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Canada

Estimation of Import Demand and Export Supply Functions in a Multi-Output, Multi-input Model of the U.K., 1960-1986

Sahadeo Debiparshad

A Thesis

in

The Department

of

Economics

Presented in Partial Fulfillment of the Requirements
for the Degree of Doctor of Philosophy at
Concordia University
Montreal, Quebec, Canada

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ABSTRACT

ESTIMATION OF IMPORT DEMAND AND EXPORT SUPPLY FUNCTIONS IN A MULTI-OUTPUT, MULTI-INPUT MODEL OF THE U.K., 1960-86.

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This thesis investigates the foreign trade sector of the United Kingdom for the period 1960-1986. The majority of studies of this nature have confined attention to a single-equation framework in which imports and exports are, *inter alia*, functions of real income and relative prices. The present study deviates from this traditional approach by estimating import demand and export supply functions within a system of simultaneous equations. The model is derived from a five-input, three-output variable profit function, which is assumed to represent U.K. technology. The inputs, labour, non-human capital, R&D and capital, are fixed in the short run and the prices of exports, imports, investment goods and consumption goods are assumed to be exogeneous. This representation of the technology is similar to Samuelson's [1953-54] gross national product(GNP function). From this GNP function, the following functions can be derived as partial derivatives of the GNP function with respect to its arguments: the import demand and export supply functions, the supply equations for investment goods and consumption goods and the inverse demand functions for labour, non-human capital, human capital and R&D.

The entire system is then estimated simultaneously by a modified iterative Zellner's efficient estimation procedure (MIZEF) and the parameter estimates are used to compute the elasticities of transformation, the elasticities of complementarity, and the elasticities of intensity. These elasticities provide information on the substitution possibilities inherent in the U.K. technology.

No comprehensive study of this nature has ever been undertaken for the U.K. Thus the thesis fills a substantial gap in the literature. The thesis also makes a substantial contribution to economic statistics in terms of statistical series of human capital and research and development for the U.K.(Chapter 4). Finally, a third contribution of the thesis is the empirical result that both the neo-factor endowment theory and the neo-technology theory of trade provide a good explanation of U.K. export trade patterns Moreover, the low technology syndrome is confirmed.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF SYMBOLS

C	Personal Consumption Expenditures
e_c	Error term of Consumption Equation
e_H	Error term of Human Capital Equation
e_I	Error term of Investment Goods Equation
e_K	Error term of Capital Equation
e_L	Error term of Labour Equation
e_M	Error term of Import Equation
e_R	Error term of R&D Equation
e_X	Error term of Export Equation
H	Human Capital
I	Investment Expenditures
K	Capital (non-human)
L	Labour
M	Imports of Goods and Services
P	A Vector of Output Prices
P_C	Divisia Price Index of Consumption Goods
P_I	Divisia Price Index of investment Goods
P_M	Divisia Price Index of Imports
P_X	Divisia Price Index of Exports
R	Quantity of Research and Development
t	Time
W_H	Price of Human Capital
W_K	Price of Capital(Non-human)
W_L	Price of Labour

W_R	Price of R&D
X	Quantity of Exports
X_H	Divisia Quantity Index of Human Capital
X_K	Divisia Quantity Index of Capital
X_L	Divisia Quantity Index of Labour
X_R	Divisia Quantity Index of R&D
Y	A Vector of Outputs
ε	Own-and Cross-elasticities of Outputs and Inputs
θ	Elasticity of Transformation
ψ	Elasticity of Intensity
ω	Elasticity of Complementarity

Chapter 1

INTRODUCTION

Traditionally import and export functions have been analysed by estimating either linear or log-linear models of real income and relative prices (Khan et al. [1985]). Since this procedure has been criticized for its lack of theoretical foundation and its implicit restrictive assumptions (Thursby and Thursby [1984]), import and export functions have recently been derived within a more general theoretical setting. One such framework is that suggested by Samuelson [1953]. While this system-wide framework has been applied by Kohli [1978; 1981; 1982; 1983] to the Canadian, U.S., Swiss and Australian economies; by Mohabbat and Dalal [1983] to the Korean economy; by Mohabbat et al. [1984] to the Indian economy; by Mountain [1986] to the Swiss economy; and by Diewert and Morrison [1986] to the U.S. economy, no such attempt has ever been made for the United Kingdom. One objective of this thesis is to provide a set of empirical estimates of import demand and export supply for the United Kingdom within this framework.

