed in the previous chapter was used to estimate the structure of the United States technology over the period 1948-76 using yearly data. The factor inputs employed were: labor (L), human capital (H), research and development (R&D), and capital (K). The outputs: consumption (C), investment (I), exports (X), and imports (M). Imports were considered as a negative output, rather than an input, for estimation purposes.

Two models were estimated. One model without technology and a second model using the same inputs and outputs as model one but also allowing for technological change to take place over time.

Using the likelihood ratio test we were able to determine that the technology coefficients were not statistically equal to zero indicating that the second model was a more complete model, thus we proceeded to present the coefficients and the elasticity estimates of model 2 evaluated at the means. The actual likelihood test and the year to year elasticities and other estimates appear in detail in the appendix.

Model 1 Without Technology

Taking partial derivatives the share equations of consumption, investment, exports, imports, labor, human capital, R & D and capital are:

$$P_C Y_C/\Pi = \alpha_C + \gamma_{CC} \ln P_C + \gamma_{CI} \ln P_I + \gamma_{CX} \ln P_X + \gamma_{CM} \ln P_M$$

$$+ \delta_{CL} \ln L + \delta_{CH} \ln H + \delta_{CRD} \ln RD + \delta_{CK} \ln K$$

$$P_I Y_I/\Pi = \alpha_I + \gamma_{IC} \ln P_C + \gamma_{II} \ln P_I + \gamma_{IX} \ln P_X + \gamma_{IM} \ln P_M$$

$$+ \delta_{IL} \ln L + \delta_{IH} \ln H + \delta_{IRD} \ln RD + \delta_{IK} \ln K$$

$$P_X Y_X/\Pi = a_X + \gamma_{XC} \ln P_C + \gamma_{XI} \ln P_I + \gamma_{XX} \ln P_X + \gamma_{XM} \ln P_M$$

$$+ \delta_{XL} \ln L + \delta_{XH} \ln H + \delta_{XRD} \ln RD + \delta_{XK} \ln K$$

$$P_M Y_M/\Pi = a_M + \gamma_{MC} \ln P_C + \gamma_{MI} \ln P + \gamma_{MX} \ln P_X + \gamma_{MM} \ln P_M$$

$$+ \delta_{ML} \ln L + \delta_{MH} \ln H + \delta_{MRD} \ln RD + \delta_{MK} \ln K$$

$$W_L X_L/\Pi = \beta_L + \phi_{LL} \ln L + \phi_{LH} \ln H + \phi_{LRD} \ln RD + \phi_{LK} \ln K$$

$$+ \delta_{CL} \ln P_C + \delta_{CH} \ln P_I + \delta_{CRD} \ln P_X + \delta_{CK} \ln P_M$$

$$W_H X_H/\Pi = \beta_H + \phi_{HL} \ln L + \phi_{HH} \ln H + \phi_{HRD} \ln RD + \phi_{HK} \ln K$$

$$+ \delta_{IL} \ln P_C + \delta_{IH} \ln P_I + \delta_{IRD} \ln P_X + \delta_{IK} \ln P_M$$

$$W_{RD}X_{RD}/\Pi = \beta_{RD} + \phi_{RDL}\ \ln L + \phi_{RDH}\ \ln H + \phi_{RDRD}\ \ln RD + \phi_{RDK}\ \ln K$$

$$+ \delta_{XL}\ \ln P_C + \delta_{XH}\ \ln P_I + \delta_{XRD}\ \ln P_X + \delta_{XK}\ \ln P_M$$

$$W_K X_K/\Pi = \beta_K + \phi_{KL}\ \ln L + \phi_{KH}\ \ln H + \phi_{KRD}\ \ln RD + \phi_{KK}\ \ln K$$

$$+ \delta_{ML}\ \ln P_C + \delta_{MH}\ \ln P_I + \delta_{MRD}\ \ln P_X + \delta_{MK}\ \ln P_M$$

It is important to note that generally

$$\partial \ln Q/\partial \ln X = (\partial Q/\partial X)\ (X/Q) = P_X X/Q = S_X$$

where P_X is the factor price of the X-imput and equal to its marginal product

$(\partial Q/\partial X)$

Thus: $P_C Y_C/\Pi = S_C$

$$P_I Y_I/\Pi = S_I$$

$$P_X Y_I/\Pi = S_X$$

$$P_M Y_M/\Pi = S_M$$

$$W_L X_L/\Pi = S_L$$

$$W_H X_H/\Pi = S_H$$

$$W_{RD} X_{RD}/\Pi = S_{RD}$$

$$W_K X_K/\Pi = S_K$$

After deletion of the equations of imports and capital for estimation purposes, and imposition of the symmetry and homogeneity constraints the system of equations without technology to be estimated is as follows:

$$S_C = P_C Y_C/\Pi = \alpha_C + \gamma_{CC} \ln(P_C/P_M) + \gamma_{CI} \ln(P_I/P_M) + \gamma_{CX} \ln(P_X/P_M)$$

$$+ \delta_{CL} \ln(L/K) + \delta_{CH} \ln(H/K) + \delta_{CRD} \ln(RD/K) + e_C$$

$$S_I = P_I Y_I/\Pi = a_I + \gamma_{CX} \ln(P_C/P_M) + \gamma_{II} \ln(P_I/P_M) + \gamma_{IX} \ln(P_X/P_M)$$

$$+ \delta_{CH} \ln(L/K) + \delta_{IH} \ln(H/K) + \delta_{IRD} \ln(RD/K) + e_I$$

$$S_X = P_X Y_X/\Pi = a_X + \gamma_{CX} \ln(P_C/P_M) + \gamma_{IX} \ln(P_I/P_M) + \gamma_{XX} \ln(P_X/P_M)$$

$$+ \delta_{CRD} \ln(L/K) + \delta_{IRD} \ln(H/K) + \delta_{XRD} \ln(RD/K) + e_X$$

$$S_L = W_L X_L/\Pi = \beta_L + \phi_{LL} \ln(L/K) + \phi_{LH} \ln(H/K) + \phi_{LRD} \ln(RD/K)$$

$$+ \delta_{CL} \ln(P_C/P_M) + \delta_{CH} \ln(P_I/P_M) + \delta_{CRD} \ln(P_X/P_M) + e_L$$

$$S_H = W_H X_H/\Pi = \beta_H = \phi_{LH} \ln(L/K) + \phi_{HH} \ln(H/K) + \phi_{HRD} \ln(RD/K)$$

$$+ \delta_{CH} \ln(P_C/P_M) + \delta_{IH} \ln(P_I/P_M) + \delta_{IRD} \ln(P_X/P_M) + e_H$$

$$S_{RD} = W_{RD} X_{RD}/\Pi = \beta_{RD} + \phi_{LRD} \ln(L/K) + \phi_{HRD} \ln(H/K) + \phi_{RDRD} \ln(RD/K)$$

$$+ \delta_{CRD} \ln(P_C/P_M) + \delta_{IRD} \ln(P_I/P_M) + \delta_{XRD} \ln(P_X/P_M) + e_{RD}$$

Where the disturbances are the sum of the errors of measurement and the stochastic error terms. The current time subscripts have been ommitted throughout the thesis for clarity and simplicity.

Model 2 With Technological Change

Using Model 1 as introduced in the previous section it is desireable to allow technological change to take place. Jorgenson (1974) had suggested introducing time in exponential form as an additional fixed input into the profit function. Several other authors such as Appelbaum and Harris (1974) used time as the extra input. In our case instead of using the notion of a missing input we will allow directly for factor augmenting disembodied technological processs, both at the input and at the output levels as introduced by Kohli (1978). By specifying an exponential rate of technological change:

$$q_i = P_i e^{-\mu_i t}$$

$$V_j = X_j e^{\lambda_i t}$$

where X_j is the observed fixed input quantity

V_j is the augmented quantity

P_i is the observed price of output i

q_i is the price of augmented output

the share equations for model 2 are:

$$\partial \ln\Pi/\partial \ln P_i = P_i Y_i/\Pi = S_i = a_i + \Sigma\delta_{ih} \ln P_h + \Sigma\delta_{ij} \ln X_j + \delta_{it} t$$

$$\partial \ln\Pi/\partial \ln X_j = W_j X_j/\Pi = V_j = \beta_j + \Sigma\delta_{ij} \ln P_i + \Sigma\phi_{jk} \ln X_k + \phi_{it} t$$

Deleting the imports and tangible capital equations, the system to be estimated becomes the following set of equations.

$$S_C = P_C Y_C/\Pi = a_C + \gamma_{CC}\ln(P_C/P_M) + \gamma_{CI}\ln(P_I/P_M) + \gamma_{CX}\ln(P_X/P_M)$$

$$+ \delta_{CL}\ln(L/K) + \delta_{CH}\ln(H/K) + \delta_{CRD}\ln(RD/K) + \delta_{ct}t + V_c$$

$$S_I = P_I Y_I/\Pi = a_I + \gamma_{CI}\ln(P_C/P_M) + \gamma_{II}\ln(P_I/P_M) + \gamma_{IX}\ln(P_X/P_M)$$

$$+ \delta_{CH}\ln(L/K) + \delta_{IH}\ln(H/K) + \delta_{IRD}\ln(RD/K) + \delta_{It}t + V_I$$

$$S_X = P_X Y_X/\Pi = a_X + \gamma_{CX}\ln(P_C/P_M) + \gamma_{IX}\ln(P_I/P_M) + \gamma_{XX}\ln(P_X/P_M)$$

$$+ \delta_{CRD}\ln(L/K) + \delta_{IRD}\ln(H/K) + \delta_{XRD}\ln(RD/K) + \delta_{Xt}t + V_X$$

$$S_L = W_L W_L/\Pi = \beta_L + \phi_{LL}\ln(L/K) + \phi_{LH}\ln(H/K) + \phi_{LRD}\ln(RD/K)$$

$$+ \delta_{CL}\ln(P_C/P_M) + \delta_{CH}\ln(P_I/P_M) + \delta_{CRD}\ln(P_X/P_M) + \phi_{Lt}t + V_L$$

$$S_H = W_H X_H/\Pi = \beta_H + \phi_{LH}\ln(L/K) + \phi_{HH}\ln(H/K) + \phi_{HRD}\ln(RD/K)$$

$$+ \delta_{CH}\ln(P_C/P_M) + \delta_{IH}\ln(P_I/P_M) + \delta_{IRD}\ln(P_X/P_M) + \phi_{Ht}t + V_H$$

$$S_{RD} = W_{RD} X_{RD}/\Pi = \beta_{RD} + \phi_{LRD}\ln(L/K) + \phi_{HRD}\ln(H/K) + \phi_{RDRD}\ln(RD/K)$$

$$+ \delta_{CRD}\ln(P_C/P_M) + \delta_{IRD}\ln(P_I/P_M) + \delta_{XRD}\ln(P_X/P_M) + \phi_{RDt}t + V_{RD}$$

Final Set of Data Used for Model 1 and Model 2

Estimation of the parameters of Model 1 and Model 2 requires data on factor inputs, and factor outputs as well as price indices for outputs. Divisia price indices were constructed for all outputs. The technique for this estimation and the table of data are reported in a later chapter.

The final set of data used included the following variables: SC, SI, SX, SL, SH, SRD, X1, X2, X3, Y1, Y2, and Y3.

Where;

SC = C/GNP

SI = I/GNP

SX = X/GNP

SL = YL/YT

SH = YH/YT

SRD = YRD/YT

X1 = ln PC/PM

X2 = ln PI/PM

X3 = ln PX/PM

Y1 = ln I/K

Y2 = ln H/K

Y3 = ln RD/K

Where;

GNP - gross national income in nominal terms

C - consumption expenditures in nominal terms

I - investment expenditures in nominal terms

X - export expenditures in nominal terms

YT - total income real terms

YL - income going for Labor in real terms

YH - income going for human capital in real terms

YRD - income going for R & D in real terms

PC - price index of consumption goods

PI - price index for investment goods

PX - price index for exports

PM - price index for imports

L - labor hours

H - human capital

RD - Research & Development

K - non-human capital

TABLE 6.1

DATA USED FOR ESTIMATION OF MODEL 1 AND 2

YEAR	SC	SH	SI	SL	SRD	SX
1948	0.645180	0.424240	0.339970	0.386840	0.148000E-02	0.385100E-01
1949	0.635890	0.410220	0.350000	0.391050	0.950000E-03	0.359900E-01
1950	0.634840	0.415240	0.361020	0.413860	0.128000E-02	0.303300E-01
1951	0.572890	0.385130	0.420140	0.404270	0.127000E-02	0.344100E-01
1952	0.621350	0.415250	0.374290	0.440230	0.219000E-02	0.331600E-01
1953	0.629950	0.405950	0.369030	0.438060	0.264000E-02	0.293100E-01
1954	0.647160	0.418260	0.349520	0.429680	0.265000E-02	0.300700E-01
1955	0.597120	0.384020	0.399610	0.402390	0.235000E-02	0.295100E-01
1956	0.602140	0.387210	0.391830	0.420670	0.343000E-02	0.336600E-01
1957	0.610410	0.389340	0.381400	0.425290	0.320000E-02	0.360200E-01
1958	0.616170	0.393030	0.380630	0.413860	0.321000E-02	0.302500E-01
1959	0.627150	0.395420	0.372150	0.432470	0.336000E-02	0.296800E-01
1960	0.629630	0.394630	0.365190	0.430970	0.355000E-02	0.327000E-01
1961	0.637730	0.399090	0.355570	0.433910	0.356000E-02	0.332900E-01
1962	0.627090	0.391700	0.367080	0.435590	0.354000E-02	0.331800E-01
1963	0.618100	0.386890	0.375430	0.433620	0.346000E-02	0.335900E-01
1964	0.609550	0.380340	0.381890	0.430780	0.340000E-02	0.357700E-01
1965	0.607200	0.378100	0.386000	0.432140	0.354000E-02	0.354500E-01
1966	0.605700	0.371200	0.390090	0.443000	0.367000E-02	0.356300E-01
1967	0.594150	0.372830	0.402080	0.435310	0.374000E-02	0.348400E-01
1968	0.583150	0.370200	0.415280	0.433260	0.367000E-02	0.345100E-01
1969	0.594030	0.380280	0.404820	0.455280	0.383000E-02	0.358200E-01
1970	0.615730	0.401810	0.381790	0.471000	0.352000E-02	0.392100E-01
1971	0.612650	0.404810	0.386430	0.472310	0.307000E-02	0.384300E-01
1972	0.558810	0.359180	0.442830	0.430920	0.255000E-02	0.361500E-01
1973	0.533400	0.343840	0.463460	0.422530	0.252000E-02	0.445700E-01
1974	0.563690	0.368320	0.433810	0.445780	0.248000E-02	0.572700E-01
1975	0.593890	0.390720	0.398140	0.451280	0.206000E-02	0.575200E-01
1976	0.561350	0.363100	0.436140	0.426820	0.183000E-02	0.550500E-01
	1	2	3	4	5	6

TABLE 6.2

DATA USED FOR ESTIMATION OF MODEL 1 AND 2

YEAR	X1	X2	X3	Y1	Y2	Y3
1948	-0.375660	-0.200870	0.319570	-2.56343	-0.221440	-4.28314
1949	-0.321240	-0.144370	0.247360	-2.60327	-0.200200	-4.18323
1950	-0.438960	-0.262720	0.447100E-01	-2.60322	-0.203840	-4.10465
1951	-0.572930	-0.406750	0.900000E-04	-2.59759	-0.233080	-4.06054
1952	-0.475840	-0.346990	0.374900E-01	-2.64236	-0.263180	-3.96229
1953	-0.405090	-0.303990	0.487600E-01	-2.68763	-0.278860	-3.81566
1954	-0.409760	-0.333150	-0.930000E-03	-2.76748	-0.281710	-3.71922
1955	-0.382360	-0.298740	-0.474000E-02	-2.78859	-0.283940	-3.66200
1956	-0.364700	-0.258040	0.987000E-02	-2.81973	-0.288440	-3.59319
1957	-0.337860	-0.233850	-0.605700E-01	-2.87015	-0.288880	-3.51154
1958	-0.257220	-0.169330	0.453400E-01	-2.94196	-0.286830	-3.43010
1959	-0.198180	-0.117680	0.571900E-01	-2.95309	-0.286140	-3.35539
1960	-0.170360	-0.112310	0.481300E-01	-2.98213	-0.283820	-3.28610
1961	-0.132390	-0.821500E-01	0.913300E-01	-3.02134	-0.277170	-3.22036
1962	-0.908800E-01	-0.408100E-01	0.105320	-3.03657	-0.272680	-3.16596
1963	-0.904300E-01	-0.453400E-01	0.886900E-01	-3.06823	-0.269570	-3.11761
1964	-0.116910	-0.786400E-01	0.490200E-01	-3.09018	-0.263950	-3.07119
1965	-0.948500E-01	-0.680000E-01	0.703500E-01	-3.09974	-0.257960	-3.03284
1966	-0.855800E-01	-0.677500E-01	0.751800E-01	-3.11154	-0.254420	-3.00450
1967	-0.423700E-01	-0.301600E-01	0.730600E-01	-3.14346	-0.245300	-2.97890
1968	0.405000E-02	0.484000E-02	0.495900E-01	-3.16167	-0.227960	-2.95597
1969	0.215300E-01	0.221800E-01	0.327600E-01	-3.17306	-0.206840	-2.93929
1970	0.839000E-02	0.349000E-02	0.130200E-01	-3.21573	-0.177360	-2.92451
1971	0.270300E-01	0.259300E-01	0.247600E-01	-3.24110	-0.142500	-2.91252
1972	0.000000E+00	0.000000E+00	0.000000E+00	-3.24784	-0.116930	-2.91173
1973	-0.128100	-0.134930	0.971400E-01	-3.25728	-0.105880	-2.92698
1974	-0.502770	-0.517150	-0.719400E-01	-3.29643	-0.948200E-01	-2.94987
1975	-0.464200	-0.473400	-0.732000E-01	-3.34452	-0.649900E-01	-2.96172
1976	-0.451320	-0.467760	-0.132860	-3.33707	-0.361100E-01	-2.97638
	7	8	9	10	11	12

A Further Look at the Estimation Technique

The same estimation technique is employed for both model 1 and model 2. Both regression models form multivariate systems which may provide estimates of the parameters using Zellner's (1962) efficient estimation procedure (ZEF) for estimating unrelated regressions. But ZEF will fail due to singularity of the distrubance covariance matrix since the factor share equations sum up to one. The standard technique for this case is to delete one of the share equations from the system, which unfortunately introduces a problem since the estimated parameters are not invariant to the choice of the equation deleted. However Barten (1969) has shown that maximum likelihood estimates of a system of share equations with one equation dropped are invariant as to which equation is ommitted. Oberhofer and Kmenta (1974) have proven that iteration of Zellner's efficient estimation procedure (IZEF) until covergence yields asymptotically equivalent estimators to maximum-likelihood estimators.

Thus applying IZEF to both models after deleting the share equation of imports from the demand side and the share equation of non-human capital from the supply side and applying the log likelihood ratio test, see the appendix for detailed explanation, we choose model 2 as the more complete model. The results of model 2 are reported in tables 6.3 - 6.16.

TABLE 6.3

Model 2 with Technology: Zellner's iterative estimates of the Translog profit function. United States private economy, 1948-1976. (Asymptotic standard errors in parentheses).

Consumption Equation Estimated Coefficients

γ_{CC} = 0.455453
(0.151525)

γ_{CI} = -0.398238
(0.156968)

γ_{CX} = -0.0630567
(0.0144099)

δ_{CL} = -0.191896
(0.0377229)

δ_{CH} = 0.212751
(0.0373071)

δ_{CRD} = -0.00153471
(0.00211243)

TABLE 6.4

Model 2 with Technology: Zellner's iterative estimates of the Translog profit function. United States private economy, 1948-1976. (Asymptotic standard errors in parentheses).

Investment Equation Estimated Coefficients

γ_{IC} = -0.398238
(0.156968)

γ_{II} = 0.355331
(0.163954)

γ_{IX} = 0.0279987
(0.0157565)

δ_{IL} = 0.212751
(0.0373071)

δ_{IH} = -0.192367
(0.0377166)

δ_{IRD} = 0.00297025
(0.00210969)

TABLE 6.5

Model 2 with Technology: Zellner's iterative estimates of the Translog profit function. United States private economy, 1948-1976. (Asymptotic standard errors in parentheses).

Exports Equation Estimated Coefficients

γ_{XC} = -0.0630657
(0.0144099)

γ_{XI} = 0.0279987
(0.0157565)

γ_{XX} = 0.0371454
(0.00461156)

δ_{XL} = 0.00153471
(0.00211243)

δ_{XH} = 0.00297025
(0.00210969)

δ_{XRD} = -0.0064210
(0.00055116)

TABLE 6.6

Model 2 with Technology: Zellner's iterative estimates of the Translog profit function. United States private economy, 1948-1976. (Asymptotic standard errors in parentheses).

Labor Equation Estimated Coefficients

ϕ_{LL} = 0.170342
(0.0401045)

ϕ_{LH} = -0.143237
(0.0275312)

ϕ_{LRD} = 0.00047264
(0.00136310)

δ_{CL} = -0.191896
(0.0377229)

δ_{CH} = 0.212751
(0.037301)

δ_{CRD} = -0.0015437
(0.00211243)

TABLE 6.7

Model 2 with Technology: Zellner's iterative estimates of the Translog profit function. United States private economy, 1948-1976. (Asymptotic standard errors in parentheses).

Human Capital Equation Estimated Coefficients

ϕ_{HL} = -0.143237
(0.0275312)

ϕ_{HH} = 0.188042
(0.0252806)

ϕ_{HRD} = -0.0185959
(0.00245087)

δ_{IL} = 0.212751
(0.0373071)

δ_{IH} = -0.192367
(0.0377166)

δ_{IRD} = 0.00297025
(0.00210969)

TABLE 6.8

Model 2 with Technology: Zellner's iterative estimates of the Translog profit function. United States private economy, 1948-1976. (Asymptotic standard errors in parentheses).

R&D Equation Estimated Coefficients

ϕ_{RDL} = 0.0047264
(0.00136310)

ϕ_{RDH} = -0.018595
(0.00245087)

ϕ_{RDRD} = -0.00245680
(0.00118207)

δ_{XL} = -0.00153471
(0.00211243)

δ_{XH} = 0.00297025
(0.00210969)

δ_{XRD} = -0.00064210
(0.00055116)

TABLE 6.9

Model 2 with Technology: Elasticities of transformation evaluated at the means. U.S. private economy 1948-1976. (Standard error in parentheses).

<u>Elasticities of Transformation</u>

θ_{CI} = -0.688999
(0.665731)

θ_{CX} = -1.83443
(0.647730)

θ_{CM} = 0.699739
(0.689664)

θ_{IX} = 2.96291
(1.10465)

θ_{IM} = -0.195256
(1.08301)

θ_{XM} = -2.77359
(2.57517)

TABLE 6.10

Model 2 with Technology: Elasticities of Complementarity evaluated at the means. U.S. private economy 1948-1976. (Standard error in parentheses).

Elasticities of Complementarity

σ_{LH} = 0.144533
(0.164427)

σ_{LRD} = 1.38832
(1.11991)

σ_{LK} = 0.639556
(0.767219)

σ_{HRD} = -15.9074
(2.22833)

σ_{HK} = 0.620832
(0.583316)

σ_{RDK} = 41.2443
(8.59848)

TABLE 6.11

Model 2 with Technology: Elasticities of Intensity evaluated at the means. U.S. private economy 1948-1976. (Standard error in parentheses).

Elasticities of Intensity

Ψ_{CL} = 0.264865
(0.144513)

Ψ_{CH} = 1.90194
(0.158159)

Ψ_{CRD} = 0.104970
(1.23195)

Ψ_{CK} = 0.820746
(0.056437)

Ψ_{IL} = 2.27117
(0.222907)

Ψ_{IH} = -0.271934
(0.249382)

Ψ_{IRD} = 3.70168
(1.91893)

Ψ_{IK} = 0.662065
(0.0694863)

Ψ_{XL} = 0.902814
(0.133771)

$$\Psi_{XH} = \underset{(0.147842)}{1.20815}$$

$$\Psi_{XRD} = \underset{(5.31337)}{-5.19004}$$

$$\Psi_{XK} = \underset{(0.0606358)}{0.878316}$$

$$\Psi_{LM} = \underset{(0.440512)}{2.39914}$$

$$\Psi_{HM} = \underset{(0.384826)}{2.87154}$$

$$\Psi_{RDM} = \underset{(4.35888)}{9.74701}$$

$$\Psi_{MK} = \underset{(1.54158)}{-6.62339}$$

TABLE 6.12

Elasticities of the Derived Demand for Consumption, Investment, Imports and the Supply of Exports evaluated at the means U.S. private economy. (Standard error in parentheses).

Outputs

Consumption	Investment	Exports	Imports
ε_{CC} = 0.357473 (0.249869	ε_{II} = 0.302697 (0.421678)	ε_{XX} = 0.0492213 (0.125705)	ε_{MM} = -0.450330 (0.083051)
ε_{CI} = -0.267892 (0.258845)	ε_{IC} = -0.417821 (0.403710)	ε_{XI} = 1.15202 (0.429503)	ε_{MC} = 0.424334 (0.418224)
ε_{CX} = -0.0672970 (0.0237623)	ε_{IX} = 0.108696 (0.0405246)	ε_{XC} = -1.11243 (0.392794)	ε_{MI} = -0.0759182 (0.42109)
ε_{CM} = -0.0224478 (0.0221246)	ε_{IM} = 0.00626387 (0.0347433)	ε_{XM} = 0.0889775 (0.0826123)	ε_{MX} = -0.101750 (0.0944715)
ε_{CL} = 0.114012 (0.0622062)	ε_{IL} = 0.977634 (0.095951)	ε_{XL} = 0.388620 (0.0575822)	ε_{ML} = 1.03272 (0.189620)
ε_{CH} = 0.739811 (0.0615205)	ε_{IH} = -0.105776 (0.0970043)	ε_{XH} = 0.469943 (0.0575074)	ε_{MH} = 1.11697 (0.149689)
ε_{CRD} = 0.000296813 (0.00348346)	ε_{IRD} = 0.0104668 (0.0054259)	ε_{XRD} = -0.0146753 (0.015024)	ε_{MRD} = 0.0275606 (0.0123246)
ε_{CK} = 0.145880 (0.0100312)	ε_{IK} = 0.117676 (0.012350)	ε_{XK} = 0.156113 (0.0107775)	ε_{MK} = -1.17725 (0.274002)

TABLE 6.13

Model 2 with Technology: Elasticities of the Derived Demand of Labor evaluated at the means. U.S. private economy 1948-1976. (Standard error in parentheses).

Labor

ε_{LL} = -0.173821
(0.093163)

ε_{LH} = 0.0562203
(0.0639585)

ε_{LRD} = 0.00392561
(0.00316665)

ε_{LK} = 0.113675
(0.136366)

ε_{LC} = 0.160619
(0.0876351)

ε_{LI} = 0.883063
(0.0866692)

ε_{LX} = 0.0331202
(0.0049074)

ε_{LM} = -0.076965
(0.0141318)

TABLE 6.14

Model 2 with Technology: Elasticities of the Derived Demand of Human Capital evaluated at the means. U.S. private economy 1948-1976. (Standard error in parentheses).

<u>Human Capital</u>

ε_{HH} = -0.127596
(0.0649924)

ε_{HL} = 0.0622149
(0.0707783)

ε_{HRD} = -0.0449796
(0.0063008)

ε_{HK} = 0.110347
(0.103679)

ε_{HC} = 1.15337
(0.0959106)

ε_{HI} = -0.105732
(0.0969634)

ε_{HX} = 0.0443215
(0.0054236)

ε_{HM} = -0.0921199
(0.0123453)

TABLE 6.15

Model 2 with Technology: Elasticities of the Derived Demand of R&D evaluated at the means. U.S. private economy 1948-1976. (Standard error in parentheses).

R&D

$\varepsilon_{RDRD} = -1.86604$
(0.418047)

$\varepsilon_{RDL} = 0.597609$
(0.482070)

$\varepsilon_{RDH} = -6.18762$
(0.866771)

$\varepsilon_{RDK} = 7.33080$
(1.52830)

$\varepsilon_{RDC} = 0.0636558$
(0.747078)

$\varepsilon_{RDI} = 1.43927$
(0.746108)

$\varepsilon_{RDX} = -0.190399$
(0.194924)

$\varepsilon_{RDM} = -0.312687$
(0.139828)

TABLE 6.16

Model 2 with Technology: Elasticities of the Derived Demand of Cpaital evaluated at the means. U.S. private economy 1948-1976. (Standard error in parentheses).

Capital

ε_{KK} = -0.633572
(0.535077)

ε_{KL} = 0.275299
(0.330252)

ε_{KH} = 0.241490
(0.226897)

ε_{KRD} = 0.116622
(0.024313)

ε_{KC} = 0.497714
(0.0342243)

ε_{KI} = 0.257420
(0.0270172)

ε_{KX} = 0.0322215
(0.0022244)

ε_{KM} = 0.212480
(0.0494544)

In this chapter two possible models explaining in a macro sense the U.S. economy were presented, both including the same inputs and the same outputs with one model (model 2) allowing for technological change overtime. The coefficients of both models were estimated and by applying the log likelihood ratio test it was determined that the coefficients for technology were statistically significant, thus model two was chosen as the more complete model. Using the coefficients of model 2 the various elasticities as outlined in CHAPTER V were estimated.

For convenience and analytical reasons the elasticities reported in this chapter were the ones evaluated at the means. In the next chapter the interpretation of these elasticities along with policy implications will follow. It should be noted that all elasticities containing the Human Capital and/or Research and Development inputs are original and are part of the contributions of this thesis.

CHAPTER VII

INTERPRETATION OF RESULTS

This chapter is divided into two sections. The first section consists of tables of elasticities and the second section consists of the interpretations of these elasticities.

Empirical Results Reported

In this section TABLE 7.1 shows a summation of what has been established in the literature in terms of the elasticity of substitution between imports, exports, to and from different countries and elasticities of substitution between major economic components, such as capital, labor, consumption and investment. The corresponding elasticities obtained from our study are also reported. It is important to note that a meaningful comparison of our estimates and these estimates cannot be made due to differences in data, empirical technique estimation and differences in assumptions. In addition, the elasticities of transformation, complementation and intensity, along with the own and cross elasticities are reported according to their statistical significance at the 5% level, in TABLES 7-2-7.5. TABLES 7.6 and 7.7 report elasticities never before estimated with human capital and R & D inputs.

TABLE 7.1

Comparison of Certain Estimated Elasticities of This Study and Other Studies

	Our Study	Kohli 1978	Simos/Roddy 1980	Berndt/Wood 1975	Simos 1981a	Simos 1981b	IMF 1981	Meyer-Schlochtern/Yujima 1970	Humphrey/Moroney 1975	Dennis/Smith 1978	Griffin/Gregory 1976	Hudson/Jorgenson 1974
ϵ_{KL}	0.6395			1.01	1.351 to 2.504	1.57 to 2.012			0.37 to 36.75	.040 to 3.52	.06	1.09
ϵ_{LL}	-0.174	-0.319 -0.373	-0.580 -0.661	-0.45 -0.46	-.454 -.892						-.12	-0.45
ϵ_{KK}	-0.633	-0.738 -0.802	-3.183 -4.275	-0.44 -0.50	-.971 -1.652						-.18	-0.42
ϵ_{LK}	0.114	0.319 0.373	2.115 2.830	0.05 0.06	0.475 0.992						0.1	0.14
ϵ_{KL}	0.275	0.738 0.802	0.612 0.711	0.26 0.30	0.844 1.470						0.5	0.29
ϵ_{II}	0.303	1.456 1.898	0.488 1.160									
ϵ_{CC}	0.357	0.293 0.308	0.252 0.280									
ϵ_{IC}	-0.418	-0.988 -1.264	-0.252 -0.289									
ϵ_{CI}	-0.268	-0.360 0.372	-0.471 -1.160									
ϵ_{MM}	-0.450	-0.902 0.993					-0.01 -0.16	-0.717				
ϵ_{MC}	0.424	-0.255 -0.434										
ϵ_{XX}	0.049	1.476 2.213										
ϵ_{XI}	1.152	-0.445 -0.722										

TABLE 7.2

Elasticities of Transformation (Θ_{ih}), Elasticities of Substitution (σ_{jk}), and Elasticities of Intensity (Ψ_{ij}), Significant at the 5% Level Evaluated at the Means. U.S. Private Economy 1948-1976. (Asymptotic Standard Errors in Parentheses.)

Θ_{CH} =	-1.83	(0.64)
Θ_{IX} =	2.96	(1.10)
σ_{HRD} =	-15.90	(2.23)
σ_{RDK} =	41.2	(8.60)
Ψ_{CH} =	1.90	(0.16)
Ψ_{CK} =	0.82	(0.05)
Ψ_{IL} =	2.27	(0.22)
Ψ_{IRD} =	3.70	(1.91)
Ψ_{IK} =	0.66	(0.07)
Ψ_{XL} =	0.90	(0.13)
Ψ_{XH} =	1.21	(0.14)
Ψ_{XK} =	0.88	(0.06)
Ψ_{LM} =	2.40	(0.44)
Ψ_{HM} =	2.87	(0.38)
Ψ_{RDM} =	9.74	(4.36)
Ψ_{MK} =	-6.62	(1.54)

TABLE 7.3

Elasticities ($\varepsilon_{\text{Lead, Second}}$) Statistically Significant at the 5% Level, Evaluated at the Means. U.S. Private Economy, 1948-1976. (Asymptotic Standard Errors in Parentheses.)

LEAD / SECOND	C	I	X	M	L	H	R & D	K
C			-0.67 (0.02)		0.11 (0.06)	0.74 (0.06)		0.14 (0.01)
I			0.11 (0.04)		0.98 (0.09)		0.01 (0.005)	0.12 (0.01)
X	-1.11 (0.39)	1.15 (0.43)			0.39 (0.06)	0.47 (0.05)		0.15 (0.01)
M				0.45 (0.08)	1.03 (0.19)	1.12 (0.15)	0.027 (0.012)	-1.18 (0.27)
L	0.16 (0.08)	0.88 (0.08)	0.03 (0.004)	-0.07 (0.01)	-0.17 (0.09)			
H	1.15 (0.09)		0.04 (0.005)	-0.09 (0.01)		-0.13 (0.06)	-0.045 (0.0006)	
R & D		1.44 (0.74)		-0.31 (0.14)		-6.19 (0.86)	-1.86 (0.41)	7.33 1.53
K	0.50 (0.03)	0.26 (0.02)	0.03 (0.002)	0.21 (0.05)			0.11 (0.02)	

TABLE 7.4

Elasticities of Transformation (Θ_{ih}), Elasticities of Substitution (σ_{jk}), and elasticities of Intensity (Ψ_{ij}), Insignificant at the 5% Level Evaluated at the Means. U.S. Private Economy 1948-1976. (Asymptotic Standard Errors in Parentheses.)

Θ_{CI} =	-0.69	(0.66)
θ_{CM} =	0.70	(0.69)
θ_{IM} =	-0.20	(1.08)
θ_{XM} =	-2.77	(2.57)
σ_{LH} =	0.14	(0.16)
σ_{LRD} =	1.39	(1.11)
σ_{LK} =	0.64	(0.76)
σ_{HK} =	0.62	(0.58)
Ψ_{CL} =	0.26	(0.14)
Ψ_{CRD} =	0.10	(1.23)
Ψ_{IH} =	-0.27	(0.25)
Ψ_{XRD} =	-5.20	(5.31)

TABLE 7.5

Elasticities (εLead, Second) Statistically Insignificant at the 5% Level, Evaluated at the Means. U.S. Private Economy, 1948-1976. (Asymptotic Standard Errors in Parentheses.)

LEAD / SECOND	C	I	X	M	L	H	R & D	K
C	0.36 (0.25)	-0.27 (0.26)		-0.02 (0.02)			0.0002 (0.003)	
I		0.30 (0.42)		0.0006 (0.03)				
X			0.05 (0.12)	0.09 (0.08)			-0.01 (0.01)	
M	0.42 (0.42)	-0.07 (0.42)	-0.10 (0.09)					
L						0.05 (0.06)	0.004 (0.003)	0.11 (0.10)
H		-0.10 (0.09)			0.06 (0.07)			0.11 (0.10)
R & D	0.06 (0.75)		-0.19 (0.19)		0.60 (0.48)			
K					0.27 (0.33)	0.24 (0.22)		-0.63 (0.53)

TABLE 7.6

Original Contribution Elasticities of Substitution (σ_{jk}), and Elasticities of Intensity (Ψ_{ij}), Evaluated at the Means. U.S. Private Economy, 1948-1976. (Asymptotic Standard Errors in Parentheses.)

σ_{LH} =	0.14	(0.16)
σ_{LRD} =	1.39	(1.12)
σ_{HRD} =	-15.90	(2.23)
σ_{HK} =	0.62	(0.58)
σ_{RDK} =	41.24	(8.60)
Ψ_{CH} =	1.90	(0.16)
Ψ_{CRD} =	0.10	(1.23)
Ψ_{IH} =	-0.27	(0.25)
Ψ_{IRD} =	3.70	(1.91)
Ψ_{XH} =	1.21	(0.15)
Ψ_{XRD} =	-5.19	(5.31)
Ψ_{HM} =	2.87	(0.38)
Ψ_{RDM} =	9.75	(4.36)

TABLE 7.7

Original Contribution Elasticities (εLead, Second) Evaluated at the Means. U.S. Private Economy, 1948-1976. (Asymptotic Standard Errors in Parentheses.)

LEAD / SECOND	C	I	X	M	L	H	R & D	K
C						0.74 (0.06)	0.002 (0.003)	
I						-0.10 (0.09)	0.01 (0.005)	
X						0.47 (0.05)	-0.014 (0.015)	
M						1.11 (0.15)	0.03 (0.01)	
L						0.05 (0.06)	0.0004 (0.003)	
H	1.15 (0.09)	-0.10 (0.09)	0.04 (0.005)	-0.09 (0.01)	0.06 (0.07)	-0.13 (0.06)	-0.04 (0.006)	0.11 (0.10)
R & D	0.06 (0.74)	1.44 (0.74)	-0.19 (0.19)	-0.31 (0.14)	0.60 (0.48)	-6.19 (0.86)	-1.86 (0.42)	7.33 (1.53)
K						0.24 (0.22)	0.12 (0.02)	

Interpretation of Results

The elasticity of transformation between consumption and investment, Θ_{CI}, was found to be -0.69. The standard error was found to be 0.66 indicating that Θ_{CI} is not significantly different from zero. Thus, one percent change in the price ratio of investment and consumption (P_I/P_C) does not necessarily bring any change in the consumption investment ratio (C/I). The negative sign of the elasticity is consistent with other studies reporting elasticities of this kind.

The elasticity of transformation between consumption and exports, Θ_{CX}, was estimated to be -1.83. This elasticity is statistically significant since the standard error is equal to 0.65. The negative sign indicates substitutability between consumption and exports. The implication of this finding is that when export prices increase in the international markets faster than domestic consumption prices, production in the United States will switch from domestic consumption to exports.

The elasticity of transformation between consumption and imports indicates them to be complements in production. The numerical size of the elasticity is about 0.7 but in a statistical sense the elasticity is equal to zero. Thus a change in the imports consumption price ratio (P_M/P_C) will not affect the consumption import ratio (C/M). The economic implication of this finding is the following: consumers view the majority of imports as either luxury goods or necessary goods, so a change in the price of imported products in relation to the price of domestic products will not change the relative ratio of the amount of the consumption to imported goods, at least in the short run, which also indicates that a temporary tarrif or tax by the federal government might not curb the consumption of imported goods.

The elasticity of transformation between investment and exports was statistically significant and it was about 2.96. Again the positive sign indicates complementarity in production between investment and export goods. One percent increase of the price of exports investment ratio (P_X/P_I) will lead to an increase in the investment export ratio (I/X) of 2.96 percent. This indicates that in the short run when the price of exports rises faster than the price of investment, the American producers will increase investment in anticipation of profits in the foreign markets.

It is clear from the large size of the standard error (1.08) that the elasticity of transformation between investment and imports is statistically insignificant since the size of the elasticity is only -0.195. One, looking only at the sign of the elasticity, could argue that investment goods and import goods are substitutes. But in real terms they are complements in production so a change in the ratio of import prices to investment prices (P_M/P_I) will not affect the investment import ratio (I/M). This finding is consistent with the Θ_{CM} elasticity analyzed earlier. We can see that increase in the price of imports in relation to the price of investment goods will not spur additional investment which will not spur additional consumption.

The last elasticity of transformation that will be analyzed is the export-import elasticity. This elasticity is not statistically different from zero indicating complementarity between exports and imports. Changes in their relative price ratio will have no effect on the export import ratio.

The next set of elasticities to be investigated are the elasticities of complementarity.

The partial inverse elasticity of substitution between labor and human capital was found to be 0.144. It is statistically insignificant indicating a complementarity relationship between labor and human capital. An increase in the relative cost of these two inputs (P_H/P_L) does not affect the labor-human capital ratio (L/H). The first important contribution of this finding is the actual measurement of this elasticity since no previous economists have used human capital as one of the inputs of production in a multi-input output framework. The second contribution, is the economic meaning of this elasticity which implies that a faster increase in the cost of human capital in relation to the cost of labor will not affect the labor-human capital ratio indicating the need for skilled labor and the willingness of the individuals of the society to educate themselves.

The next elasticity investigates the relationship between labor and research and development. The size of the elasticity is 1.39 but the standard error is 1.12 again indicating a complementarity relationship, between L and R&D. The increase of the (P_{RD}/P_L) ratio does not affect the (L/RD) ratio indicating the importance of R&D in the production process and the belief of the producers in the United States that short run higher costs in the price of R&D may be necessary for better future prospects. This elasticity is unique in its kind due to the method and framework of its calculation.

The elasticity of substitution between capital and labor was found to be 0.64. The positive sign initially indicates substitutability. But an examination of the standard error indicates that the elasticity is statistically equal to zero thus our finding shows capital and labor to be complements. An examination of previous studies shows the majority of the studies claiming substitutability between these two factors of production even though a number of these studies do not bother to report the standard error. There are studies that have supported claims of complementarity as well. The uniqueness of our data, the technique of estimation and the model used in our study make it difficult to make any meaningful comparisons.

The elasticity of substitution between human capital and R&D is first of all statistically significant, carrying a negative sign and being in the neighborhood of -15.9, indicating complementarity between H and R&D. Again it is a unique elasticity estimated for the first time in our study. If the price ratio of R&D and human capital (P_{RD}/P_H) is to increase by 1% then the human capital - R&D ratio is to decrease by approximately sixteen percent. The implication of this finding is very important and meaningful because if the price of R&D goes up in relation to the price of human capital this implies less investment in human capital since there is a need of human capital for R&D purposes. This further implies that corporations when cutting R&D due to high prices cause the labor employed to be less human capital intensive.

The elasticity of substitution between human capital and non-human capital is equal to 0.62. Despite the positive sign these two factors could be complements because the standard error is sufficiently large (0.58) to make the elasticity insignificant. So even though the relative price ratio of H and K may change their relative ratio (K/H) will not.

The last elasticity of substitution is the elasticity between R&D and K (σ_{RDK}). The size of the elasticity is very high, close to 41 and it is statistically significant with standard error being about

8.6. The positive sign indicates that research and development and capital are substitutes. This is a very important finding because it indicates that when the price of non human capital increases in relation to the price of R&D, producers will substitute R&D for capital and the magnitude of the substitution is large. Thus governmental policies in favor of R&D development will help the economy enormously, since producers consider R&D to be of such great importance. This also entails the development of new products, technologies, etc.

The next set of elasticities to be discussed are the elasticities of intensity. These elasticities show the relationship between the i^{th}output and the quantity of the j^{th}input. Thus comparing any two elasticities of intensity we can define if an output is say X_1 or X_2 intensive.

For our purposes we will compare each of our outputs, C,I,X and M against our inputs L,H,RD, and K.

From Table (6.11) we can observe that Ψ_{CRD} can be eliminated since it is statistically insignificant. The remaining three elasticities Ψ_{CL}, Ψ_{CH}, Ψ_{CK} are all statistically significant but the one with the largest size is Ψ_{CH} which implies that consumption is human capital intensive.

From Table (6.11) we can observe the second group of elasticities of intensity and again we can eliminate one of them (Ψ_{IH}) for being statistically insignificant. From the other three the largest elasticity of 3.7 is the elasticity Ψ_{IRD} which indicates that investment is R&D intensive.

The third group of elasticities, Table (6.11) shows Ψ_{XRD} to be insignificant and the largest being Ψ_{XH}. Thus exports are human capital intensive.

In the last group, Table (6.11) all of the elasticities are statistically significant but the largest one is $\Psi_{MRD} = 9.74$, showing imports to be R&D intensive.

All of the findings are of extensive importance, since these are the first elasticities of intensity including among the factors of production human capital and R&D, and as we have seen from the above analysis they were the predominant factors in all categories, indicating again that both of them might be the important factors missing in the analysis of foreign trade.