A second objective is to introduce within this framework human capital and research and development (R&D) as factors of production and to analyse their effects on trade. Most studies on the relationship between trade, human capital and R&D have confined their attention to the viability of the neo-factor endowment and the neo-technology theories of international trade flows. For example, with respect to the United Kingdom, Smith et al. [1982] have found support for the neo-factor endowment theory; Greenhaigh [1990] and Lyons [1983] for the neo-technology theory and Cable et al. [1980] and Hughes [1986a,b] for both theories. These authors, however, have used a flow concept of R&D and human capital. In this study, a stock dimension of these variables will be used.

A third objective is to test the hypothesis that the United Kingdom has lost international competitiveness in technology-intensive or R&D-intensive exports. Albu [1980], Fagerberg [1988], Prais [1981] and Thirlwell [1986] have all suggested that the United Kingdom has fallen behind her main competitors through failing to increase R&D fast enough, i.e. at a rate comparable to its competitors, with consequent detrimental effects on R&D-intensive exports. These authors, however, did not actually test the hypothesis that a comparatively slow rate of increase in U.K. R&D expenditures led to a lower rate of increase in R&D-intensive exports.

The thesis is divided into seven chapters. In the remainder of this chapter the organization of this study is outlined and then in Chapter 2 there is a review of empirical studies related to the estimation of aggregate import demand functions and the neo-factor endowment and neo-technology theories of trade. Import demand is divided into two parts: import demand for final goods and import demand for intermediate goods. Four alternative specifications of the former, based on simplicity and frequency of use in the literature, are discussed. Their estimates using U.K. data are also analysed. This is done in Section 2.2. Import demand regarded as a demand for intermediate goods, is discussed within the profit or cost function framework and is given in Section 2.3. Section 2.4 discusses the neo-factor endowment theory and the neo-technology theory of trade.

These theories incorporate the roles of human capital and R&D in the explanation of international flows. Both a theoretical examination and an empirical application to the United Kingdom are undertaken. This is followed, in Section 2.5, by a discussion of the objectives of the present study.

Chapter 3 focuses on the theoretical derivation of the model to be estimated. The equations are derived as partial derivatives of a variable profit function with respect to its arguments. The chapter is divided into two sections. The first Section is devoted to the derivation of the theoretical model. The second focuses on the functional form of the variable profit function and the elasticity matrices to be estimated.

Chaper 4 is concerned with the definition and construction of the human capital and R&D variables. The market value of R&D and human capital stocks are not available, since these are not calculated by the Central Statistical Office. Thus a human capital series and a series for R&D must be calculated *de novo*. Section 1 of Chapter 4 describes the method of calculating the human capital variable and Section 2 the R&D variable.

Chapter 5 is devoted to the empirical model, its estimation, and the empirical results derived therefrom. It is divided into 6 Sections. The first Section introduces the chapter. The second Section presents the empirical model. The third Section is concerned with the sources and construction of data. This is followed by a discussion of the stochastic specification and the estimation technique to be applied, in the fourth Section. Model validation and empirical results are then reported in Section 5. Section 6 summarises Chapter 5.

Chapter 6 discusses the empirical results and comprises 2 Sections. The first Section deals with the calculation of various average partial elasticities and their standard errors. These include the elasticities of transformation, of complementarity, and of intensity; partial own-price and cross-price elasticities and the partial-cross quantity elasticities. The interpretation and analysis of these elasticities are the central theme of the second Section of Chapter 6.

Finally, in the last chapter of the thesis, which is Chapter 7, the various conclusions of the thesis are summarised.