Looking at the elasticities of the derived supply for consumption, investment, exports and the derived demand for imports evaluated at the means for the period 1948-76, we have found the following results: The own elasticity for consumption is equal to 0.36 with a standard error of 0.25. The sign of the elasticity is consistent with the sign of the own elasticity of consumption reported by Kohli (1978) which ranged from 0.293 to 0.308 and by Simos and Roddy (1980) which ranged from 0.252 to 0.280. The above studies unfortunately did not report the standard errors. The standard error of our study was sufficiently large as to indicate that the elasticity is statistically insignificant thus the supply function for consumption is inelastic. So in the short run other things being equal only shifts in the demand function affect price.

The cross elasticity of consumption to investment indicated complementarity in production. Even though the elasticity is recorded with a negative sign again with a standard error of 0.26 a test at the 5% level of significance indicated the elasticity not to be different that zero.

Other studies such as Simos and Roddy (1980) and Kohli (1978) reported negative elasticities but failed to report the standard error. Thus their conclusion was that consumption and investment goods are substitutes in production since an increase in the price of one output all other prices and fixed quantities held constant, leads to a decrease in the production of the other output. At first glance our finding may seem paradoxical but it should be noted that the consumption and investment concept used in our study differs significantly from that of other studies as it is discussed in CHAPTER V.

It is interesting to compare our estimates of consumption to exports price elasticities with those of other authors. We find ε_{CX} to be of the magnitude of -0.067 and statistically significant which is consistent with other studies ranging from -0.001 to 0.046. The substitutability between consumption and exports is intuitively obvious. Consumption goods and exports are substitutes in production. Thus an increase in the price of export goods will result in a decrease in the production of domestic goods since it will be more profitable to sell overseas.

On the other hand the price elasticity of imports to consumption was not statistically significant indicating complementarity. The other studies range from 0.072 to 0.101 also indicating complementarity in production, as well.

Turning to another group of own and cross elasticities of investment with respect to consumption, exports and imports we find the following.

The own elasticity of investment, ε_{II}, is equal to 0.302, well within the range of similar studies which range from 0.14 to 1.898. Studies by Kohli, Simos, and Roddy fail to report standard errors thus making any kind of meaningful comparison impossible. In our case we have an inelastic supply function because the elasticity is statistically insignificant. Other things being equal, in the short run, any shift in the demand function will affect the prices of investment goods.

Considering the cross elasticity of investment with respect to consumption, other studies have found negative coefficients which indicates that investment and consumption goods are substitutes in production.

An increase in the price of one output, all other prices and quantities held constant, leads to a decrease in the production of the other output. This elasticity in our study was found to be -0.418 which is well within the range of other studies (other studies reporting elasticities from -0.252 to -1.264). The standard error of this elasticity was equal to 0.403 thus indicating complementarity between investment and consumption.

The next elasticity is that of investment with respect to exports. The elasticity is equal to 0.108 and it is statistically significant. Thus an increase in the price of goods being exported will result in an increase in the investment goods produced for export purposes.

The elasticity of investment to imports in statistically insignificant and extremely small in size (0.006). For all intensive purposes it is equal to zero indicating an inelastic supply function. Changes in the price of imports will not affect the amount of the investment goods produced domestically.

The own elasticity of exports is equal to 0.049 giving a positive sign for the supply of exports. The sign was expected to be positive since we are dealing with a supply function, but the standard error (0.12) indicates that the function is perfectly inelastic, so only changes in the demand function will affect the price of exports. Other studies have found the elasticity to be positive as well but again all of them fail to report standard errors.

The elasticity of exports to investment is equal to 1.15 and statistically significant (standard error is equal to 0.42). An increase in the price of investment goods will result in an increase in the export output. Due to the increase in the price of investment goods domestic supply of investment goods will also increase which may necessitate increase in the amount of exports for any surplus produced.

The elasticity of exports to domestic consumption goods was found to be negative and statistically significant. The size of the elasticity is equal to -1.11. An increase in the price of consumption goods will lead to a larger supply of consumption goods but a smaller output of exports because it will be more profitable to produce for the domestic rather than the foreign market.

The exports to imports elasticity is very small (0.09) and insignificant. Thus changes in the price of imports have no effect on the amount of exports produced, in the short run other things being equal.

The own elasticity for the demand of imports is equal to -0.45 with the standard error equal to 0.08. The sign is the expected sign and the elasticity is statistically significant. In comparing it with other studies reporting own elasticities for imports, our elasticity is of the low side. Kohli is reporting the elasticity to range from -0.902 to -0.993 for Canada.

It should be clear that when the price of imports rises then the quantity demanded for imports will fall.

Looking at the estimates for the elasticity of imports to consumption $\hat{\varepsilon}_{MC}$ = 0.42 (0.42) we find that for the United States increases in the prices of domestically produced goods have no effect on the amounts of imports. This result may seem strange but if we were to consider that the consumption goods as used in this thesis contain human capital, foreign goods may not be able to substitute domestic consumption.

Investigating the elasticity of imports to investment, $\hat{\varepsilon}_{MI}$ = 0.07 (0.42) we find it to be insignificant. Thus changes in the price of investment goods will not affect in the short run, other things being equal, the quantity of imports demanded.

The elasticity of imports with respect to exports, $\hat{\varepsilon}_{MX}$ = -0.10 (0.09) is insignificant as well. Thus again changes in the price of exports will not affect the demand for imports.

The elasticity of consumption in relation to labor is equal to 0.114 with a standard error of 0.06. A quick analysis indicates that the elasticity is statistically significant. The elasticity compares very well with other reported elasticities from different authors. Kohli (1975) for Canada finds ε_{CL} to range from 0.857 to 0.922, Simos and Roddy find ε_{CL} to range from 0.055 to 0.229 for the United States. The implication of this finding is the following: when the quantity of labor is increased then the amount of consumption goods produced will also increase.

The elasticity of consumption in relation to human capital was found to be positive and statistically significant ($\hat{\varepsilon}_{CH}$ = 0.74 (0.06)). This implies that when human capital is increased the supply of consumption goods will also increase. This result was expected since in previous analysis we found consumption goods to be human capital intensive.

The elasticity of consumption to R&D is extremely small in size (0.0002). In addition the standard error is sufficiently large (0.003) as to make the elasticity statistically insignificant. This indicates that in the short run, other things being equal, increases in R&D expenditures do not affect the production of consumption goods, as there is always a time lag between the introduction or improvement of technology and actual increase in production of goods and services.

The elasticity of consumption to non human capital is positive and statistically significant (0.14 (0.01)). Increases in the amount of intangible capital will result in increases in the quantities of consumption goods produced. The sign and the size of the elasticity compares favorably with other studies. (See Kohli, Simos and Roddy)

Going to the elasticity of investment with respect to labor $\hat{\varepsilon}_{IL}$ = 0.97 (0.09) we find what other researchers found as well. The elasticity is positive and statistically significant, thus increases in the amount of labor will result in increases in the amount of investment goods produced.

Looking at the $\hat{\varepsilon}_{IH}$ = -0.10 (0.09) we find it to be statistically equal to zero, so changes in the quantities of human capital, in the short run other things being equal, have no effect on the quantities of investment goods produced.

The elasticity of investment with respect to R&D is statistically significant which implies that R&D changes do affect investment, increases in the quantities of research and development used in production increase the amount of investment goods produced. This result is consistent with the estimates of the elasticities of intensity where investment was found to be R&D intensive.

Another elasticity that it is not surprising, and consistent with the finding of other studies is the elasticity of investment with respect to non human capital. We found it to be equal to 0.12, statistically significant and very close to the size of previous findings reported by other researchers. Thus an increase in the quantity of capital will increase, other things being equal in the short run, the amount of investment goods produced.

The elasticity of exports to labor implies that an increase in the input of labor services would result in an increase in exports. This finding was again expected and consistent with the results of other studies. The elasticity was equal to 0.39 and the standard error was equal to 0.06 thus the estimate is statistically significant. Studies for other countries ranged from 0.5 to 1.54.

A very important and unique finding is the $\hat{\varepsilon}_{XH}$ elasticity which indicates that increases in the amount of human capital used in production will result in an increase in the amount of exports produced. The implications and contributions of this elasticity are important because they support Leontief's findings that exported goods from the United States are labor intensive. ε_{XH} pinpoints that they are labor intensive due to human capital. Again this finding was consistent with the elasticities of intensity discussed previously, where exports were found to be human capital intensive.

The size of this elasticity was 0.46 with a standard error equal to 0.06, thus making the elasticity statistically significant.

At a glance the elasticity of exports with respect to R&D indicates that research and development does not affect exports in the short run other things being equal. The sign of the elasticity was negative but the standard error was sufficiently large to make the elasticity in a statistical sense equal to zero.

Tangible capital has an effect on the amount of export goods produced. The elasticity of ε_{XK} is equal to 0.15 (0.01), thus increases in tangible capital input result in more export goods produced.

The elasticity of imports to labor is statistically significant and equal to 1.03. This implies that an increase in the input of labor services will result in a more than proportional increase in imports. It further implies a negative net effect on the balance of trade near equilibrium.

It should also be noted that this result was again consistent with previous empirical studies.

Turning to another contribution of this thesis we look at the elasticity of imports to human capital, $\hat{\varepsilon}_{MH}$ = 1.11 (0.15). The elasticity is large, above one, statistically significant and positive. Increases in the amount of the human capital input will result in more than proportional increases in the amount of goods imported.

$\breve{\varepsilon}_{MRD}$ = 0.027 (0.012) is an additional contribution of this thesis. The elasticity is significant, and consistent with the previous discussion in the section of the elasticities of intensity where we had found imports to be R&D intensive. Thus an increase in R&D imput will result in an increase in the amount of imports demanded in the short run. (Again all other things being equal.)

The elasticity of imports with respect to tangible capital is statistically significant, and negative $\hat{\varepsilon}_{MK}$ = -1.18 (0.27). Thus an increase in capital input results in a larger decrease in the amount of imported goods. The size and sign of this elasticity coincides with Kohli's findings for the Canadian economy. Kohli's $\hat{\varepsilon}_{MK}$ elasticity ranged from -0.649 to -0.83.

The own elasticity for the demand of labor was found to be -0.17 with a standard error equal to 0.09. The negative sign was expected since we are dealing with a demand function. Numerous other studies have reported similar results whether it is for the United States or a foreign country. To mention a few here we start with Kohli (1975) who found ε_{LL} to range from -0.319 to -0.373. Simos and Roddy (1980) reported ε_{LL} to range from -0.580 to -0.661. Berndt and wood (1975) found ε_{LL} to be between -0.45 and -0.46 and Simos (1981) reported ε_{LL} to be between -0.454 and -0.892.

$$\hat{\varepsilon}_{LH} = 0.06\ (0.06),$$

$$\hat{\varepsilon}_{LRD} = 0.0039\ (0.0032),$$

$$\hat{\varepsilon}_{LK} = 0.11\ (0.13)$$

Looking at ε_{LH}, ε_{LRD} and ε_{LK} together all of them have in common the following characteristics: a) all of them are positive b) all of them are very small and c) all of them are statistically insignificant. Thus increases in either the amount of human capital input either the amount of R&D or the amount of tangible capital in production will have no effect on the price of labor input.

The effect of H and RD on the price of labor is a contribution of this thesis since no other study attempted to estimate these relationships. The effect of K on the price of labor is consistent with a number of other studies reported in the literature, some of them reported here.

Kohli (1975) found ε_{LK} to range from 0.319 to 0.373. Simos and Roddy (1980) found ε_{LK} to range from 2.115 to 2.83. Berndt and Wood (1975) found ε_{LK} to range from 0.05 to 0.06. Simos (1981) found ε_{LK}

to range from 0.475 to 0.992.

The demand function for human capital $\hat{\varepsilon}_{HH} = -0.13$ (0.06) was found as expected to have a negative slope and to be statistically significant, which is consistent with economic theory.

$$\hat{\varepsilon}_{HL} = 0.06\ (0.07),$$

$$\hat{\varepsilon}_{HK} = 0.11\ (0.10),$$

The elasticities of human capital with respect to both labor and non human capital share the same characteristics. They are both small in size, positive and statistically insignificant. Thus changes in the amounts of either labor or capital used in the production process have no effect on the price of human capital in the short run other things being equal.

A very interesting relationship is the elasticity of human capital to R&D (both factors introduced for the first time in this thesis). A negative relationship was found between these two inputs, in the order of -0.045. The standard error was 0.006. An increase in the quantity of R&D results in a decrease in the price of human capital. The elasticity even though small in size was statistically significant.

The own elasticity of R&D was found as expected with a negative sign. The elasticity is equal to -1.86 and it is significant. The standard error being 0.42.

Changes in the amount of the labor input used in production showed no effect on the price of R&D. Even though the elasticity ε_{RDL} is equal to 0.6 and the standard error is equal to 0.48 a test indicated that the elasticity is insignificant.

Looking at the elasticity of R&D with respect to human capital we find it statistically significant and equal to -6.19. This shows that increases in the amounts of labor input in production will result in decreases in the price of R&D.

The elasticity of R&D to non human capital is statistically significant and equal to 7.33. Increases of tangible capital in production will result in an increase in the price of R&D.

Going to the own elasticity of non human capital (ε_{KK}) we find it equal to -0.63. The negative sign was expected as we are dealing with the demand for capital. The standard error is equal to 0.53 which indicates that the demand function is perfectly inelastic and that the elasticity in a statistical sense is equal to zero.

Other studies can be found in the literature giving negative own elasticities for non human capital but none of these studies bother to report the standard error. In reference to some of these studies we have Kohli (1975) with ε_{KK} ranging between -0.738 and -0.802, Simos and Roddy (1980) with ε_{KK} ranging from -3.18 to -4.27 and Berndt and Wood (1975) with ε_{KK} ranging from -0.44 to -0.50. The size of our elasticity is within the range of these other studies.

$$\hat{\varepsilon}_{KL} = 0.27\ (0.33),$$

$$\hat{\varepsilon}_{KH} = 0.24\ (0.22),$$

ε_{KL} and ε_{KH} can be looked at together since all of their characteristics are the same. Both elasticities are positive but statistically insignificant thus neither the quantity of labor nor the quantity of human capital used in production have any effect on the price of non human capital.

The elasticity of non human capital with respect to R&D is statistically significant and equal to 0.12. Thus increases of R&D in production result in higher prices for tangible capital.

The elasticity of labor to consumption, indicates the effect in the price of input (labor) due to changes in the price of output (consumption goods). In this case ε_{LC} is equal to 0.16 and statistically significant. This indicates that an increase in the price of consumption goods produced domestically will result in an increase in the price of the labor input used in production.

Other authors such as Kohli and Simos and Roddy reported ε_{LC} in their studies 0.932 to 1.002 and 0.038 to 0.180 respectively. It can be seen that the finding of this study is within the range of the second study which was done for the United States.

The elasticity of ε_{LI} is similar in terms of analysis with ε_{LC}. The elasticity is positive and significant $\hat{\varepsilon}_{LI} = 0.88$ (0.08). Thus changes in the price of investment goods lead to changes in the price of labor input. Again studies by Kohli and Simos/Roddy find similar estimates.

Similarly increases in the price of export goods contribute to increases in the price of labor input as well. The elasticity is equal to 0.03 and it is statistically significant. Kohli's findings also support our findings. He reports ε_{LX} to range between 0.372 and 0.411.

On the other hand increases in the prices of the imported goods contributes to the decline in the price of domestic labor input other things held constant. So a negative sign is reported for this elasticity whose size is 0.077 and its standard error is 0.014, the elasticity being significant. Our finding is consistent with other studies that report ε_{LM} to range from -0.477 to -0.511.

Increases in the prices of the domestically produced goods lead to a more than proportional increase in the price of human capital. ε_{HC} is equal to 1.15 and it is statistically significant. This elasticity is another contribution of this thesis and there are no other estimates in the economic literature for comparison purposes.

The elasticity of human capital to investment goods is equal to -0.10, but is insignificant at the 5% level. Thus increases in the price of investment goods have no effect on the price of human capital. Again this elasticity is an original contribution.

The price of exports when increased has a positive effect on the price of human capital. ε_{HX} is equal to 0.044 and the standard error is equal to 0.005, the elasticity even though very small in size is significant.

On the contrary when the price of imported goods is increased there is a negative effect on the price of human capital. ε_{HM} is equal to -0.09 and the standard error is equal to 0.01, thus statistically significant.

Looking at the elasticity of R&D with respect to consumption goods we find it insignificant, $\hat{\varepsilon}_{RDC}$ = 0.063 (0.75). Thus increases in the price of consumption goods do not affect the cost of R&D.

The elasticity of R&D with respect to investment is positive and equal to 1.44, and is statistically significant as well. When the price of investment goods increase the price of R&D will also increase.

The elasticity of R&D with respect to exports is equal to -0.19 but is statistically insignificant. Changes in the price of exports do not affect the price of the R&D input.

The price of imports on the other hand when it increases results in a decrease in the price of R&D. The elasticity of R&D to imports is statistically significant and equal to -0.31.

Looking at the effect of the prices of consumption goods on the prices of non-human capital we find ε_{KC} equal to 0.50 and statistically significant. This means that when the price of consumption goods increases the price of non-human capital will also increase.
Other studies have found similar results. Kohli for example reports ε_{KC} to range from 0.198 to 0.332 and Simos and Roddy report ε_{KC} to range from 0.195 to 0.256.

The elasticity of non-human capital with respect to investment is equal to 0.26 and the standard error is very small which makes it statistically significant. Since the sign is positive, it indicates that increases in the price of investment goods will lead to increases in the price of non-human capital. Again our finding is along the lines of reports from other researchers, such as Simos (1981) whose estimates for ε_{KI} range from 0.037 to 5.76.

ε_{KX} is significant and equal to 0.03. This implies that increases in the price of exporting goods will result in increases in the prices of non-human capital.

Similarly ε_{KM} = 0.21 (0.05) is also significant and positive which again indicates increases in the price of imported goods tend to affect the price of tangible capital upward. This finding is consistent with Kohli's finding of ε_{KM} which he reported to range from 0.405 to 0.499.

CHAPTER VIII

SUMMARY AND CONCLUSIONS

This chapter serves as a place of summation and conclusion of the findings of our study. The thesis is an econometric investigation of the foreign trade sector of the United States for the period of 1948-76. A lot of studies in this field were undertaken within the framework of imports (exports) as a function of real income and relative price. The present study did not follow this traditional approach. Utilizing a multi-input, multi-output variable profit function import and export functions were derived within a more general and vigorous theoritical framework thus we were able to obtain a much larger variety of information about imports and exports, namely, how they relate to other aggregates of the economy and specifically as to how they relate to human capital and research and development.

CHAPTER I which is the introduction chapter, established the foundations for all of the subsequent analysis, and briefly outlined the contents of each chapter.

CHAPTER II was devoted to a review of the theories of international trade, in order to show that there is a luck of understanding and explaining fully trade flows but also to show that there is theoritical justification in introducing human capital and research and development as variables affecting trade flows. Following Chipman's classification of trade theories, the chapter was devided into three sections. In section one the Classical Theory was introduced, The Neoclassical Heckscher-Ohlin Theory was presented in section two and section three traced the Modern Theories of international trade. The Modern Theories of international trade begin with Keesing's (1966) claim that the quality of labor, as measured by skill and educational levels, differs markedly within and among countries, which of course is a strong statement in favor of human capital. We continued by introducing the claims of Gruben, Metha and Vernon (1967) that a major causal factor influencing the commodity pattern of trade is the differences in technological knowledge among countries, which of course this is a strong statement in favor of research and development since differences in expenditures on R&D activities per dollar of output are usually used to indicate differences in levels of technological knowledge.

Keesing's, Gruber's, Metha's and Vernon's claims are the foundations of our own assumption that human capital and research and development play a very important role in international trade.

CHAPTER III is an extention of the second chapter, in the sense that we have investigated here the empirical studies undertaken to prove or disprove the above outlined theories. This chapter was divided into three sections, in section one we presented the functional forms of import demand and export supply functions specified in empirical analysis and we also outlined the explanatory variables used in this kind of investigation. Section two dealt with some traditional problems and objections that one always associated with empirical tests and the last section was used to report the actual results (elasticities) found by these studies.

CHAPTER IV was devoted to a historical look at human capital and research and development since these are the two important variables that are treated together for the first time in both theoretical and empirical analysis, in addition of this chapter was used to describe Professor Eisner's data that were employed in our empirical estimation.

In CHAPTER V we have introduced the model used in our analysis. The general description appears in section one. Sections two and three show the translog profit function, the way by which the share equations are deriven and the way by which the various elasticities are estimated. The stochastic specification and estimation technique is treated in section four where in section five we introduced the elasticity matrices to be estimated along with the definitions of these elasticities. The last section, section six is where we present the system of share demand and share supply equations that we have estimated.

In CHAPTER VI after allowing for technological change over time, and using Iterative Zellner Efficient Estimation procedure (IZEF), our system of multi-demand and multi-supply equations was estimated simultaneously producing asymptotically equivalent estimators to maximum-likelihood estimators. It should be noted, that the share equation of imports was deleted from the demand side and the share equation of non-human capital was deleted from the supply side before estimation. This was maintained by the fact that if we have not deleted an equation, any equation, from the demand side, and an equation, any equation, from the supply side IZEF would have failed due to singularity of the disturbance covarience matrix since the factor share equations sum up to one. The various estimated coefficients are reported along with their asymptotic errors. These coefficients were used to estimate the elasticities of transformation, complementarity, intensity, cross and own elasticities, which were presented along with their standard errors.

The interpretation of results appear in CHAPTER VI. This chapter was devided into two sections. In section one the elasticities of substitution, transformation and intensity significant were reported in tables indicating whether or not they were statistically significant at the 5% level. The same was done for cross and own elasticities. In addition the original contribution elasticities of substitution and intensity along with the original cross and own elasticities were reported in separate tables. These elasticities are reported for the first time in the literature. The interpretation of these elasticities was the central theme of the second section. All the elasticities were interpreted in terms of the relationship between the variables in question, but a special emphasis was given to the relationships between human capital, and research and development to consumption, investment, imports, exports, non-human capital and labor.

We found that consumption and exports are human capital intensive, where investment and imports are research and development intensive, these findings reinforce our original claims that imports and exports are affected by human capital and R&D. In addition we were able to explain the Leontief paradox as to why United States, a technologically advanced country is exporting labor intensive products and importing capital intensive products from less developed countries.

United States is exporting labor intensive products due to high levels of human capital where it is importing capital intensive products because the capital (non-human capital) to human capital ratio is high in relative terms in these countries.

Based on these findings it is desirable that in the future, further research should be undertaken with disaggregated variables. For example: consumption can be disaggregated into durables, non durables and services, investment into, residential, non residential construction, equipment, etc., imports and exports can be disaggregated into, food, beverages, tobacco, crude materials and fuels, manufactured goods, etc. Thus we will be able to find the interrelationships between various categories of the major economic aggregates. Additional research may be possible on a sectional basis, i.e. investigation of the chemical industry, automotive industry, computer industry, steel industry, etc. Further more research can be undertaken on an international basis, i.e., a country wide model link analysis.

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APPENDICES

LIST OF APPENDICES

This dissertation contains eight appendices:

APPENDIX A

Indices

There are various ways in which relative changes in prices and quantities can be described. In our thesis we have used the divisia index method which enjoys certain advantages over the other indexing methods. In order to better understand these advantages, we must outline some alternative methods of indexing and then show the superiority of our method.

The notation used in this section is the following:

I is index numbers;
P_o is the base-year prices;
P_n is the given year prices;
q_o is the base-year quantities;
q_u is the given-year quantities.

The first method to be discussed is the simple aggregative method and the index it leads to is called the simple aggregation index. The general formula for a simple aggregative index is:

$$I = \frac{\Sigma P_n}{\Sigma P_o} \cdot 100$$

where ΣP_n is the sum of the given year prices and ΣP_o is the sum of the base-year prices, and the ratio of the first to the second is multiplied by 100 to express the indices as a percentage. A simple aggregative index is easy to construct and easy to understand, but it does not satisfy the unit test criterion, that is depending on the units for which the prices of the various items are quoted the index can yield substantially different results. Another way to compare two sets of prices is to first calculate a separate index for each item and then average all these indexes, or price relatives, using some measure of central location. This index is called an arithmetic mean of price relatives and its formula is:

$$I = \frac{\Sigma \frac{P_n}{P_o} \cdot 100}{K}$$

where K is the number of items whose price relatives are being combined into an index. In principle, price relatives can be averaged with any measure of central location, but in practice the arithmetic mean and the geometric mean are most widely used.

Today the need for weighting index items has been almost universally accepted; a very few indexes are usually computed without using weights.

A commonly used index is the Laspeyres Index or the weighted aggregative index with lease-year weights. The formula for this index is:

$$I = \frac{\Sigma P_n q_o}{\Sigma P_o q_o} \cdot 100$$

Clearly, this kind of index reflects changes in prices alone, the same quantities of goods (the base year quantities) are priced at two different times and any difference between the given-year total (the quantity in the numerator of the index) and the base year total (the quantity of the denominator of the index) must be accounted for by changes in price.

Another common index is the Paasche Index whose formula is:

$$I = \frac{\Sigma P_n q_n}{\Sigma P_o q_n} \cdot 100$$

In essence this index uses given-year quantities to weight both the base-year prices and the given-year prices; that is, price the given year quantities at the two different times, and construct a weighted aggregative index with given-year weights.

An index that is currently in favor with the federal government is the fixed-weight aggregative index whose formula is:

$$I = \frac{\Sigma P_n q_a}{\Sigma P_o q_a} \cdot 100$$

where the weights are quantities for some other period than the base year 0 or the given year n.

In addition to weighted aggregative indexes, we can also obtain weighted indexes by weighting the individual price relatives. The formula for a weighted arithmetic mean of price relatives is:

$$I = \frac{\Sigma \frac{P_n}{P_o} W}{\Sigma W} \cdot 100$$

where the W's are suitable weights assigned to the individual price relatives of the index items (written as proportions, not as percentages).

The divisia price index is a logarithmic index, thus making it compatible to the translog functional form. It concerns itself with the price differences in different years, taking into account the relative differences as much as possible.

This price index is expressed as follows:

$$I = (\log P_t) = \sum_{i=1}^{N} \frac{W_{it} + W_{it-1}}{2} \cdot \Delta \log P_{it}$$

Where P_{it} is the price of the i^{th} commodity in period t

$i = 1,2,3,\ldots N$ and

W_{it} is the share of the i^{th} commodity in period t.

The theoretical foundations for the divisia index were carried out by Theil (1967) where the advantages of the index were discussed by Jorgenson and Egriliches (1967) and by Usher (1980).

In short, the divisia price index avoids comparison in absolute price series between regions and/or comparisons between different time periods. It takes each observation at a time, cumulates the change of the prices, times the average share of the commodity from period t to t-1.

APPENDIX B

Robert Eisner's Economic Data

Table A-II - 1: Income to Human Capital and Consumption Categories, Billions of Current Dollars.

Year	AI	C	CN1	CN2
1948	161.11	282.83	103.00	2.2490
1949	154.65	280.24	103.65	2.2860
1950	161.99	291.27	109.18	2.5440
1951	180.23	315.22	119.65	2.9060
1952	193.63	341.10	126.17	3.0730
1953	204.46	368.52	131.68	3.2320
1954	213.39	387.43	135.92	3.2480
1955	225.34	405.62	143.34	3.5000
1956	235.53	426.79	152.00	3.8580
1957	247.23	452.87	160.82	4.0260
1958	257.86	474.30	168.38	4.0940
1959	269.00	501.24	177.75	4.2030
1960	283.91	531.40	185.87	4.3810
1961	292.79	553.26	193.53	4.4530
1962	306.12	578.50	202.47	4.7200
1963	319.83	601.96	211.44	4.7110
1964	339.22	637.19	223.69	5.2310
1965	362.00	677.42	238.82	5.6020
1966	383.89	727.06	257.20	6.1410
1967	420.63	776.97	271.38	6.5180
1968	461.69	843.80	293.03	7.0770
1969	496.53	907.21	315.06	7.7700
1970	540.26	981.03	340.44	8.1630
1971	579.18	1045.7	360.81	8.6080
1972	619.48	1123.0	390.58	9.4430
1973	674.58	1215.3	432.07	10.593
1974	750.19	1357.4	487.48	11.673
1975	834.40	1520.4	533.98	12.110
1976	914.25	1664.0	587.18	13.609

AI: Employee Training, Expense Account Items of Consumption, Opportunity Costs of Self Employed, Opportunity Costs of Students, Unpaid Household Work.

C: Total Consumption
CN1 + CN2 + CN3 + CN4 + CN5 + CN6

CN1: Household Expenditures for Services and Nondurables.

CN2: Expense Account Items of Consumption.

Table A-II - 2: Additional Consumption Categories,
Billions of Current Dollars.

Year		CN3		CN4		CN5		CN6
1948		6.0010		0.20400		28.257		143.12
1949		5.7160		0.15400		25.654		142.78
1950		6.0200		0.22900		24.407		148.89
1951		7.2120		0.18700		22.345		162.92
1952		7.4260		0.23400		26.815		177.38
1953		7.4560		0.24800		34.130		191.78
1954		7.2690		0.33500		35.798		204.86
1955		7.3770		0.31100		37.429		213.66
1956		7.6780		0.52300		39.340		223.39
1957		7.9900		0.82600		43.484		235.72
1958		8.2380		0.89500		45.244		247.45
1959		8.6470		0.69900		49.280		260.66
1960		9.2040		0.79500		52.010		279.14
1961		9.2950		1.3810		55.258		289.35
1962		9.4580		1.5140		58.439		301.90
1963		10.022		1.4510		60.079		314.25
1964		10.427		1.7420		64.311		331.79
1965		11.322		1.8870		68.437		351.36
1966		12.986		2.4410		75.853		372.44
1967		14.294		2.3570		81.529		400.89
1968		15.684		2.5730		86.928		438.51
1969		17.745		2.7570		93.105		470.78
1970		19.500		2.9270		100.07		509.93
1971		20.593		2.7810		106.29		546.64
1972		22.514		3.6910		115.82		580.96
1973		24.833		2.9570		124.44		620.45
1974		28.840		1.9700		132.22		695.24
1975		33.701		2.9030		152.47		785.23
1976		35.616		3.3590		161.56		862.67

CN3: BEA Imputations Other than Owner-Occupied Nonfarm Dwellings.

CN4: Subsities Allocated to Consumption.

CN5: Transfers from Business, Nonprofit Institutions, Government Enterprises and Government.

CN6: Nonmarket Services Produced in Households.

Table A-II - 3: Categories of Consumption, Billions of 1972 Dollars.

Year	CR1	CR2	CR3	CR4
1948	193.22	3.8760	12.980	1.8580
1949	195.51	3.8870	12.451	1.4970
1950	203.05	4.2370	12.738	1.0450
1951	207.64	4.5430	13.809	0.85100
1952	211.85	4.6530	13.721	1.0170
1953	217.33	4.9200	13.616	1.0320
1954	220.76	4.8320	13.459	0.89000
1955	231.43	5.2220	13.613	0.010000
1956	240.95	5.4790	13.641	-1.1380
1957	246.40	5.5730	13.627	0.94000
1958	250.73	5.6120	13.712	0.47500
1959	260.49	5.6830	14.094	0.79800
1960	266.13	5.8340	14.556	0.42300
1961	273.26	5.8740	14.929	0.44600
1962	281.42	6.1820	15.154	0.89700
1963	289.07	6.0920	15.645	1.4200
1964	301.44	6.7220	16.273	1.6180
1965	315.24	7.1120	16.855	1.9950
1966	328.08	7.6260	17.889	2.7810
1967	338.80	7.9220	18.850	2.9530
1968	351.92	8.2730	19.561	3.2280
1969	361.41	8.7130	20.486	3.2400
1970	371.36	8.7670	21.174	3.1070
1971	376.29	8.8610	21.534	2.7790
1972	390.58	9.4430	22.515	3.6910
1973	402.95	10.134	23.293	2.4870
1974	401.00	10.135	24.918	1.6900
1975	405.64	9.7850	26.244	2.3270
1976	423.38	10.474	27.239	2.5160

CR1: Household Expenditures for Services and Nondurables.

CR2: Expense Account Items of Consumption.

CR3: BEA Imputations Other than Owner-Occupied Nonfarm Dwellings.

CR4: Subsities Allocated to Consumption

Table A-II - 4: Additional Categories of Consumption, Human Capital and Total Investment.

Year	CR5	CR6	H	I
1948	68.236	364.57	1356.0	149.03
1949	58.589	361.76	1392.6	154.25
1950	55.318	367.17	1427.0	165.64
1951	45.198	372.75	1461.6	231.17
1952	52.565	382.65	1505.7	205.47
1953	65.287	392.59	1562.4	215.88
1954	66.087	404.52	1626.3	209.25
1955	68.378	409.94	1694.8	271.45
1956	69.676	417.28	1765.4	277.73
1957	74.427	424.92	1835.3	282.96
1958	74.905	435.72	1905.7	292.99
1959	79.933	443.53	1980.0	297.44
1960	82.960	454.55	2058.5	308.21
1961	86.775	463.74	2139.8	308.48
1962	90.071	472.91	2227.8	338.64
1963	90.739	483.51	2323.7	365.63
1964	95.107	495.52	2429.0	399.21
1965	98.021	506.74	2545.5	430.64
1966	104.10	515.01	2670.9	468.24
1967	107.89	523.86	2810.2	525.80
1968	110.26	531.66	2964.6	600.89
1969	111.75	539.86	3127.2	618.24
1970	112.27	550.85	3298.2	608.31
1971	112.57	563.77	3481.1	659.59
1972	115.82	580.96	3677.5	889.93
1973	117.33	590.02	3886.1	1056.0
1974	112.60	605.36	4096.5	1044.7
1975	119.11	622.25	4306.9	1019.3
1976	118.81	637.59	4520.1	1292.9

CR5: Transfers from Business, Nonprofit Institutions, Government Enterprises and Government (Billions of 1972 Dollars).

CR6: Nonmarket Services Produced in Households (Billions of 1972 Dollars).

H: Intangible Household Capital (Human Capital) (Billions of 1972 Dollars, Mid Year).

I: Total Investment (Billions of Current Dollars), IN1 + IN2 + IN3 + IN4 + IN5 + IN6 + IN7

Table A-II - 5: Categories of Investment (Billions of Current Dollars).

Year		IN1		IN2		IN3		IN4
1948		94.478		-4.7660		2.3920		36.780
1949		95.876		-5.8810		2.3770		36.894
1950		111.78		1.6070		2.6740		39.225
1951		122.39		25.536		3.1600		44.869
1952		130.32		18.091		4.1480		48.743
1953		137.69		6.5640		5.1240		54.657
1954		137.71		0.29200		5.6440		58.842
1955		152.61		7.9170		6.1720		65.590
1956		159.55		7.4680		8.3630		69.665
1957		164.57		1.8060		9.7750		74.942
1958		160.56		-0.085000		10.711		78.308
1959		176.28		4.3150		12.358		85.084
1960		175.60		2.7770		13.523		89.323
1961		178.94		-1.4400		14.316		94.401
1962		193.32		7.3230		15.394		103.61
1963		206.00		6.7200		17.059		112.26
1964		221.58		4.2500		18.854		123.99
1965		243.26		7.5500		20.044		136.83
1966		262.95		12.564		21.846		150.88
1967		270.90		11.213		23.146		174.78
1968		300.52		13.432		24.604		193.48
1969		323.72		11.657		25.626		212.46
1970		327.73		1.6490		25.905		237.44
1971		361.83		6.2500		26.595		263.88
1972		410.30		7.0510		28.257		293.31
1973		454.90		14.269		30.303		325.02
1974		466.71		14.179		32.260		357.83
1975		485.15		-4.7140		34.558		405.42
1976		545.90		15.967		37.363		436.35

IN1: Investment in Structures and Equipment and Household Durables and Semidurables.

IN2: Change in Inventories.

IN3: Investment in Research and Development.

IN4: Investment in Education and Training.

Table A-II - 6: Additional Categories of Investment and Intangible Capital.

Year	IN5	IN6	IN7	INTA
1948	5.8750	0.37600	13.899	1379.4
1949	6.0610	0.38200	18.540	1418.5
1950	6.3800	0.56500	3.4050	1455.8
1951	6.8390	0.56800	27.812	1493.4
1952	7.6290	0.48300	-3.9410	1542.9
1953	8.5100	0.46100	2.8820	1607.9
1954	9.0620	0.58900	-2.8940	1678.6
1955	9.5780	0.80500	26.778	1752.7
1956	10.232	1.1180	21.326	1830.3
1957	11.168	1.1310	19.571	1908.4
1958	12.046	1.2570	30.188	1987.9
1959	13.264	1.0440	5.0950	2072.0
1960	14.190	1.2430	11.554	2160.8
1961	15.210	1.7150	5.3320	2252.6
1962	16.503	1.8840	0.61000	2351.2
1963	17.739	1.8220	4.0250	2458.3
1964	19.687	2.1100	8.7310	2575.7
1965	21.033	2.2220	-0.29900	2704.3
1966	22.816	2.6030	-5.4180	2841.6
1967	24.923	2.3050	18.535	2992.8
1968	27.493	2.3070	39.054	3158.4
1969	31.280	2.6920	10.807	3330.7
1970	35.200	3.0600	-22.675	3509.7
1971	39.189	3.1180	-41.272	3699.2
1972	43.884	3.7710	103.35	3902.3
1973	48.991	4.1400	178.37	4117.5
1974	54.742	3.0760	115.87	4332.2
1975	63.463	3.8250	31.554	4544.6
1976	71.708	3.5340	182.04	4759.0

IN5: Investment in Health (Billions of Current Dollars).

IN6: Subsities and Government Enterprise Transfers Allocated to Investment (Billions of Current Dollars).

IN7: Net Revoluations in Land, Structures and Equipment, Household Durables and Semidurables and Inventories (Billions of Current Dollars).

INTA: Business Intangible Capital (R&D) plus Household Intangible Capital (Human Capital) (Billions of 1972 Dollars).

Table A-II - 7: Categories of Investment, Billions of 1972 Dollars.

Year		IR1		IR2		IR3		IR4
1948		159.46		-7.8080		5.4390		82.335
1949		161.32		-8.4780		5.3380		81.439
1950		184.51		3.0070		6.0040		85.181
1951		188.88		36.113		6.3160		91.533
1952		201.18		27.913		8.0030		97.010
1953		212.71		11.316		9.6470		106.23
1954		214.05		0.53300		10.567		112.17
1955		232.17		10.421		11.393		121.21
1956		232.00		9.4470		14.863		123.29
1957		231.40		2.1410		16.834		127.08
1958		225.96		0.00400		17.969		129.56
1959		243.55		5.3010		20.398		137.14
1960		241.61		3.1300		21.999		141.13
1961		246.44		-1.8110		22.916		146.80
1962		261.99		9.2150		23.975		156.97
1963		277.08		8.7560		26.050		166.06
1964		294.45		5.3130		28.244		179.55
1965		319.13		8.8550		29.130		193.12
1966		336.66		14.625		30.411		204.82
1967		336.27		13.334		30.923		227.66
1968		356.87		15.388		31.220		239.66
1969		365.55		13.104		30.837		249.60
1970		354.18		2.0380		29.132		262.61
1971		373.32		6.5190		28.142		276.28
1972		410.30		7.0510		28.257		293.31
1973		435.76		13.391		28.544		306.32
1974		408.09		11.671		27.674		305.19
1975		387.76		-5.9680		27.024		317.13
1976		416.31		10.250		27.672		322.37

IR1: Investment in Structures and Equipment and Household Durables and Semidurables.

IR2: Change in Inventories.

IR3: Investment in Research and Development.

IR4: Investment in Education and Training.

Table A-II - 8: Additional Categories of Investment and Total Capital, Billions of 1972 Dollars.

Year	IR5	IR6	IR7	K
1948	13.988	1.1890	25.931	1692.2
1949	14.354	1.0970	33.832	1701.2
1950	14.836	1.1570	6.0270	1749.6
1951	15.385	1.0940	45.743	1845.2
1952	16.393	1.0320	-6.3460	1959.0
1953	17.440	1.0010	4.5820	2065.0
1954	17.935	1.0490	-4.5650	2155.5
1955	18.485	0.90300	44.410	2251.4
1956	19.315	0.48400	31.224	2355.7
1957	20.220	1.3450	27.603	2450.0
1958	20.568	1.2530	42.638	2538.8
1959	22.537	1.2670	7.1160	2636.0
1960	23.352	1.2890	16.069	2734.1
1961	24.385	1.5270	7.4470	2823.2
1962	25.868	1.8370	0.84700	2926.1
1963	27.318	2.0910	5.5830	3042.6
1964	29.605	2.3470	11.993	3162.7
1965	30.749	2.5880	-0.40500	3254.6
1966	31.893	3.0830	-7.1100	3444.7
1967	32.811	2.8660	23.552	3591.4
1968	34.276	2.8650	47.569	3723.7
1969	36.537	3.1390	12.436	3845.8
1970	39.011	3.3060	-24.891	3938.3
1971	41.153	3.1730	-43.037	4014.2
1972	43.855	3.7710	103.35	4133.7
1973	46.681	3.7100	168.27	4320.2
1974	47.450	2.6630	98.946	4503.9
1975	48.241	3.0000	23.851	4596.1
1976	49.811	2.6450	130.40	4686.3

IR5: Investment in Health.

IR6: Subsities and Government Enterprise Transfers Allocated to Investment.

IR7: Net Revoluations in Land, Structures and Equipment, Household Durables and Semidurables and Inventories.

K: Total Capital minus Business Intangible Capital minus Household Intangible Capital.

Table A-II - 9: Hours at Work, Expenses Related to Work and Imports.

Year	L	L1	LERW	M
1948	130.36	2.5070	5.9940	10.371
1949	125.94	2.4220	6.4002	9.6400
1950	129.53	2.4910	6.6330	12.016
1951	137.38	2.6420	7.8030	15.094
1952	139.46	2.6820	9.0430	15.810
1953	140.50	2.7020	10.258	16.554
1954	135.41	2.6040	10.532	16.011
1955	138.48	2.6630	10.705	17.827
1956	140.45	2.7010	11.392	19.590
1957	138.89	2.6710	12.431	20.652
1958	133.95	2.5760	12.613	20.822
1959	137.54	2.6450	13.365	23.166
1960	138.58	2.6650	13.847	23.223
1961	137.59	2.6460	13.583	23.076
1962	140.45	2.7010	13.776	25.229
1963	141.49	2.7210	13.896	26.414
1964	143.88	2.7670	14.343	28.445
1965	148.46	2.8550	15.046	31.957
1966	153.40	2.9500	15.805	37.713
1967	154.91	2.9790	16.459	40.624
1968	157.72	3.0330	17.540	47.653
1969	161.04	3.0970	19.299	52.946
1970	158.03	3.0390	20.589	58.522
1971	157.04	3.0200	21.848	64.033
1972	160.63	3.0890	23.388	75.949
1973	166.30	3.1980	24.238	94.413
1974	166.71	3.2060	26.589	131.88
1975	162.14	3.1180	28.269	126.86
1976	166.56	3.2030	32.247	155.73

L: Total Hours at Work (L_1 * 52)

L1: Weakly Hours at Work.

LERW: Expenses Related to Work.

M: Imports (Billions of Current Dollars).

Table A-II - 10: Divisia Price Index for Consumption and Price Deflators for Consumption.

Year		PC		PC1		PC2		PC3
1948		0.44299		0.53306		0.58024		0.46233
1949		0.44566		0.53015		0.58811		0.45908
1950		0.45491		0.53767		0.60042		0.47260
1951		0.49094		0.57623		0.63967		0.52227
1952		0.51422		0.59554		0.66043		0.54121
1953		0.53298		0.60589		0.65691		0.54759
1954		0.54802		0.61567		0.67219		0.54008
1955		0.55814		0.61937		0.67024		0.54191
1956		0.57203		0.63084		0.70414		0.56286
1957		0.59234		0.65268		0.72241		0.58634
1958		0.60800		0.67157		0.72951		0.60079
1959		0.62404		0.68238		0.73957		0.61352
1960		0.64528		0.69842		0.75094		0.63232
1961		0.65478		0.70824		0.75809		0.62261
1962		0.66767		0.71948		0.76351		0.62413
1963		0.67963		0.73146		0.77331		0.64059
1964		0.69531		0.74207		0.77819		0.64075
1965		0.71621		0.75758		0.78768		0.67173
1966		0.74530		0.78395		0.80527		0.72592
1967		0.77692		0.80101		0.82277		0.75830
1968		0.82351		0.83266		0.85543		0.80180
1969		0.86792		0.87175		0.89177		0.86620
1970		0.91898		0.91676		0.93111		0.92094
1971		0.96299		0.95887		0.97145		0.95630
1972		1.0000		1.0000		1.0000		0.99996
1973		1.0600		1.0723		1.0453		1.0661
1974		1.1748		1.2157		1.1518		1.1574
1975		1.2832		1.3164		1.2376		1.2841
1976		1.3643		1.3869		1.2993		1.3075

PC: Divisia Price Index for Consumptions Derived by Aggregating PC1, PC2, PC3, PC4, PC5 and PC6.

PC1: Price Deflator for C1.

PC2: Price Deflator for C2.

PC3: Price Deflator for C3.

Table A-II - 11: Divisia Price Index for Investment and Price Deflators for Consumption.

Year		PC4		PC5		PC6		PI
1948		0.10980		0.41411		0.39257		0.52760
1949		0.10287		0.43786		0.39467		0.53188
1950		0.21914		0.44121		0.40552		0.54258
1951		0.21974		0.49438		0.43706		0.57969
1952		0.23009		0.51013		0.46356		0.58493
1953		0.24031		0.52277		0.48850		0.58969
1954		0.37640		0.54168		0.50643		0.59165
1955		31.100		0.54738		0.52120		0.60682
1956		-0.45958		0.56461		0.53536		0.63641
1957		0.87872		0.58425		0.55474		0.65726
1958		1.8842		0.60402		0.56790		0.66386
1959		0.87594		0.61652		0.58770		0.67635
1960		1.8794		0.62693		0.61410		0.68386
1961		3.0964		0.63680		0.62395		0.68852
1962		1.6878		0.64881		0.63839		0.70195
1963		1.0218		0.66211		0.64994		0.71098
1964		1.0766		0.67620		0.66958		0.72243
1965		0.94586		0.69819		0.69337		0.73570
1966		0.87774		0.72869		0.72317		0.75871
1967		0.79817		0.75566		0.76525		0.78647
1968		0.79709		0.78837		0.82479		0.82416
1969		0.85093		0.83315		0.87203		0.86849
1970		0.94207		0.89138		0.92572		0.91449
1971		1.0007		0.94427		0.96961		0.96193
1972		1.0000		1.0000		1.0000		1.0000
1973		1.1890		1.0606		1.0516		1.0528
1974		1.1657		1.1743		1.1485		1.1581
1975		1.2475		1.2801		1.2619		1.2715
1976		1.3351		1.3598		1.3530		1.3421

PC4: Price Deflator for C4.

PC5: Price Deflator for C5.

PC6: Price Deflator for C6.

PI: Divisia Price Index for Investment, Derived by Aggregating PI1, PI2, PI3, PI4, PI5, PI6 and PI7.

Table A-II - 12: Price Deflators for Investment

Year	PI1	PI2	PI3	PI4
1948	0.59247	0.61040	0.43979	0.44671
1949	0.59431	0.69368	0.44530	0.45303
1950	0.60584	0.53442	0.44537	0.46045
1951	0.64797	0.70711	0.50032	0.49019
1952	0.64778	0.64812	0.51831	0.50245
1953	0.64730	0.58006	0.53115	0.51451
1954	0.64335	0.54784	0.53412	0.52456
1955	0.65732	0.75972	0.54174	0.54113
1956	0.68773	0.79052	0.56267	0.56504
1957	0.71120	0.84353	0.58067	0.58971
1958	0.71058	-21.250	0.59608	0.60441
1959	0.72380	0.81400	0.60584	0.62042
1960	0.72678	0.88722	0.61471	0.63293
1961	0.72611	0.79514	0.62472	0.64304
1962	0.73788	0.79468	0.64209	0.66005
1963	0.74346	0.76747	0.65486	0.67603
1964	0.75255	0.79992	0.66754	0.69055
1965	0.76225	0.85263	0.68809	0.70850
1966	0.78107	0.85908	0.71836	0.73665
1967	0.80562	0.84093	0.74850	0.76771
1968	0.84211	0.87289	0.78808	0.80730
1969	0.88556	0.88958	0.83101	0.85121
1970	0.92530	0.80913	0.88923	0.90417
1971	0.96922	0.95874	0.94503	0.95510
1972	1.0000	1.0000	1.0000	1.0000
1973	1.0439	1.0656	1.0616	1.0611
1974	1.1436	1.2149	1.1657	1.1725
1975	1.2512	0.78988	1.2788	1.2784
1976	1.3113	1.5578	1.3502	1.3535

PI1: Price Deflator for I1.

PI2: Price Deflator for I2.

PI3: Price Deflator for I3.

PI4: Price Deflator for I4.

Table A-II - 13: Divisia Price Index for Imports and Additional Price Deflators for Investment

Year	PI5	PI6	PI7	PM
1948	0.42000	0.31623	0.53600	0.64497
1949	0.42225	0.34822	0.54800	0.61449
1950	0.43004	0.48833	0.56496	0.70560
1951	0.44452	0.51920	0.60801	0.87065
1952	0.46538	0.46802	0.62102	0.82757
1953	0.48796	0.46054	0.62898	0.79917
1954	0.50527	0.56149	0.63395	0.82556
1955	0.51815	0.89147	0.64801	0.81808
1956	0.52974	2.3099	0.68300	0.82376
1957	0.55232	0.84089	0.70902	0.83042
1958	0.58567	1.0032	0.70801	0.78634
1959	0.58854	0.82399	0.71599	0.76081
1960	0.60766	0.96431	0.71902	0.76514
1961	0.62374	1.1231	0.71599	0.74747
1962	0.63797	1.0256	0.72019	0.73119
1963	0.64935	0.87135	0.72094	0.74395
1964	0.66499	0.89902	0.72801	0.78153
1965	0.68402	0.85858	0.73827	0.78747
1966	0.71539	0.84431	0.76203	0.81189
1967	0.75959	0.80426	0.78698	0.81055
1968	0.80211	0.80524	0.82100	0.82018
1969	0.85612	0.85760	0.86901	0.84943
1970	0.90231	0.92559	0.91097	0.91130
1971	0.95228	0.98267	0.95899	0.93731
1972	1.0007	1.0000	1.0000	1.0000
1973	1.0495	1.1159	1.0600	1.2049
1974	1.1537	1.1551	1.1710	1.9423
1975	1.3155	1.2750	1.3230	2.0412
1976	1.4396	1.3361	1.3960	2.1425

PI5: Price Deflator for I5.

PI6: Price Deflator for I6.

PI7: Price Deflator for I7.

PM: Divisia Price Index for Imports.

Table A-II - 14: Divisia Price Index for Exports, R&D, Relative Shares of Consumption and Human Capital

Year		PX		RD		SC		SH
1948		0.88783		23.351		0.64518		0.42424
1949		0.78694		25.943		0.63585		0.41022
1950		0.73786		28.861		0.63484		0.41524
1951		0.87073		31.811		0.57289		0.38513
1952		0.85918		37.259		0.62135		0.41525
1953		0.83910		45.477		0.62995		0.40595
1954		0.82480		52.277		0.64716		0.41826
1955		0.81421		57.818		0.59712		0.38402
1956		0.83194		64.807		0.60214		0.38721
1957		0.78161		73.135		0.61041		0.38934
1958		0.82282		82.215		0.61617		0.39303
1959		0.80559		91.984		0.62715		0.39542
1960		0.80286		102.26		0.62963		0.39463
1961		0.81895		112.76		0.63773		0.39909
1962		0.81240		123.41		0.62709		0.39170
1963		0.81295		134.68		0.61810		0.38689
1964		0.82080		146.64		0.60955		0.38034
1965		0.84487		158.73		0.60720		0.37810
1966		0.87528		170.72		0.60570		0.37120
1967		0.87199		182.62		0.59415		0.37283
1968		0.86188		193.74		0.58315		0.37020
1969		0.87772		203.45		0.59403		0.38028
1970		0.92324		211.45		0.61573		0.40181
1971		0.96080		218.13		0.61265		0.40481
1972		1.0000		224.80		0.55881		0.35918
1973		1.3278		231.38		0.53340		0.34384
1974		1.8075		235.76		0.56369		0.36832
1975		1.8972		237.75		0.59389		0.39072
1976		1.8760		238.90		0.56135		0.36310

PX: Divisia Price Index for Exports.

RD: Business Intangible Capital (R&D) (Billions of 1972 Dollars, Mid Year).

SC: Relative Share of Consumption.

SH: Relative Share of Human Capital.

Table A-II - 15: Relative Shares of Investment, Capital, Labor and Imports

Year	SI	SK	SL	SM
1948	0.33997	0.18744	0.38684	0.23658E-01
1949	0.35000	0.19778	0.39105	0.21874E-01
1950	0.36102	0.16962	0.41386	0.26190E-01
1951	0.42014	0.20933	0.40427	0.27432E-01
1952	0.37429	0.14233	0.44023	0.28800E-01
1953	0.36903	0.15336	0.43806	0.28298E-01
1954	0.34952	0.14942	0.42968	0.26744E-01
1955	0.39961	0.21124	0.40239	0.26244E-01
1956	0.39183	0.18870	0.42067	0.27639E-01
1957	0.38140	0.18218	0.42529	0.27837E-01
1958	0.38063	0.18990	0.41386	0.27050E-01
1959	0.37215	0.16875	0.43247	0.28985E-01
1960	0.36519	0.17085	0.43097	0.27516E-01
1961	0.35557	0.16344	0.43391	0.26599E-01
1962	0.36708	0.16916	0.43559	0.27348E-01
1963	0.37543	0.17603	0.43362	0.27122E-01
1964	0.38189	0.18548	0.43078	0.27211E-01
1965	0.38600	0.18622	0.43214	0.28644E-01
1966	0.39009	0.18213	0.44300	0.31418E-01
1967	0.40208	0.18812	0.43531	0.31065E-01
1968	0.41528	0.19287	0.43326	0.32933E-01
1969	0.40482	0.16061	0.45528	0.34669E-01
1970	0.38179	0.12366	0.47100	0.36730E-01
1971	0.38643	0.11982	0.47231	0.37515E-01
1972	0.44283	0.20734	0.43092	0.37792E-01
1973	0.46346	0.23111	0.42253	0.41437E-01
1974	0.43381	0.18341	0.44578	0.54765E-01
1975	0.39814	0.15594	0.45128	0.49555E-01
1976	0.43614	0.20825	0.42682	0.52537E-01

SI: Relative Share of Investment

SK: Relative Share of Capital

SL: Relative Share of Labor.

SM: Relative Share of Imports.

Table A-II - 16: Relative Shares of R&D and Exports, Exports and Transformed Variables

Year	SRD	SX	X	X1
1948	0.14797E-02	0.28510E-01	16.882	-0.27566
1949	0.94637E-03	0.35985E-01	15.859	-0.32124
1950	0.12776E-02	0.30326E-01	13.914	-0.43896
1951	0.12731E-02	0.34408E-01	18.932	-0.57293
1952	0.21888E-02	0.33161E-01	18.204	-0.47584
1953	0.26379E-02	0.29308E-01	17.145	-0.40509
1954	0.26474E-02	0.30069E-01	18.001	-0.40976
1955	0.23509E-02	0.29509E-01	20.045	-0.38236
1956	0.34291E-02	0.33663E-01	23.860	-0.36470
1957	0.31986E-02	0.36021E-01	26.724	-0.33786
1958	0.32116E-02	0.30251E-01	23.286	-0.25722
1959	0.33613E-02	0.29684E-01	23.725	-0.19818
1960	0.35494E-02	0.32696E-01	27.595	-0.17036
1961	0.35577E-02	0.33292E-01	28.882	-0.13239
1962	0.35360E-02	0.33178E-01	30.607	-0.90884E-01
1963	0.34638E-02	0.33586E-01	32.709	-0.90426E-01
1964	0.34022E-02	0.35771E-01	37.393	-0.11691
1965	0.35374E-02	0.35448E-01	39.548	-0.94854E-01
1966	0.36738E-02	0.35634E-01	42.773	-0.85584E-01
1967	0.37424E-02	0.34840E-01	45.561	-0.42372E-01
1968	0.36748E-02	0.34509E-01	49.933	0.40494E-02
1969	0.38281E-02	0.35816E-01	54.699	0.21526E-01
1970	0.35235E-02	0.39207E-01	62.468	0.83857E-02
1971	0.30651E-02	0.38430E-01	65.595	0.27033E-01
1972	0.25507E-02	0.36154E-01	72.656	0.00000E+00
1973	0.25229E-02	0.44572E-01	101.56	-0.12810
1974	0.24804E-02	0.57273E-01	137.92	-0.50277
1975	0.20556E-02	0.57525E-01	147.27	-0.46420
1976	0.18307E-02	0.55048E-01	163.18	-0.45132

SRD: Relative Share of Research and Development.

SX: Relative Share of Exports.

X: Exports (Billions of Current Dollars).

X1: X1 = LOG (PC/PM)

Table A-II - 17: Transformed Variables

Year	X2	X3	Y1	Y2
1948	-0.20087	0.31957	-2.5634	-0.22144
1949	-0.14437	0.24736	-2.6033	-0.20020
1950	-0.26272	0.44711E-01	-2.6032	-0.20384
1951	-0.40675	0.93051E-04	-2.5976	-0.23308
1952	-0.34699	0.37489E-01	-2.6424	-0.26318
1953	-0.30399	0.48757E-01	-2.6876	-0.27886
1954	-0.33315	-0.92710E-03	-2.7675	-0.28171
1955	-0.29874	-0.47442E-02	-2.7886	-0.28394
1956	-0.25804	0.98714E-02	-2.8197	-0.28844
1957	-0.23385	-0.60573E-01	-2.8701	-0.28888
1958	-0.16933	0.45337E-01	-2.9420	-0.28683
1959	-0.11768	0.57192E-01	-2.9531	-0.28614
1960	-0.11231	0.48132E-01	-2.9821	-0.28382
1961	-0.82146E-01	0.91328E-01	-3.0213	-0.27717
1962	-0.40806E-01	0.10532	-3.0366	-0.27268
1963	-0.45336E-01	0.88685E-01	-3.0682	-0.26957
1964	-0.78641E-01	0.49021E-01	-3.0902	-0.26395
1965	-0.68003E-01	0.70390E-01	-3.0997	-0.25796
1966	-0.67750E-01	0.75176E-01	-3.1115	-0.25442
1967	-0.30164E-01	0.73065E-01	-3.1435	-0.24530
1968	0.48396E-02	0.49594E-01	-3.1617	-0.22796
1969	0.22182E-01	0.32755E-01	-3.1731	-0.20684
1970	0.34878E-02	0.13017E-01	-3.2157	-0.17736
1971	0.25934E-01	0.24756E-01	-3.2411	-0.14250
1972	0.00000E+00	0.00000E+00	-3.2478	-0.11693
1973	-0.13493	0.97137E-01	-3.2573	-0.10588
1974	-0.51715	-0.71938E-01	-3.2964	-0.94824E-01
1975	-0.47340	-0.73204E-01	-3.3445	-0.64990E-01
1976	-0.46776	-0.13286	-3.3371	-0.36113E-01

X2: X2 = LOG (PI/PM)

X3: X3 = LOG (PX/PM)

Y1: Y1 = LOG (L/K)

Y2: Y2 = LOG (H/K)

Table A-II - 18: Human Capital Income, Income for Capital, Income for Labor and Computed Variable.

Year		Y3		YH		YK		YL
1948		-4.2831		155.11		68.531		141.44
1949		-4.1832		148.25		71.473		141.32
1950		-4.1047		155.36		63.463		154.84
1951		-4.0605		172.43		93.723		181.00
1952		-3.9623		184.59		63.269		195.70
1953		-3.8157		194.21		73.366		209.57
1954		-3.7192		202.86		72.468		208.40
1955		-3.6620		214.64		118.07		224.91
1956		-3.5932		224.14		109.23		243.51
1957		-3.5115		234.80		109.87		256.48
1958		-3.4301		245.25		118.49		258.25
1959		-3.3554		255.63		109.10		279.58
1960		-3.2861		270.06		116.92		294.93
1961		-3.2204		279.20		114.34		303.57
1962		-3.1660		292.34		126.25		325.10
1963		-3.1176		305.93		139.19		342.88
1964		-3.0712		324.87		158.43		367.96
1965		-3.0328		346.96		170.88		396.54
1966		-3.0046		368.08		180.60		439.29
1967		-2.9789		404.17		203.93		471.92
1968		-2.9560		444.15		231.40		519.82
1969		-2.9393		477.23		201.55		571.35
1970		-2.9245		519.67		159.93		609.15
1971		-2.9125		557.34		164.97		650.27
1972		-2.9117		596.09		344.10		715.14
1973		-2.9270		650.35		437.13		799.19
1974		-2.9499		723.60		360.33		875.77
1975		-2.9617		806.13		321.73		931.08
1976		-2.9764		882.01		505.85		1 036.8

Y3: Y3 = LOG (RD/K)

YH: Human Capital Income, Inputed (Billions of Current Dollars).

YK: Income for Capital (Billions of Current Dollars).

YL: Labor Income and Compensation of Employers (Billions of Current Dollars).

Table A-II - 19: R&D Income and National Income, Billions of Current Dollars.

Year		YRD		YT				
1948		0.54100		365.63				
1949		0.34200		361.38				
1950		0.47800		374.14				
1951		0.57000		447.72				
1952		0.57300		444.53				
1953		1.2620		478.41				
1954		1.2840		485.01				
1955		1.3140		558.92				
1956		1.9850		578.87				
1957		1.9290		603.07				
1958		2.0040		623.99				
1959		2.1730		646.48				
1960		2.4290		684.34				
1961		2.4890		699.60				
1962		2.6390		746.33				
1963		2.7390		790.75				
1964		2.9060		854.16				
1965		3.2460		917.63				
1966		3.6430		991.62				
1967		4.0570		1084.1				
1968		4.4090		1199.8				
1969		4.8040		1254.9				
1970		4.5570		1293.3				
1971		4.2200		1376.8				
1972		4.2330		1659.6				
1973		4.7720		1891.4				
1974		4.8730		1964.6				
1975		4.2410		2063.2				
1976		4.4470		2429.1				

YRD: R&D Income (Net Business Investment in R and D).

YT: National Income.

APPENDIX C

Computer Program for Model 1

Table A-III-1: Computer Key

Key as to how the computer program is connected with the dissertation model(s):

Coefficients

G = γ

H = ϕ

D = δ

Elasticities

N = elasticities of transformation θ ,
elasticities of complementarity σ ,
elasticities of intensity ψ

E = own/cross elasticities of substitution

LINE 0 TIME SERIES PROCESSOR WHARTON VERSION 3.5B1 NOV 1980 DEC10 27-SEP-82 00:15 CHAROS

PROGRAM

```
LINE  *************************************************************************************

      NAME,CHAROS;
  1.  SMPL 1 29;
  2.  READ( 40, 101) SC  SH  SI  SL  SRD
  2.  SX X1  X2  X3  Y1  Y2  Y3  ;
  3.  PRINT SC  SH  SI  SL  SRD  SX  X1  X2  X3
  3.  Y1  Y2  Y3  ;
  4.  101 FORMAT '( 12F )' ;
  4.  SMPL 1 29;
  5.  PARAM A11 A12 A13 A14 A15 A16
  5.  G11  G12  G13  G22  G23  G33  D11  D12  D22
  5.  D13 D23 D33 H11 H12 H13 H22 H23 H33 ;
  6.  FRML  EQ1  SC= A11 +G11 *X1 +G12 *X2 +G13 *X3
  6.  +D11*Y1+D12*Y2+D13*Y3  ;
  6.  FRML  EQ2  SI= A12 +G12 *X1 +G22 *X2 +G23 *X3
  6.  +D12*Y1+D22*Y2+D23*Y3  ;
  6.  FRML  EQ3  SX= A13 +G13 *X1 +G23 *X2 +G33 *X3
  6.  +D13*Y1+D23*Y2+D33*Y3  ;
  6.  FRML  EQ4  SL= A14 +H11 *Y1 +H12 *Y2 +H13 *Y3
  6.  +D11*X1+D12*X2+D13*X3  ;
  6.  FRML  EQ5  SH= A15 +H12 *Y1 +H22 *Y2 +H23 *Y3
  6.  +D12*X1+D22*X2+D23*X3  ;
  6.  FRML  EQ6  SRD= A16 +H13 *Y1 +H23 *Y2 +H33 *Y3
  6.  +D13*X1+D23*X2+D33*X3  ;
  6.  LSQ  (MAXIT=100)  EQ1  EQ2  EQ3  EQ4  EQ5  EQ6  ;
  7.  STOP  ; END  ;
```

EXECUTION

```
*************************************************************************************

              SAMPLE =          1        29
```

APPENDIX D

Coefficient Estimates of Model 1

COVARIANCE MATRIX OF TRANSFORMED RESIDUALS

	1	2	3	4	5	6
1	29.0094	0.109413	0.903552E-01	-0.201196E-01	0.147074	0.761070E-01
2	0.109413	29.2970	-0.745813E-02	0.568602E-01	0.319220E-01	-0.312259
3	0.903552E-01	-0.745813E-02	28.7273	0.285103	-0.152126	0.370623
4	-0.201196E-01	0.568602E-01	0.285103	28.8167	-0.163348E-01	-0.568198
5	0.147074	0.319220E-01	-0.152126	-0.163348E-01	29.1312	0.263289
6	0.761070E-01	-0.312259	0.370623	-0.568198	0.263289	28.9750

LOG OF LIKELIHOOD FUNCTION = 757.431

RIGHT-HAND VARIABLE	ESTIMATED COEFFICIENT	STANDARD ERROR	T-STATISTIC
A11	0.597587	0.457979E-01	13.0484
G11	-0.122863	0.621860E-01	-1.97574
G12	0.153870	0.635748E-01	2.42029
G13	0.635287E-01	0.124511E-01	5.10225
D11	0.935753E-02	0.151757E-01	0.616613
D12	0.439016E-02	0.153912E-01	0.285238
D13	-0.992370E-02	0.228196E-02	-4.34876
A12	0.452964	0.465823E-01	9.72396
G22	-0.170213	0.670565E-01	-2.53835
G23	-0.999416E-01	0.142816E-01	-6.99793
D22	0.242986E-01	0.161818E-01	1.50160
D23	0.104764E-01	0.226776E-02	4.61972
A13	0.646108E-02	0.757944E-02	0.852449
G33	0.355924E-01	0.739856E-02	4.81073
D33	0.417405E-03	0.805634E-03	0.518107
A14	0.235383	0.519277E-01	4.53290
H11	-0.587918E-01	0.154345E-01	-3.80912
H12	0.509782E-01	0.109485E-01	4.65618
H13	-0.101858E-01	0.224170E-02	-4.54378
A15	0.527502	0.373222E-01	14.1337
H22	0.112435	0.198047E-01	5.67717
H23	-0.130244E-01	0.168280E-02	-7.73973
A16	-0.380899E-01	0.110563E-01	-3.44509
H33	-0.211945E-02	0.126544E-02	-1.67487

APPENDIX E

Computer Program for Model 2

PROGRAM

```
LINE  ************************************************************************************

      NAME,CHAROS;
  1.  SMPL 1 29;
  2.  READ(40,101) SC SH SI SL SRD
  2.  SX X1 X2 X3 Y1 Y2 Y3;
  3.  101 FORMAT '(12F)' ;
  3.  READ(50,102) T ;
  4.  102 FORMAT '(1F)' ;
  4.  PRINT T ;
  5.  PRINT SC SH SI SL SRD SX X1 X2 X3 Y1 Y2 Y3 ;
  5.  SMPL 1 29;
  7.  PLOTS ;
  8.  PARAM A11 A12 A13 A14 A15 A16
  8.  G11 G12 G13 G22 G23 G33 D11 D12 D22
  8.  D13 D23 D33 H11 H12 H13 H22 H23 H33
  8.  B1 B2 B3 B4 B5 B6 ;
  9.  FRML EQ1 SC= A11+G11*X1+G12*X2+G13*X3
  9.  +D11*Y1+D12*Y2+D13*Y3+B1*T ;
  9.  FRML EQ2 SI= A12+G12*X1+G22*X2+G23*X3
  9.  +D12*Y1+D22*Y2+D23*Y3+B2*T ;
  9.  FRML EQ3 SX= A13+G13*X1+G23*X2+G33*X3
  9.  +D13*Y1+D23*Y2+D33*Y3+B3*T ;
  9.  FRML EQ4 SL= A14+H11*Y1+H12*Y2+H13*Y3
  9.  +D11*X1+D12*X2+D13*X3+B4*T ;
  9.  FRML EQ5 SH= A15+H12*Y1+H22*Y2+H23*Y3
  9.  +D12*X1+D22*X2+D23*X3+B5*T ;
  9.  FRML EQ6 SRD= A16+H13*Y1+H23*Y2+H33*Y3
  9.  +D13*X1+D23*X2+D33*X3+B6*T ;
  9.  LSQ (MAXIT=100) EQ1 EQ2 EQ3 EQ4 EQ5 EQ6 ;
 10.  RETRV BETA COEF V ;
 11.  GENR SCF=A11+G11*X1+G12*X2+G13*X3
 11.  +D11*Y1+D12*Y2+D13*Y3+B1*T ;
 12.  GENR SIF=A12+G12*X1+G22*X2+G23*X3
 12.  +D12*Y1+D22*Y2+D23*Y3+B2*T ;
 13.  GENR SXF=A13+G13*X1+G23*X2+G33*X3
 13.  +D13*Y1+D23*Y2+D33*Y3+B3*T ;
 14.  GENR SLF=A14+H11*Y1+H12*Y2+H13*Y3
 14.  +D11*X1+D12*X2+D13*X3+B4*T ;
 15.  GENR SHF=A15+H12*Y1+H22*Y2+H23*Y3
 15.  +D12*X1+D22*X2+D23*X3+B5*T ;
 15.  GENR SRDF= A16+H13*Y1+H23*Y2+H33*Y3
 16.  +D13*X1+D23*X2+D33*X3+B6*T ;
 17.  GENR SMF=1-SCF-SHF-SXF ;
 18.  GENR SKF=1-SLF-SHF-SRDF ;
 19.  MSD SMF SKF ;
 20.  PRINT SCF SIF SXF SLF SHF SRDF
 20.  SMF SKF ;
 21.  FRML W1 G14=0-G11-G12-G13 ;
 21.  FRML W2 G24=0-G12-G22-G23 ;
```

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21.  FRML W3 G34=0-G13-G23-G33 ;
21.  FRML W4 G44=G11+G22+G23+2*G12+2*G13+2*G23 ;
21.  FRML W5 H14=0-H11-H12-H13 ;
21.  FRML W6 H24=0-H12-H22-H23 ;
21.  FRML W7 H34=0-H13-H23-H33 ;
21.  FRML W8 H44=H11+H22+H33+2*H12+2*H13+2*H23 ;
21.  FRML W9 D14=0-D11-D12-D13 ;
21.  FRML W10 D24=0-D12-D22-D23 ;
21.  FRML W11 D34=0-D13-D23-D33 ;
21.  FRML W12 D44=D11+D22+D33+2*D12+2*D13+2*D23 ;
21.  FRML CC NCC=(G11+(.606417**2)-.606417)/.606417**2 ;
21.  FRML CI NCI=(G12+(.606417*.388814))/(.606417*.388814) ;
21.  FRML CX NCX=(G13+(.606417*.0366855))/(.606417*.0366855) ;
21.  FRML CM NCM=((-G11-G12-G13)+(.606417*(-.0320803)))/
21.  (.606417*(-.0320803)) ;
21.  FRML IX NIX=(G23+(.388814*.0366855))/(.388814*.0366855) ;
21.  FRML IM NIM=((-G12-G22-G23)+(.388814*(-.0320803)))/
21.  (.388814*(-.0320803)) ;
21.  FRML II NII=(G22+(.388814**2)-.388814)/(.388814**2) ;
21.  FRML XX NXX=(G33+(.0366855**2)-.0366855)/(.0366855**2) ;
21.  FRML XM NXM=((-G13-G23-G33)+(.0366855*(-.0320803)))/
21.  (.0366855*(.0320803)) ;
21.  FRML MM NMM=((G11+G22+G33+2*G12+2*G13+2*G23)+(-.0320803
21.  **2)-(-.0320803))/(-.0320803**2) ;
21.  FRML LH NLH=(H12+(.430454*.388978))/(.430454*.388978) ;
21.  FRML LRD NLRD=(H13+(.430454*.00282759))/(.430454*.00282759) ;
21.  FRML LK NLK=((-H11-H12-H13)+(.430454*.177741))/
21.  (.430454*.177741) ;
21.  FRML HK NHK=((-H12-H22-H23)+(.3888978*.177741))/
21.  (.3888978*.177741) ;
21.  FRML HRD NHRD=(H23+(.388978*.00282759))/(.388978*.00282759) ;
21.  FRML RDK NRDK=((-H13-H23-H33)+(.00282759*.177741))/
21.  (.0028759*.177741) ;
21.  FRML LL NLL=(H11+(.430454**2)-.430454)/(.430454**2) ;
21.  FRML HH NHH=(H22+(.388978**2)-.388978)/(.388978**2) ;
21.  FRML RDRD NRDRD=(H33+(.00282759**2)-.00282759)/(.00282759**2) ;
21.  FRML KK NKK=((H11+H22+H33+2*H12+2*H13+2*H23)+(.177741**2)-
21.  .177741)/(.177741**2) ;
21.  FRML CL NCL=(D11+(.606417*.430454))/(.606417*.430454) ;
21.  FRML CH NCH=(D12+(.606417*.388978))/(.606417*.388978) ;
21.  FRML CRD NCRD=(D13+(.606417*.00282759))/(.606417*.00282759) ;
21.  FRML CK NCK=((-D11-D12-D13)+(.606417*.177741))/
21.  (.606417*.177741) ;
21.  FRML IL NIL=(D12+(.388814*.430454))/(.388814*.430454) ;
21.  FRML IH NIH=(D22+(.388814*.388978))/(.388814*.388978) ;
21.  FRML IRD NIRD=(D23+(.388814*.00282759))/(.388814*.00282759) ;
21.  FRML IK NIK=((-D12-D22-D23)+(.388814*.177741))/
21.  (.388814*.177741) ;
21.  FRML XL NXL=(D13+(.0366855*.430454))/(.0366855*.430454) ;
21.  FRML XH NXH=(D23+(.0366855*.388978))/(.0366855*.388978) ;
21.  FRML XRD NXRD=(D33+(.0366855*.00282759))/(.0366855*.00282759) ;
21.  FRML XK NXK=((-D13-D23-D33)+(.0366855*.177741))/
21.  (.0366855*.177741) ;
21.  FRML LM NLM=((-D11-D12-D13)+(.430454*(-.0320803)))/
```

```
21.  ((.430454)*(-.0320803)) ;
21.  FRML HM NHM=((-D12-D22-D23)+(.388978)*(-.0320803)))/
21.  ((.388978)*(-.0320803)) ;
21.  FRML RDM NRDM=((-D13-D23-D33)+(.00282759)*(-.0320803)))/
21.  ((.00282759)*(-.0320803)) ;
21.  FRML MK NMK=((D11+D22+D33+2*D12+2*D13+2*D23)+(-.0320803)
21.  *(.177741))/((-.0320803)*(.177741)) ;
21.  ANALYZ W1 W2 W3 W4 W5 W6 W7 W8 W9 W10 W11 W12
21.  CC CI CX CM IX II IM XX XM MM LH LRD LK HRD HK RDK
21.  LL HH RDRD KK CL CH CRD CK IL IH IRD IK XL XH XRD XK
21.  LM HM RDM MK ;
22.  FRML CCC ECC=NCC*.606417 ;
22.  FRML III EII=NII*.388814 ;
22.  FRML XXX EXX=NXX*.0366855 ;
22.  FRML MMM EMM=NMM*(-.0320803) ;
22.  FRML LLL ELL=NLL*.430454 ;
22.  FRML HHH EHH=NHH*.388978 ;
22.  FRML RDR ERDRD=NRDRD*.00282759 ;
22.  FRML KKK EKK=NKK*.177741 ;
22.  FRML CII ECI=NCI*.388814 ;
22.  FRML CXX ECX=NCX*.0366855 ;
22.  FRML CMM ECM=NCM*(-.0320803) ;
22.  FRML ICC EIC=NCI*.606417 ;
22.  FRML IXX EIX=NIX*.0366855 ;
22.  FRML IMM EIM=NIM*(-.0320803) ;
22.  FRML XII EXI=NIX*.388814 ;
22.  FRML XCC EXC=NCX*.606417 ;
22.  FRML XMM EXM=NXM*(-.0320803) ;
22.  FRML MCC EMC=NCM*.606417 ;
22.  FRML MII EMI=NIM*.388814 ;
22.  FRML MXX EMX=NXM*.0366855 ;
22.  FRML LHH ELH=NLH*.388978 ;
22.  FRML LRDRD ELRD=NLRD*.00282759 ;
22.  FRML LKK ELK=NLK*.177741 ;
22.  FRML HLL EHL=NLH*.430454 ;
22.  FRML HRDRD EHRD=NHRD*.00282759 ;
22.  FRML HKK EHK=NHK*.177741 ;
22.  FRML RDLL ERDL=NLRD*.430454 ;
22.  FRML RDHH ERDH=NHRD*.388978 ;
22.  FRML RDKK ERDK=NRDK*.177741 ;
22.  FRML KLL EKL=NLK*.430454 ;
22.  FRML KHH EKH=NHK*.388978 ;
22.  FRML KRDRD EKRD=NRDK*.00282759 ;
22.  FRML CLL ECL=NCL*.430454 ;
22.  FRML CHH ECH=NCH*.388978 ;
22.  FRML CRDRD ECRD=NCRD*.00282759 ;
22.  FRML CKK ECK=NCK*.177741 ;
22.  FRML ILL EIL=NIL*.430454 ;
22.  FRML IHH EIH=NIH*.388978 ;
22.  FRML IRDRD EIRD=NIRD*.00282759 ;
22.  FRML IKK EIK=NIK*.177741 ;
22.  FRML XLL EXL=NXL*.430454 ;
22.  FRML XHH EXH=NXH*.388978 ;
22.  FRML XRDRD EXRD=NXRD*.00282759 ;
```

```
22.  FRML XKK EXK=NXK*.177741 ;
22.  FRML MLL EML=NLM*.430454 ;
22.  FRML MHH EMH=NHM*.388978 ;
22.  FRML MRDRD EMRD=NRDM*.0022759 ;
22.  FRML MKK EMK=NMK*.177741 ;
22.  FRML LCC ELC=NCL*.606417 ;
22.  FRML LII ELI=NIL*.388814 ;
22.  FRML LXX ELX=NXL*.0366855 ;
22.  FRML LMM ELM=NLM*(-.0320803) ;
22.  FRML HCC EHC=NCH*.606417 ;
22.  FRML HII EHI=NIH*.388814 ;
22.  FRML HXX EHX=NXH*.0366855 ;
22.  FRML HMM EHM=NHM*(-.0320803) ;
22.  FRML RDCC ERDC=NCRD*.606417 ;
22.  FRML RDII ERDI=NIRD*.388814 ;
22.  FRML RDXX ERDX=NXRD*.0366855 ;
22.  FRML RDMM ERDM=NRDM*(-.0320803) ;
22.  FRML KCC EKC=NCK*.606417 ;
22.  FRML KII EKI=NIK*.388814 ;
22.  FRML KXX EKX=NXK*.0366855 ;
22.  FRML KMM EKM=NMK*(-.0320803) ;
22.  ANALYZ CCC III XXX MMM LLL HHH RDR KKK
22.  CII CXX CMM ICC IXX IMM XII XCC XMM MCC
22.  MII MXX LHH LRDRD LKK HLL HRDRD HKK RDLL
22.  RDHH RDKK KLL KHH KRDRD CLL CHH CRDRD CKK
22.  ILL IHH IRDRD IKK XLL XHH XRDRD XKK MLL
22.  MHH MRDRD MKK LCC LII LXX LMM HCC HII HXX
22.  HMM RDCC RDII RDXX RDMM KCC KII KXX KMM ;
23.  GENR NCC=(G11+(SCF**2)-SCF)/(SCF**2) ;
24.  GENR NCI=(G12+(SCF*SIF))/(SCF*SIF) ;
25.  GENR NCX=(G13+(SCF*SXF))/(SCF*SXF) ;
26.  GENR NCM=((-G11-G12-G13)+(SCF*SMF))/(SCF*SMF) ;
27.  GENR NIX=(G23+(SIF*SXF))/(SIF*SXF) ;
28.  GENR NIM=((-G12-G22-G23)+(SIF*SMF))/(SIF*SMF) ;
29.  GENR NII=(G22+(SIF**2)-SIF)/(SIF**2) ;
30.  GENR NXX=(G33+(SXF**2)-SXF)/(SXF**2) ;
31.  GENR NXM=((-G13-G23-G33)+(SXF*SMF))/(SXF*SMF) ;
32.  GENR NMM=((G11+G22+G33+2*G12+2*G13+2*G23)+
32.  (SMF**2)-SMF)/(SMF**2) ;
33.  GENR NLH=(H12+(SLF*SHF))/(SLF*SHF) ;
34.  GENR NLRD=(H13+(SLF*SRDF))/(SLF*SRDF) ;
35.  GENR NLK=((-H11-H12-H13)+(SLF*SKF))/(SLF*SKF) ;
36.  GENR NHK=((-H12-H22-H23)+(SHF*SKF))/(SHF*SKF) ;
37.  GENR NHRD=(H23+(SHF*SRDF))/(SHF*SRDF) ;
38.  GENR NRDK=((-H13-H23-H33)+(SRDF*SKF))/(SRDF*SKF) ;
39.  GENR NLL=(H11+(SLF**2)-SLF)/(SLF**2) ;
40.  GENR NHH=(H22+(SHF**2)-SHF)/(SHF**2) ;
41.  GENR NRDRD=(H33+(SRDF**2)-SRDF)/(SRDF**2) ;
42.  GENR NKK=((H11+H22+H33+2*H12+2*H13+2*H23)+
42.  (SKF**2)-SKF)/(SKF**2) ;
43.  GENR NCL=(D11+(SCF*SLF))/(SCF*SLF) ;
44.  GENR NCH=(D12+(SCF*SHF))/(SCF*SHF) ;
45.  GENR NCRD=(D13+(SCF*SRDF))/(SCF*SRDF) ;
46.  GENR NCK=((-D11-D12-D13)+(SCF*SKF))/(SCF*SKF) ;
```

```
GENR NIL=(D12+(SIF*SLF))/(SIF*SLF) ;
GENR NIH=(D22+(SIF*SHF))/(SIF*SHF) ;
GENR NIRD=(D23+(SIF*SRDF))/(SIF*SRDF) ;
GENR NIK=((-D12-D22-D23)+(SIF*SKF))/(SIF*SKF) ;
GENR NXL=(D13+(SXF*SLF))/(SXF*SLF) ;
GENR NXH=(D23+(SXF*SHF))/(SXF*SHF) ;
GENR NXRD=(D33+(SXF*SRDF))/(SXF*SRDF) ;
GENR NXK=((-D13-D23-D33)+(SXF*SKF))/(SXF*SKF) ;
GENR NLM=((-D11-D12-D13)+(SLF*SMF))/(SLF*SMF) ;
GENR NHM=((-D12-D22-D23)+(SHF*SMF))/(SHF*SMF) ;
GENR NRDM=((-D13-D23-D33)+(SRDF*SMF))/(SRDF*SMF) ;
GENR NMK=((D11+D22+D33+2*D12+2*D13+2*D23)+
(SMF*SKF))/(SMF*SKF) ;
GENR ECC=NCC*SCF ;
GENR EII=NII*SIF ;
GENR EXX=NXX*SXF ;
GENR EMM=NMM*SMF ;
GENR ELL=NLL*SLF ;
GENR EHH=NHH*SHF ;
GENR ERDRD=NRDRD*SRDF ;
GENR EKK=NKK*SKF ;
GENR ECI=NCI*SIF ;
GENR ECX=NCX*SXF ;
GENR ECM=NCM*SMF ;
GENR EIC=NCI*SCF ;
GENR EIX=NIX*SXF ;
GENR EIM=NIM*SMF ;
GENR EXI=NIX*SIF ;
GENR EXC=NCX*SCF ;
GENR EXM=NXM*SMF ;
GENR EMC=NCM*SCF ;
GENR EMI=NIM*SIF ;
GENR EMX=NXM*SXF ;
GENR ELH=NLH*SHF ;
GENR ELRD=NLRD*SRDF ;
GENR ELK=NLK*SKF ;
GENR EHL=NLH*SLF ;
GENR EHRD=NHRD*SRDF ;
GENR EHK=NHK*SKF ;
GENR ERDL=NLRD*SLF ;
GENR ERDH=NHRD*SHF ;
GENR ERDK=NRDK*SKF ;
GENR EKL=NLK*SLF ;
GENR EKH=NHK*SHF ;
GENR EKRD=NRDK*SRDF ;
GENR ECL=NCL*SLF ;
GENR ECH=NCH*SHF ;
GENR ECRD=NCRD*SRDF ;
GENR ECK=NCK*SKF ;
GENR EIL=NIL*SLF ;
GENR EIH=NIH*SHF ;
GENR EIRD=NIRD*SRDF ;
GENR EIK=NIK*SKF ;
GENR EXL=NXL*SLF ;
```

```
100.  GENR EXH=NXH*SHF ;
101.  GENR EXRD=NXRD* SRDF ;
102.  GENR EXK=NXK *SKF ;
103.  GENR EML=NLM* SLF ;
104.  GENR EMH= NHM *SHF ;
105.  GENR EMRD =NRDM* SRDF ;
106.  GENR EMK=NMK *SKF ;
107.  GENR ELC =NCL* SCF ;
108.  GENR ELI=NIL *SIF ;
109.  GENR ELX=NXL* SXF ;
110.  GENR ELM= NLM *SMF ;
111.  GENR EHC =NCH* SCF ;
112.  GENR EHI=NIH*SIF ;
113.  GENR EHX=NXH* SXF ;
114.  GENR EHM= NHM *SMF ;
115.  GENR ERDC =NCRD* SCF ;
116.  GENR ERDI=NIRD*SIF ;
117.  GENR ERDX=NXRD* SXF ;
118.  GENR ERDM= NRDM *SMF ;
119.  GENR EKC =NCK* SCF ;
120.  GENR EKI=NIK *SIF ;
121.  GENR EKX=NXK* SXF ;
122.  GENR EKM= NMK *SMF ;
123.  PRINT NCC NCI NCX NCM NIX NIM NII NXX NXM NMM
123.  NLH NLRD NLK NHK NHRD NRDK NLL NHH NRDRD NKK
123.  NCL NCH NCRD NCK NIL NIH NIRD NIK NXL NXH NXRD NXK
123.  NLM NHM NRDM NMK ECC EII EXX EMM ELL EHH ERDRD EKK ECI
123.  ECX ECM EIC EIX EIM EXI EXC EXM EMC EMI EMX
123.  ELH ELRD ELK EHL EHRD EHK ERDL ERDH ERDK EKL
123.  EKH EKRD ECL ECH ECRD ECK EIL EIH EIRD EIK
123.  EXL EXH EXRD EXK EML EMH EMRD EMK ELC ELI ELX
123.  ELM EHC EHI EHX EHM ERDC ERDI ERDX ERDM
123.  EKC EKI EKX EKM ;
124.  STOP ;
125.  END ;
```

EXECUTION

****

SAMPLE = 1 29

APPENDIX F

Coefficient Estimates of Model 2

COVARIANCE MATRIX OF TRANSFORMED RESIDUALS

	1	2	3	4	5	6
1	29.0347	-0.723789E-01	0.281373E-01	-0.231289	0.232762E-01	0.768541E-01
2	-0.723789E-01	28.9513	0.962958E-01	-0.298899E-01	0.446571E-01	-0.132711
3	0.281373E-01	0.962958E-01	28.9118	0.188064	-0.484132E-01	0.208556
4	-0.231289	-0.298899E-01	0.188064	29.1703	0.103467	-0.377174
5	0.232762E-01	0.446571E-01	-0.484132E-01	0.103467	28.9703	0.307644
6	0.768541E-01	-0.132711	0.208556	-0.377174	0.307644	28.9391

LOG OF LIKELIHOOD FUNCTION = 810.181

RIGHT-HAND VARIABLE	ESTIMATED COEFFICIENT	STANDARD EFFOR	T-STATISTIC
A11	0.303023	0.749798E-01	4.04140
G11	0.455453	0.151525	3.00581
G12	-0.398238	0.156968	-2.53706
G13	-0.630567E-01	0.144099E-01	-4.37595
D11	-0.191896	0.377229E-01	-5.08698
D12	0.212751	0.373071E-01	5.70270
D13	-0.153471E-02	0.211243E-02	-0.726512
B1	-0.125576E-01	0.212028E-02	-5.92260
A12	0.771462	0.739385E-01	10.4338
G22	0.355331	0.163954	2.16725
G23	0.279987E-01	0.157565E-01	1.77695
D22	-0.192367	0.377166E-01	-5.10034
D23	0.297025E-02	0.210969E-02	1.40791
B2	0.125474E-01	0.213511E-02	5.87671
A13	-0.644478E-03	0.579708E-02	-0.111173
G33	0.371454E-01	0.461156E-02	8.05485
D33	-0.642103E-03	0.551164E-03	-1.16499
B3	0.131173E-02	0.122133E-03	10.7402
A14	0.774402	0.110220	7.02596
H11	0.170342	0.401045E-01	4.24744
H12	-0.143237	0.275312E-01	-5.20271
H13	0.472646E-03	0.136310E-02	0.346744
B4	0.849730E-02	0.112776E-02	7.53468
A15	0.677869E-01	0.718912E-01	0.942909
H22	0.188042	0.252806E-01	7.43819
H23	-0.185959E-01	0.245087E-02	-7.58747
B5	-0.743064E-02	0.988252E-03	-7.51898
A16	-0.121918E-01	0.804030E-02	-1.51633
H33	-0.245680E-02	0.118207E-02	-2.07839
B6	0.286111E-03	0.596199E-04	4.79892

APPENDIX G

Likelihood Ratio Test

APPENDIX G

Likelihood Ratio Test

This section of the thesis serves as a place of justification as to why we have chosen model 2 (model with technological trend over time) over model 1 (model without technology) in the estimation of the various coefficients and desirable elasticities. The criterion used was the likelihood ratio test. The likelihood ratio (λ) is the maximum value of the likelihood function for the constrained case divided by the maximum value of the likelihood function for the unconstrained case.

$$\lambda = \frac{\hat{L} \text{ (constrained)}}{\hat{L} \text{ (unconstrained)}}$$

Theory stibulates that -2 ($\ln \lambda$) is assymptotically χ^2 distributed with as many degrees of freedom (d.f.) as the number of restrictions. Thus we can compute χ^2 corresponding to the computed λ and compare it to some pre-assigned critical level of χ^2, and if the computed χ^2 is less than the critical value then we say that our restrictions are statistically significant.

In our case the constrained model is model 1 (since we restrict the technology coefficients to be equal to zero) and the unconstrained model is model 2.

At $\alpha = 0.05$ and since d.f = 8 (we have eight equations each with one restriction) the χ^2 critical value is 15.51.

From page 193 we find the $\ln \hat{L}$ (constrained) to be equal to 757.431 and from page 202 we find the $\ln \hat{L}$ (unconstrained) to be equal to 810.181.

Since -2 (757.431 - 810.181) > 15.51 this implies that the restricted model is rejected in favor of the unconstrained model.

APPENDIX H

Year-to-Year Elasticities

NCC	NCI	NCX	NCM	NIX	NIM
0.559569	-0.775540	-1.73006	0.899775	3.14908	0.546492
0.552716	-0.774641	-1.95831	0.904919	3.37427	0.561364
0.560552	-0.722662	-2.19920	0.875760	3.45075	0.452926
0.586079	-0.696811	-1.93798	0.773509	3.06106	0.866866E-01
0.576200	-0.708314	-2.06113	0.805952	3.21590	0.192573
0.567804	-0.717467	-2.17903	0.827705	3.36608	0.262884
0.551462	-0.741287	-2.20733	0.876542	3.53518	0.439068
0.562475	-0.721778	-2.21743	0.839088	3.43606	0.299684
0.582973	-0.700431	-2.11856	0.717432	3.20933	-0.150683
0.577898	-0.698065	-2.32979	0.724718	3.38609	-0.133900
0.570595	-0.723123	-2.09404	0.808834	3.29314	0.185588
0.576542	-0.711560	-2.17173	0.759383	3.29888	-0.247639E-02
0.570975	-0.714101	-2.21059	0.786202	3.36470	0.948459E-01
0.572389	-0.717649	-2.07989	0.789916	3.26465	0.112057
0.581476	-0.705241	-2.08132	0.715685	3.19734	-0.165430
0.585206	-0.699351	-2.04413	0.669384	3.14332	-0.338058
0.589955	-0.689283	-2.00902	0.573957	3.08181	-0.694322
0.597004	-0.681546	-1.94742	0.379387	2.99621	-1.41609
0.605431	-0.672483	-1.90067	-0.371230	2.91665	-4.20815
0.604964	-0.670904	-1.92960	-0.321054	2.93597	-4.01810
0.600142	-0.667188	-2.03470	0.567971E-01	3.02303	-2.61426
0.605731	-0.657684	-2.04180	-1.00776	2.99079	-6.55324
0.598989	-0.661970	-1.93209	0.358731	2.95369	-1.45610
0.601136	-0.660431	-1.83381	0.434459	2.87717	-1.15340
0.610504	-0.648949	-1.75584	0.987943E-02	2.77522	-2.66618
0.642318	-0.646808	-1.29661	3.22236	2.38363	8.69619
0.661896	-0.635942	-1.00237	1.80169	2.15518	3.65851
0.655596	-0.639040	-0.982766	3.34904	2.15936	8.89519
0.656434	-0.626161	-1.03776	2.35524	2.18032	5.51222
1	2	3	4	5	6

NII	NXX	NXM	NMM	NLH	NLRD
0.997182	1.38549	1.61657	9.63488	0.167825	1.89945
1.02399	4.28293	1.64654	9.36103	0.170424	2.10495
0.927444	6.96600	1.89316	11.0457	0.159504	1.97581
0.797432	2.52899	2.39827	14.2069	0.145080	1.65830
0.840461	4.34186	2.27930	13.6522	0.145207	1.49050
0.879997	6.26490	2.20642	13.0781	0.142876	1.45117
0.975860	7.67088	1.91356	11.0916	0.135469	1.45898
0.904417	7.09760	2.15713	12.7145	0.136410	1.41174
0.810639	4.71773	2.66598	14.2516	0.135127	1.36694
0.821926	7.71666	2.96604	14.3052	0.133218	1.35000
0.878869	5.02405	2.29303	13.6157	0.136114	1.35338
0.844158	5.69542	2.64251	14.3588	0.138993	1.33364
0.864923	6.50292	2.49908	14.0866	0.138726	1.33059
0.865403	4.75882	2.40730	14.0167	0.140004	1.33200
0.821201	4.34113	2.86205	14.2257	0.142338	1.31674
0.803081	3.74102	3.11939	13.2859	0.140543	1.30744
0.777664	3.14868	3.66854	8.73658	0.136864	1.30392

NII	NXX	NXM	NMM	NLH	NLRD
0.750706	2.22339	4.74456	-11.2444	0.138161	1.29616
0.720769	1.46938	8.98683	-223.681	0.138127	1.28330
0.719955	1.76995	8.77948	-202.897	0.141753	1.27612
0.726303	3.03347	6.81710	-76.8073	0.147100	1.27907
0.703131	2.90242	13.2551	-575.215	0.150430	1.28548
0.722774	1.99629	4.83138	-14.0476	0.152612	1.31775
0.716197	0.960928	4.24960	-3.58093	0.158231	1.35740
0.683551	-0.107246E-01	6.41771	-86.5392	0.159075	1.38228
0.624984	-3.69511	-8.49019	-1103.30	0.150409	1.40383
0.586252	-5.01181	-1.87720	-187.370	0.119095	1.47261
0.597779	-5.03526	-7.44500	-1192.15	0.126966	1.51842
0.584779	-4.87275	-3.99960	-451.067	0.132658	1.56078
7	8	9	10	11	12

NLK	NHK	NHRD	NRDK	NLL	NHH
0.596156	0.634617	-32.6892	94.9771	-0.430823	-0.311743
0.593988	0.633071	-40.3396	117.301	-0.430432	-0.311160
0.613490	0.634145	-37.2377	102.076	-0.423678	-0.318523
0.634558	0.632960	-26.3715	68.2550	-0.414454	-0.325399
0.632663	0.632418	-19.3193	51.1931	-0.415254	-0.325127
0.633420	0.634525	-17.6214	46.7793	-0.416688	-0.325058
0.632173	0.647367	-17.2160	45.5500	-0.426878	-0.322593
0.636929	0.639749	-15.9129	41.8728	-0.419395	-0.325254
0.644200	0.630776	-14.7638	38.2775	-0.409601	-0.327922
0.645661	0.631281	-14.0773	36.4296	-0.409475	-0.328133
0.638902	0.635822	-13.7542	36.4499	-0.415872	-0.326354
0.640426	0.627840	-13.2954	35.3172	-0.409169	-0.327593
0.639952	0.628864	-13.1072	34.8993	-0.410192	-0.327407
0.638787	0.628284	-13.1438	35.1481	-0.410235	-0.327245
0.640478	0.620364	-12.8458	34.3626	-0.403459	-0.328296
0.642947	0.619269	-12.5714	33.4091	-0.401585	-0.328711
0.647345	0.618790	-12.6003	32.9413	-0.399269	-0.329174
0.648340	0.613368	-12.4797	32.6161	-0.394631	-0.329409
0.650302	0.608002	-12.1465	31.6614	-0.389654	-0.329465
0.647716	0.604141	-11.8448	31.3068	-0.387916	-0.329488
0.643788	0.599535	-11.9881	32.1809	-0.386144	-0.329485
0.642810	0.592972	-12.4671	33.5466	-0.381493	-0.329478
0.639400	0.598145	-13.6592	36.8579	-0.386750	-0.329370
0.634994	0.595265	-15.4059	41.8922	-0.386314	-0.329182
0.636310	0.590965	-16.7986	45.2478	-0.382270	-0.329389
0.645232	0.595045	-18.0828	46.8044	-0.381041	-0.329471
0.667440	0.621865	-21.2464	49.2761	-0.391623	-0.328950
0.660792	0.621321	-22.9590	54.5102	-0.394030	-0.329437
0.658754	0.613831	-25.2715	60.4148	-0.388830	-0.329361
13	14	15	16	17	18

NRDRC	NKK	NCL	NCH	NCRD	NCK
-2227.22	-3.76100	0.248230	1.79346	-0.874815	0.816373
-3150.86	-3.78385	0.256399	1.78395	-1.28269	0.819021
-2626.99	-3.66704	0.260322	1.81676	-1.07298	0.822835
-1428.93	-3.54359	0.251087	1.87747	-0.477075	0.823078
-901.734	-3.55553	0.258936	1.86507	-0.851759E-01	0.824647
-791.125	-3.53702	0.264852	1.85500	0.161240E-01	0.827515
-783.197	-3.46545	0.264345	1.82273	0.451308E-01	0.834886
-684.363	-3.48190	0.265711	1.84993	0.114120	0.831450
-596.923	-3.48693	0.261788	1.89366	0.171129	0.826587
-557.743	-3.47354	0.266703	1.89014	0.214237	0.828356
-554.263	-3.49070	0.263438	1.86657	0.225066	0.829144
-521.247	-3.52705	0.268458	1.88325	0.251784	0.826010
-512.853	-3.52399	0.272175	1.87519	0.265618	0.827424
-515.919	-3.53499	0.270745	1.87545	0.261164	0.826557
-492.394	-3.56857	0.272605	1.89602	0.276614	0.822832
-474.647	-3.55783	0.272020	1.90554	0.291862	0.822550
-470.092	-3.53078	0.271220	1.91900	0.292603	0.822890
-459.211	-3.55325	0.271855	1.93389	0.298434	0.820257
-437.385	-3.56758	0.271877	1.95214	0.315821	0.817775
-423.970	-3.60531	0.274675	1.95079	0.331279	0.815913
-432.314	-3.65656	0.281064	1.94287	0.325573	0.814254
-451.746	-3.69738	0.282765	1.95343	0.299621	0.810918
-518.383	-3.69610	0.281194	1.93446	0.233987	0.812431
-614.811	-3.74252	0.280012	1.93132	0.135568	0.809512
-686.072	-3.75681	0.277913	1.94738	0.585121E-01	0.806734
-746.634	-3.67609	0.255529	1.99132	-0.300925E-01	0.804742
-917.893	-3.37944	0.226380	2.02615	-0.203525	0.817271
-1050.15	-3.43157	0.227220	2.00639	-0.306445	0.815558
-1205.22	-3.48738	0.234369	2.01073	-0.428603	0.812427
19	20	21	22	23	24

NIL	NIH	NIRD	NIK	NXL	NXH
2.47764	-0.271918	7.43283	0.610782	0.896492	1.19071
2.49014	-0.281226	8.98537	0.604594	0.886832	1.20827
2.41482	-0.274107	7.92173	0.630542	0.880987	1.22941
2.31182	-0.253507	5.51654	0.662127	0.896520	1.21165
2.33944	-0.275181	4.42397	0.654451	0.890654	1.22262
2.36619	-0.295856	4.19182	0.650525	0.884792	1.23390
2.45191	-0.324269	4.28981	0.644718	0.878163	1.23786
2.38818	-0.310439	3.92358	0.652595	0.881820	1.23879
2.30564	-0.289227	3.55950	0.665561	0.890894	1.23057
2.31205	-0.298922	3.45428	0.665168	0.882786	1.24838
2.36207	-0.307863	3.50342	0.655281	0.888496	1.22900
2.32392	-0.303643	3.36380	0.656699	0.888229	1.23558
2.33891	-0.312654	3.35764	0.653978	0.885782	1.23976
2.33889	-0.310841	3.36796	0.652823	0.890627	1.22920
2.29518	-0.301160	3.24850	0.656067	0.893378	1.22927
2.27981	-0.298336	3.17322	0.659882	0.895555	1.22680
2.25896	-0.294746	3.13325	0.666428	0.897836	1.22489

NIL	NIH	NIRD	NIK	NXL	NXH
2.23136	-0.288001	3.07107	0.668604	0.901671	1.22015
2.20130	-0.281148	2.97051	0.672220	0.905081	1.21667
2.19681	-0.279470	2.92619	0.668835	0.904403	1.21876
2.19668	-0.279946	2.95968	0.662917	0.900763	1.22719
2.17209	-0.270687	2.99797	0.663122	0.902017	1.22737
2.19569	-0.267923	3.22473	0.659771	0.903881	1.21813
2.19086	-0.256283	3.49589	0.656498	0.907408	1.20908
2.16142	-0.242723	3.64347	0.661091	0.911570	1.20253
2.11991	-0.216197	3.70503	0.679762	0.928847	1.16539
2.11436	-0.205504	4.02637	0.713025	0.937860	1.14389
2.12824	-0.198294	4.32965	0.706415	0.937820	1.14136
2.10730	-0.192157	4.60678	0.704236	0.936785	1.14568
25	26	27	28	29	30

NXRC	NXK	NLM	NHM	NFDM	NMK
-12.5041	0.871591	1.51642	1.59425	7.61308	-1.78794
-17.1740	0.858571	1.49431	1.56816	8.79170	-1.68825
-16.4488	0.853629	1.62811	1.75617	10.0390	-2.36170
-9.67690	0.874474	2.08413	2.38487	11.9794	-4.72291
-7.37659	0.867142	1.94201	2.19889	8.08315	-3.98077
-7.06616	0.861202	1.84857	2.07599	6.83148	-3.44883
-7.27309	0.859586	1.63735	1.77712	5.24790	-2.19644
-6.45663	0.860707	1.80324	2.01366	5.97603	-3.11996
-5.40874	0.868394	2.34351	2.77320	8.74594	-6.05222
-5.57066	0.859119	2.31694	2.74290	8.24608	-5.88809
-5.13712	0.867188	1.93627	2.20094	6.05805	-3.85295
-4.98049	0.863497	2.15235	2.51691	7.05202	-5.12428
-5.02903	0.860936	2.03366	2.35514	6.35549	-4.47666
-4.79694	0.866428	2.01390	2.32701	6.27460	-4.38835
-4.54709	0.866652	2.33701	2.79560	7.82749	-6.27668
-4.31505	0.869271	2.54161	3.09071	8.70018	-7.39684
-4.18783	0.872510	2.96587	3.70272	10.7982	-9.67544
-3.95623	0.875364	3.81375	4.93454	14.9208	-14.5205
-3.66591	0.878022	7.09804	9.69388	30.4227	-33.1018
-3.61061	0.875416	6.85847	9.37269	28.7347	-32.2246
-3.87011	0.868347	5.19169	6.99346	21.1911	-23.1993
-4.00542	0.867363	9.78936	13.7384	45.0713	-50.7761
-4.35863	0.871208	3.85693	5.04926	16.6333	-15.6584
-4.81565	0.874211	3.51127	4.54158	16.4819	-13.8463
-5.03177	0.878467	5.31777	7.17619	29.9076	-24.8232
-4.15036	0.904175	-8.35717	-12.5844	-65.4813	55.8389
-4.05733	0.924633	-2.38114	-3.88960	-26.0095	18.8455
-4.49925	0.923796	-9.01136	-13.2144	-85.9070	54.3924
-5.17066	0.920476	-4.71361	-7.22343	-53.7431	32.2784
31	32	33	34	35	36

ECC	EII	EXX	EMM	ELL	EHH
0.352856	0.354665	0.507479E-01	-0.890501	-0.174396	-0.132557
0.352013	0.360806	0.143342	-0.902993	-0.174411	-0.132591
0.352965	0.338514	0.218039	-0.824704	-0.174550	-0.131758
0.356885	0.307348	0.891365E-01	-0.601707	-0.174396	-0.129564
0.355277	0.317815	0.145080	-0.666627	-0.174423	-0.129705
0.353990	0.327298	0.199324	-0.711192	-0.174466	-0.129740
0.351869	0.349779	0.236356	-0.822471	-0.174513	-0.130738
0.353242	0.333093	0.221495	-0.734935	-0.174523	-0.129640
0.356361	0.310577	0.156052	-0.481955	-0.174182	-0.127712
0.355531	0.313325	0.237529	-0.493399	-0.174175	-0.127478
0.354401	0.327028	0.164853	-0.669846	-0.174443	-0.129002
0.355315	0.318707	0.183729	-0.565612	-0.174159	-0.128038
0.354457	0.323700	0.205735	-0.619961	-0.174213	-0.128207
0.354671	0.323812	0.157239	-0.628968	-0.174215	-0.128345
0.356113	0.313149	0.145058	-0.477231	-0.173795	-0.127281
0.356737	0.308731	0.127121	-0.385067	-0.173654	-0.126669
0.357556	0.302488	0.108870	-0.197638	-0.173464	-0.125735
0.358818	0.295806	0.791423E-01	0.176087	-0.173038	-0.124857
0.360392	0.288315	0.536608E-01	1.60072	-0.172516	-0.123679
0.360303	0.288110	0.639656E-01	1.50635	-0.172316	-0.123791
0.359396	0.289705	0.105253	0.794303	-0.172109	-0.124147
0.360449	0.283865	0.101111	2.81230	-0.171524	-0.123550
0.359163	0.288819	0.715947E-01	0.213390	-0.172182	-0.125055
0.359581	0.287164	0.357460E-01	0.635590E-01	-0.172130	-0.125714
0.361371	0.278896	-0.414568E-03	0.862520	-0.171626	-0.124967
0.367929	0.263848	-0.177116	-5.06261	-0.171465	-0.123441
0.372243	0.253759	-0.280637	-2.42754	-0.172730	-0.121271
0.370837	0.256772	-0.283097	-5.24085	-0.172978	-0.123121
0.371023	0.253374	-0.266774	-3.43971	-0.172423	-0.122659
37	38	39	40	41	42

ERDRC	EKK	ECI	ECX	ECM	EIC
-2.89125	-0.634462	-0.275850	-0.633689E-01	-0.831614E-01	-0.489044
-3.32622	-0.634275	-0.272946	-0.655411E-01	-0.872912E-01	-0.493351
-3.08851	-0.635075	-0.267419	-0.688359E-01	-0.653870E-01	-0.461364
-2.43815	-0.635500	-0.268566	-0.683061E-01	-0.327605E-01	-0.424314
-2.06864	-0.635479	-0.267844	-0.688711E-01	-0.393542E-01	-0.436661
-1.97942	-0.635511	-0.266848	-0.693279E-01	-0.450110E-01	-0.447295
-1.97282	-0.635540	-0.265701	-0.680126E-01	-0.649976E-01	-0.472990
-1.88765	-0.635546	-0.265828	-0.691996E-01	-0.485018E-01	-0.453286
-1.80807	-0.635547	-0.268354	-0.700772E-01	-0.242619E-01	-0.428161
-1.77069	-0.635544	-0.266103	-0.717142E-01	-0.249962E-01	-0.429459
-1.76731	-0.635547	-0.269076	-0.687111E-01	-0.397918E-01	-0.449134
-1.73464	-0.635524	-0.268645	-0.700581E-01	-0.299130E-01	-0.438525
-1.72645	-0.635527	-0.267251	-0.699372E-01	-0.346014E-01	-0.443308
-1.72952	-0.635514	-0.268526	-0.687232E-01	-0.354456E-01	-0.444678
-1.70574	-0.635450	-0.268930	-0.695469E-01	-0.240091E-01	-0.431910
-1.68748	-0.635474	-0.268853	-0.694605E-01	-0.194009E-01	-0.426318
-1.68275	-0.635519	-0.268110	-0.694649E-01	-0.129840E-01	-0.417756

	ERDRC	EKK	ECI	ECX	ECM	EIC
•	-1.67137	-0.635483	-0.268555	-0.693190E-01	-0.594120E-02	-0.409630
•	-1.64820	-0.635452	-0.269000	-0.694111E-01	0.265663E-02	-0.400306
•	-1.63372	-0.635343	-0.268481	-0.697351E-01	0.238357E-02	-0.399576
•	-1.64275	-0.635128	-0.266126	-0.705987E-01	-0.587367E-03	-0.399547
•	-1.66350	-0.634904	-0.265518	-0.711295E-01	0.492708E-02	-0.391365
•	-1.73198	-0.634912	-0.264522	-0.692923E-01	-0.544930E-02	-0.396945
•	-1.82476	-0.634602	-0.264804	-0.682166E-01	-0.750184E-02	-0.395050
•	-1.88937	-0.634494	-0.264778	-0.678733E-01	-0.984665E-04	-0.384126
•	-1.94197	-0.635027	-0.273062	-0.621497E-01	0.147861E-01	-0.370501
•	-2.08125	-0.635369	-0.275268	-0.561277E-01	0.233424E-01	-0.357647
•	-2.18092	-0.635499	-0.274495	-0.552540E-01	0.147229E-01	-0.361472
•	-2.29070	-0.635547	-0.271303	-0.568153E-01	0.179604E-01	-0.353912
	43	44	45	46	47	48

	EIX	EIM	EXI	EXC	EXM	EMC
•	0.115345	-0.505093E-01	1.12009	-1.09095	-0.149411	0.567365
•	0.112930	-0.541508E-01	1.18893	-1.24721	-0.158830	0.576323
•	0.108010	-0.338169E-01	1.25951	-1.38486	-0.141349	0.551474
•	0.107890	-0.367144E-02	1.17980	-1.18011	-0.101574	0.471018
•	0.107457	-0.940321E-02	1.21607	-1.27065	-0.111297	0.496853
•	0.107095	-0.142957E-01	1.25195	-1.35849	-0.119986	0.516021
•	0.108926	-0.325579E-01	1.26712	-1.40842	-0.141895	0.559292
•	0.107229	-0.173226E-01	1.26549	-1.39258	-0.124689	0.526958
•	0.106157	0.509575E-02	1.22958	-1.29504	-0.969207E-01	0.438554
•	0.104229	0.461833E-02	1.29081	-1.43332	-0.102301	0.445856
•	0.108057	-0.913028E-02	1.22539	-1.30061	-0.112809	0.502369
•	0.106419	0.975479E-04	1.24547	-1.33841	-0.104096	0.467998
•	0.106450	-0.417424E-02	1.25923	-1.37232	-0.109987	0.488068
•	0.107869	-0.502829E-02	1.22155	-1.28877	-0.108044	0.489457
•	0.106838	0.554969E-02	1.21924	-1.27466	-0.960133E-01	0.438306
•	0.106811	0.979800E-02	1.20840	-1.24609	-0.904098E-01	0.408051
•	0.106558	0.157069E-01	1.19873	-1.21761	-0.829895E-01	0.347860
•	0.106651	0.221759E-01	1.18062	-1.17046	-0.742998E-01	0.228023
•	0.106514	0.301147E-01	1.16669	-1.13140	-0.643123E-01	-0.220960
•	0.106105	0.298312E-01	1.17491	-1.14922	-0.651806E-01	-0.191213
•	0.104891	0.270354E-01	1.20582	-1.21849	-0.704990E-01	0.340131E-01
•	0.104189	0.320396E-01	1.20743	-1.21500	-0.648060E-01	-0.599685
•	0.105931	0.221189E-01	1.18029	-1.15857	-0.733911E-01	0.215112
•	0.107029	0.199159E-01	1.15362	-1.09693	-0.733782E-01	0.259880
•	0.107276	0.265733E-01	1.13232	-1.03932	-0.639641E-01	0.584765E-02
•	0.114254	0.399033E-01	1.00629	-0.742717	-0.389581E-01	1.84581
•	0.120660	0.473990E-01	0.932869	-0.563721	-0.243207E-01	1.01325
•	0.121405	0.391045E-01	0.927536	-0.555900	-0.327293E-01	1.89438
•	0.119366	0.420347E-01	0.944690	-0.586551	-0.304998E-01	1.33121
	49	50	51	52	53	54

EMI	ENX	ELH	ELRD	ELK	EHL
0.194380	0.592120E-01	0.713611E-01	0.246576E-02	0.100569	0.679350E-01
0.197798	0.551065E-01	0.726207E-01	0.222210E-02	0.995683E-01	0.590559E-01
0.165316	0.592567E-01	0.659795E-01	0.232292E-02	0.106247	0.657136E-01
0.334109E-01	0.845293E-01	0.577664E-01	0.282952E-02	0.113800	0.610476E-01
0.728201E-01	0.761610E-01	0.579284E-01	0.341931E-02	0.113076	0.609929E-01
0.977746E-01	0.701993E-01	0.570258E-01	0.363088E-02	0.113809	0.598215E-01
0.157376	0.589610E-01	0.549021E-01	0.367507E-02	0.115936	0.553816E-01
0.110372	0.673177E-01	0.543708E-01	0.389437E-02	0.116258	0.567645E-01
-0.577306E-01	0.947999E-01	0.526262E-01	0.414044E-02	0.117415	0.574624E-01
-0.510438E-01	0.912989E-01	0.517547E-01	0.428589E-02	0.118135	0.566660E-01
0.690578E-01	0.752407E-01	0.538034E-01	0.431537E-02	0.116324	0.570948E-01
-0.934946E-03	0.852481E-01	0.543248E-01	0.443868E-02	0.115395	0.591610E-01
0.354959E-01	0.790645E-01	0.543225E-01	0.447920E-02	0.115411	0.589183E-01
0.419289E-01	0.795579E-01	0.549097E-01	0.446528E-02	0.114840	0.594557E-01
-0.630835E-01	0.956351E-01	0.551849E-01	0.456140E-02	0.114049	0.613141E-01
-0.129961	0.105998	0.541669E-01	0.464826E-02	0.114839	0.607738E-01
-0.270070	0.126845	0.522782E-01	0.466753E-02	0.116518	0.594610E-01
-0.557991	0.168884	0.523677E-01	0.471757E-02	0.115953	0.605808E-01
-1.68330	0.328193	0.518489E-01	0.483584E-02	0.115831	0.611544E-01
-1.60795	0.317266	0.532577E-01	0.491738E-02	0.114143	0.629691E-01
-1.04277	0.236535	0.554260E-01	0.486031E-02	0.111823	0.655642E-01
-2.64565	0.461764	0.564092E-01	0.473360E-02	0.110381	0.676352E-01
-0.581856	0.173272	0.579436E-01	0.440277E-02	0.109835	0.679433E-01
-0.462463	0.158083	0.604282E-01	0.402881E-02	0.107673	0.705030E-01
-1.08783	0.248081	0.603515E-01	0.380664E-02	0.107467	0.714191E-01
3.67125	-0.406956	0.563528E-01	0.365131E-02	0.111461	0.676825E-01
1.58359	-0.105114	0.439054E-01	0.333903E-02	0.125486	0.525283E-01
3.82087	-0.418580	0.474515E-01	0.315341E-02	0.122373	0.557381E-01
2.38834	-0.218970	0.494040E-01	0.296652E-02	0.120053	0.588259E-01
55	56	57	58	59	60

EHRD	EHK	ERDL	ERDH	ERDK	EKL
-0.424353E-01	0.107057	0.768889	-13.8998	16.0222	0.241322
-0.425847E-01	0.106120	0.852928	-17.1894	19.6627	0.240684
-0.437796E-01	0.109824	0.814004	-15.4035	17.6780	0.252750
-0.449972E-01	0.113514	0.697789	-10.5004	12.2407	0.267013
-0.443197E-01	0.113032	0.626070	-7.70715	9.14972	0.265744
-0.440893E-01	0.114008	0.607601	-7.03320	8.40502	0.265210
-0.433659E-01	0.118723	0.596451	-6.97720	8.35357	0.258441
-0.438966E-01	0.116773	0.587468	-6.34261	7.64299	0.265045
-0.447193E-01	0.114969	0.581289	-5.74988	6.97666	0.273945
-0.446918E-01	0.115504	0.574239	-5.46898	6.66543	0.274640
-0.438562E-01	0.115763	0.567693	-5.43676	6.63638	0.267995
-0.442505E-01	0.113128	0.567651	-5.19646	6.36365	0.272591
-0.441230E-01	0.113411	0.565113	-5.13252	6.29385	0.271794
-0.440622E-01	0.112952	0.565661	-5.15501	6.31886	0.271274
-0.445002E-01	0.110467	0.567202	-4.98037	6.11890	0.275895
-0.446944E-01	0.110609	0.565365	-4.84517	5.96728	0.278024
-0.451044E-01	0.111379	0.566492	-4.81297	5.92923	0.281242

EHRC	EHK	ERDL	ERDH	ERDK	EKL
-0.454217E-01	0.109698	0.568341	-4.73022	5.83325	0.284284
-0.457717E-01	0.108297	0.568168	-4.55547	5.63950	0.287916
-0.456425E-01	0.106464	0.566873	-4.45017	5.51701	0.287726
-0.455534E-01	0.104136	0.570097	-4.51702	5.58967	0.286944
-0.459084E-01	0.101823	0.577967	-4.67500	5.76053	0.289016
-0.456370E-01	0.102749	0.586665	-5.18609	6.33141	0.284662
-0.457254E-01	0.100936	0.604814	-5.88349	7.10346	0.282934
-0.462615E-01	0.998091E-01	0.620593	-6.37321	7.64199	0.285680
-0.470326E-01	0.102791	0.631709	-6.77496	8.08522	0.290348
-0.481746E-01	0.116917	0.649513	-7.83268	9.26442	0.294383
-0.476805E-01	0.115064	0.666585	-8.58054	10.0949	0.290066
-0.480325E-01	0.111866	0.692115	-9.41152	11.0101	0.292118
61	62	63	64	65	66

EKH	EKRD	ECL	ECH	ECRD	ECK
0.269846	0.123294	0.100483	0.762598	-0.113564E-02	0.138056
0.269763	0.123829	0.103893	0.760171	-0.135408E-02	0.137290
0.262316	0.120009	0.107249	0.751510	-0.126149E-02	0.142502
0.252025	0.116462	0.105654	0.747551	-0.814023E-03	0.147609
0.252294	0.117440	0.108763	0.744043	-0.155399E-03	0.147389
0.253257	0.117043	0.110893	0.740384	0.403427E-04	0.148683
0.262361	0.114737	0.108068	0.738706	0.113681E-03	0.153113
0.254993	0.115508	0.110570	0.737351	0.314806E-03	0.151764
0.245660	0.115942	0.111325	0.737499	0.518347E-03	0.150658
0.245250	0.115654	0.113445	0.734312	0.680145E-03	0.151562
0.251328	0.116224	0.110502	0.737819	0.717640E-03	0.150961
0.245366	0.117544	0.114267	0.736060	0.837998E-03	0.148835
0.246251	0.117483	0.115595	0.734290	0.894156E-03	0.149220
0.246413	0.117827	0.114977	0.735551	0.875502E-03	0.148597
0.240517	0.119038	0.117429	0.735093	0.958241E-03	0.146521
0.238673	0.118777	0.117627	0.734417	0.103764E-02	0.146918
0.236361	0.117917	0.117833	0.733005	0.104741E-02	0.148115
0.232487	0.118711	0.119203	0.733012	0.108620E-02	0.146699
0.228227	0.119310	0.120371	0.732778	0.119011E-02	0.145661
0.226960	0.120637	0.122015	0.732925	0.127655E-02	0.143784
0.225900	0.122284	0.125274	0.732057	0.123714E-02	0.141432
0.222357	0.123531	0.127135	0.732513	0.110332E-02	0.139249
0.227103	0.123147	0.125188	0.734472	0.781779E-03	0.139558
0.227330	0.124338	0.124765	0.737568	0.402371E-03	0.137265
0.224206	0.124608	0.124773	0.738815	0.161136E-03	0.136251
0.222942	0.121737	0.114985	0.746078	-0.782697E-04	0.139015
0.229256	0.111730	0.998478E-01	0.746958	-0.461478E-03	0.153655
0.232208	0.113205	0.997491E-01	0.749852	-0.636415E-03	0.151035
0.228601	0.114828	0.103929	0.748828	-0.814627E-03	0.148058
67	68	69	70	71	72

EIL	EIH	EIRD	EIK	EXL	EXH
1.00294	-0.115623	0.964888E-02	0.103036	0.362896	0.506303
1.00900	-0.119836	0.948544E-02	0.101346	0.359344	0.514866
0.994872	-0.113385	0.931343E-02	0.109200	0.362955	0.508549
0.972781	-0.100939	0.941277E-02	0.118745	0.377243	0.482442
0.982661	-0.109780	0.101489E-01	0.116970	0.374110	0.487828
0.990714	-0.118085	0.104881E-01	0.116882	0.370459	0.492486
1.00238	-0.131418	0.108057E-01	0.118237	0.359005	0.501673
0.993795	-0.123736	0.108234E-01	0.119117	0.366952	0.493761
0.980551	-0.112642	0.107817E-01	0.121309	0.378851	0.479254
0.983460	-0.116130	0.109664E-01	0.121704	0.375504	0.484991
0.991216	-0.121693	0.111709E-01	0.119306	0.372690	0.485802
0.989154	-0.118678	0.111955E-01	0.118328	0.378066	0.482920
0.993186	-0.122429	0.113029E-01	0.117940	0.376200	0.485465
0.993258	-0.121912	0.112904E-01	0.117363	0.378223	0.482093
0.988683	-0.116761	0.112534E-01	0.116825	0.384835	0.476593
0.985837	-0.114982	0.112816E-01	0.117863	0.387257	0.472822
0.981416	-0.112585	0.112158E-01	0.119953	0.390068	0.467876
0.978408	-0.109162	0.111776E-01	0.119577	0.395365	0.462479
0.974607	-0.105535	0.111937E-01	0.119735	0.400717	0.456705
0.975858	-0.104999	0.112757E-01	0.117865	0.401750	0.457855
0.979089	-0.105481	0.112464E-01	0.115146	0.401481	0.462397
0.976595	-0.101504	0.110396E-01	0.113869	0.405559	0.460250
0.977616	-0.101725	0.107742E-01	0.113335	0.402409	0.462498
0.976179	-0.978739E-01	0.103760E-01	0.111319	0.404313	0.461744
0.970400	-0.920865E-01	0.100337E-01	0.111653	0.409263	0.456229
0.953939	-0.810014E-01	0.963667E-02	0.117426	0.417972	0.436631
0.932575	-0.757609E-01	0.912950E-02	0.134056	0.413655	0.421704
0.934295	-0.741091E-01	0.899167E-02	0.130823	0.411701	0.426563
0.934465	-0.715622E-01	0.875591E-02	0.128342	0.415409	0.426669
73	74	75	76	77	78

EXRD	EXK	EML	EMH	EMRD	EMK
-0.162321E-01	0.147033	0.613841	0.677893	0.988287E-02	-0.301617
-0.181299E-01	0.143920	0.605494	0.658222	0.928100E-02	-0.282996
-0.193385E-01	0.147835	0.670761	0.726447	0.118026E-01	-0.409010
-0.165115E-01	0.156827	0.876973	0.949584	0.204402E-01	-0.846997
-0.169224E-01	0.154984	0.815722	0.877215	0.185433E-01	-0.711481
-0.176798E-01	0.154735	0.773987	0.828586	0.170926E-01	-0.619665
-0.183204E-01	0.157642	0.669371	0.720222	0.132191E-01	-0.402812
-0.178170E-01	0.157104	0.750385	0.802611	0.164852E-01	-0.569481
-0.163830E-01	0.158278	0.996574	1.08005	0.264913E-01	-1.10311
-0.176854E-01	0.157191	0.985537	1.06561	0.261791E-01	-1.07732
-0.163801E-01	0.157888	0.812192	0.869992	0.193166E-01	-0.701500
-0.165763E-01	0.155590	0.916129	0.983721	0.234708E-01	-0.923321
-0.169294E-01	0.155264	0.863714	0.922226	0.213947E-01	-0.807335
-0.160806E-01	0.155765	0.855243	0.912653	0.210344E-01	-0.788930
-0.157519E-01	0.154323	1.00670	1.08386	0.271158E-01	-1.11768
-0.153410E-01	0.155263	1.09905	1.19119	0.309312E-01	-1.32117
-0.149909E-01	0.157047	1.28853	1.41434	0.386536E-01	-1.74152

EXRD	EXK	EML	EMH	EMRD	EMK
-0.143993E-01	0.156555	1.67226	1.87036	0.543064E-01	-2.59692
-0.138142E-01	0.156392	3.14259	3.63881	0.114642	-5.89605
-0.139138E-01	0.154269	3.04664	3.52138	0.110726	-5.67875
-0.147060E-01	0.150828	2.31400	2.63508	0.805238E-01	-4.02961
-0.147495E-01	0.148941	4.40143	5.15173	0.165969	-8.71912
-0.145627E-01	0.149655	1.71711	1.91709	0.555739E-01	-2.66976
-0.142930E-01	0.148236	1.56451	1.73442	0.489191E-01	-2.34785
-0.138569E-01	0.148366	2.38749	2.72258	0.823622E-01	-4.19243
-0.107950E-01	0.156192	-3.76064	-4.71493	-0.170315	9.64589
-0.919969E-02	0.173841	-1.05023	-1.43394	-0.589747E-01	3.54314
-0.934389E-02	0.171080	-3.95597	-4.93867	-0.178409	10.0730
-0.982766E-02	0.167750	-2.09021	-2.69012	-0.102147	5.88248
79	80	81	82	83	84

ELC	ELI	ELX	ELM	EHC	EHI
0.156530	0.881264	0.328369E-01	-0.140155	1.13093	-0.967178E-01
0.163295	0.877404	0.296806E-01	-0.144145	1.13616	-0.990906E-01
0.163927	0.881401	0.275753E-01	-0.121560	1.14403	-0.100048
0.152896	0.891027	0.315987E-01	-0.882693E-01	1.14326	-0.977071E-01
0.159629	0.884646	0.297605E-01	-0.948272E-01	1.14978	-0.104058
0.165119	0.880059	0.281505E-01	-0.100526	1.15648	-0.110038
0.168670	0.878843	0.270581E-01	-0.121413	1.16302	-0.116228
0.166870	0.879557	0.275190E-01	-0.104233	1.16178	-0.114333
0.160026	0.883426	0.294687E-01	-0.792522E-01	1.15756	-0.110811
0.164079	0.881373	0.271734E-01	-0.799131E-01	1.16284	-0.113952
0.163622	0.879303	0.291540E-01	-0.952577E-01	1.15933	-0.114557
0.165447	0.877382	0.286535E-01	-0.847838E-01	1.16062	-0.114639
0.168964	0.875182	0.280238E-01	-0.895028E-01	1.16411	-0.117010
0.167762	0.875155	0.294278E-01	-0.903689E-01	1.16209	-0.116309
0.166951	0.875223	0.298521E-01	-0.783997E-01	1.16118	-0.114842
0.165821	0.876433	0.304313E-01	-0.736640E-01	1.16160	-0.114690
0.164379	0.878667	0.310441E-01	-0.670937E-01	1.16305	-0.114647
0.163393	0.879238	0.320953E-01	-0.597233E-01	1.16233	-0.113483
0.161839	0.880542	0.330530E-01	-0.507956E-01	1.16204	-0.112462
0.163590	0.879114	0.326849E-01	-0.509186E-01	1.16185	-0.111837
0.168316	0.876205	0.312540E-01	-0.536899E-01	1.16349	-0.111664
0.168263	0.876904	0.314232E-01	-0.478614E-01	1.16242	-0.109281
0.168617	0.877474	0.324167E-01	-0.585886E-01	1.15999	-0.107061
0.167495	0.878438	0.337551E-01	-0.606294E-01	1.15526	-0.102758
0.164503	0.881882	0.352373E-01	-0.530012E-01	1.15269	-0.990335E-01
0.146371	0.894959	0.445220E-01	-0.383477E-01	1.14066	-0.912716E-01
0.127314	0.915211	0.525156E-01	-0.308496E-01	1.13948	-0.889523E-01
0.128526	0.914172	0.527270E-01	-0.396152E-01	1.13491	-0.851760E-01
0.132467	0.913055	0.512872E-01	-0.359447E-01	1.13648	-0.832577E-01
85	86	87	88	89	90

EHX	EHW	ERDC	ERDI	ERDX	ERDM
0.436136E-01	-0.147348	-0.551646	2.64376	-0.458004	-0.703637
0.404386E-01	-0.151270	-0.816919	3.16601	-0.574783	-0.348074
0.384809E-01	-0.131121	-0.675666	2.89140	-0.514853	-0.749540
0.427057E-01	-0.101007	-0.290509	2.12620	-0.341072	-0.507365
0.408596E-01	-0.107370	-0.525092E-01	1.67289	-0.246483	-0.394695
0.392578E-01	-0.112893	0.100523E-01	1.55907	-0.224817	-0.371499
0.381411E-01	-0.131778	0.287954E-01	1.53760	-0.224099	-0.389144
0.386591E-01	-0.116396	0.716690E-01	1.44504	-0.201561	-0.345432
0.407043E-01	-0.937834E-01	0.104608	1.36374	-0.178909	-0.295767
0.384269E-01	-0.946051E-01	0.131801	1.31680	-0.171473	-0.284414
0.403270E-01	-0.108279	0.139789	1.30363	-0.168563	-0.298035
0.398587E-01	-0.991440E-01	0.155171	1.26998	-0.160666	-0.277787
0.392227E-01	-0.103651	0.164893	1.25659	-0.159105	-0.279710
0.406150E-01	-0.104419	0.161825	1.26021	-0.158499	-0.281558
0.410760E-01	-0.937840E-01	0.169407	1.23875	-0.151940	-0.262589
0.416871E-01	-0.895785E-01	0.177917	1.21989	-0.146627	-0.252159
0.423526E-01	-0.837628E-01	0.177339	1.21874	-0.144801	-0.244277
0.434317E-01	-0.772747E-01	0.179368	1.21012	-0.140823	-0.233659
0.444322E-01	-0.693722E-01	0.187997	1.18823	-0.133877	-0.217713
0.440455E-01	-0.695846E-01	0.197303	1.17099	-0.130494	-0.213332
0.425803E-01	-0.723229E-01	0.194970	1.18054	-0.134282	-0.219148
0.427576E-01	-0.671688E-01	0.178294	1.21033	-0.139535	-0.220359
0.436870E-01	-0.767007E-01	0.140310	1.28859	-0.156318	-0.252668
0.449771E-01	-0.784199E-01	0.810927E-01	1.40170	-0.179140	-0.284595
0.464847E-01	-0.715238E-01	0.346346E-01	1.48658	-0.194506	-0.298083
0.558603E-01	-0.577448E-01	-0.172375E-01	1.56415	-0.198938	-0.300468
0.640521E-01	-0.503929E-01	-0.114460	1.74282	-0.227191	-0.336975
0.641705E-01	-0.580926E-01	-0.173340	1.85977	-0.252961	-0.377660
0.627237E-01	-0.550839E-01	-0.242250	1.99603	-0.283084	-0.409830
91	92	93	94	95	96

EKC	EKI	EKX	EKM
0.516054	0.217247	0.319248E-01	0.165250
0.521616	0.213030	0.287348E-01	0.162854
0.518146	0.230146	0.267189E-01	0.176332
0.501203	0.255199	0.308217E-01	0.200030
0.508376	0.247476	0.289748E-01	0.194378
0.515903	0.241950	0.274000E-01	0.187549
0.532714	0.231088	0.264857E-01	0.162871
0.522162	0.240348	0.268601E-01	0.180343
0.505278	0.254994	0.287245E-01	0.204672
0.509616	0.253567	0.264449E-01	0.203084
0.514984	0.243832	0.284548E-01	0.189551
0.509059	0.247933	0.278556E-01	0.201851
0.513658	0.244750	0.272378E-01	0.197021
0.512161	0.244270	0.286282E-01	0.196917
0.503926	0.250178	0.289590E-01	0.210564
0.501420	0.253680	0.295382E-01	0.214384
0.498731	0.259220	0.301684E-01	0.218877

	EKC	EKI	EKX	EKM
.	0.492999	0.263455	0.311589E-01	0.227390
.	0.486793	0.268894	0.320648E-01	0.236886
.	0.485939	0.267653	0.316373E-01	0.239241
.	0.487618	0.264422	0.301293E-01	0.239915
.	0.482549	0.267713	0.302160E-01	0.248251
.	0.487173	0.263643	0.312450E-01	0.237859
.	0.484226	0.263227	0.325202E-01	0.239085
.	0.477523	0.269732	0.339577E-01	0.247408
.	0.460968	0.286974	0.433394E-01	0.256222
.	0.459624	0.308633	0.517750E-01	0.244158
.	0.461319	0.303436	0.519385E-01	0.239117
.	0.459192	0.305132	0.503943E-01	0.246146
	97	98	99	100

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END OF OUTPUT FOR USER CHAROS

WORKING SPACE AVAILABLE IS 27450 WORDS.