Chapter 2

BACKGROUND

2.1 Introduction

This chapter seeks to bring together a diverse literature on two different themes: import demand functions, on the one hand, and the role of human capital and of research and development (R&D) in trade, on the other. The discussion of the first of these is divided in two parts: import demand treated as a demand for final goods and import demand regarded as a demand for intermediate goods. Section 2.2 is devoted to the former and Section 2.3 to the latter. In regard to the roles of human capital and of R&D, these will be examined within the framework of the neo-factor-endowment and the neo-technology theories of trade. This is done in Section 2.4. Finally having surveyed the literature, a number of propositions suggest themselves as central features of interest in a study of trade, particularly U.K. trade, on which the thesis concentrates. This is done in Section 2.5.

Generally speaking, theory will be discussed without a specific economy in mind; but when empirical work is discussed this will be done within the context of the U.K. economy. Of course, there is a natural interplay between the two in the literature with few exceptions. For example, the literature provides many different specifications of aggregate import demand functions for final goods, estimated for various countries over different time periods. This chapter focuses on four such functions, which are to be regarded as the most important in respect of empirical work on U.K. trade; moreover this choice ties in naturally with available empirical estimates for the United Kingdom, particularly the size and significance of parameter estimates.

Turning to import demand regarded as a demand for intermediate goods, this problem is tackled, *inter alia*, either *via* the profit or *via* the cost function. From the chosen function, share equations may be derived and used as a means of restricting parameters and hence of improving the efficiency of the corresponding estimates. While this approach has been applied by Kohli [1978; 1981; 1982; 1983], to the Canadian, U.S., Swiss and Australian economies; by Mohabbat and Dalal [1983] for the Korean economy; by Mohabbat et al. [1984] for the Indian economy; by Mountain [1986] for the Swiss economy; and by Diewert and Morrison [1986] for the U.S. economy, no such attempt has ever been reported for the United Kingdom. Thus no U.K. empirical estimates are available for comparison and discussion. Indeed one important contribution of this thesis is to provide a set of empirical estimates of import demand within the framework which treats import demand as a demand for intermediate goods.

2.2 Import Demand as a Demand for Final Goods

2.2.1 Functional Specifications

The simpliest specification of an aggregate import demand equation is derived from a simple utility function, and relates the quantity of imports (M) to the price of imports (P_m) relative to domestic prices (P_d) and domestic real income (RY). Symbolically,

$$M = f(P_m/P_d, RY). \qquad (1)$$

This approach has been adopted in empirical work by Leamer and Stern [1970], Thursby and Thursby [1984], and Khan et al. [1985]. The sign of the partial derivative $\partial M/\partial(P_m/P_d)$ is expected to be negative while the sign of $\partial M/\partial RY$ is generally expected to be positive[1]. If the general function (1) is approximated by a linear form, the import equation becomes

$$M_t = a_0 + a_1(P_m/P_d)_t + a_2 RY_t + e_t; \qquad (1a)$$

where the signs of the parameters are expected to obey

$$a_1 < 0, \quad a_2 \gtrless 0,$$

and e_t is a random error introduced, *inter alia*, in recoginition that (1a) is a linear approximation to (1). It is usually assumed that the e_t are generated by independent normal distributions with mean zero and common variance (σ^2), $e_t \sim [NID(0,\sigma^2)]$. When an exponential relationship is preferred as an approximation to equation (1), the demand for imports at time t is specified in double logarithmic form:

---

[1] The partial derivative of the demand for imports with respect to real income could also be negative. The reason for this ambiguity is that imports can be viewed as the difference between domestic consumption and domestic production of importables. As domestic income rises, consumption may rise slower (faster) than production. Thus the partial derivative could be negative (positive). For a theoretical examination of this, see Magge [1975]. Some further results are contained in Khan & Ross [1975].

$$\log M_t = b_0 + b_1 \log (P_m/P_d)_t + b_2 \log RY_t + u_t. \qquad (1b)$$

The parameters b_1 and b_2 are the relative price and real income elasticities and u_t is assumed to be NID$(0,\sigma^2)$. The coefficients b_1 and b_2 are assumed to obey $b_1 < 0$, $b_2 \gtrless 0$.

The other three specifications[2] to be discussed originate as extensions of equation (1), partly in response to criticisms of the implicit assumptions of the traditional import demand function (Magee [1975]), and partly because economic theory provides little or no guidance on the precise functional specification of the import demand relation (Thursby and Thursby [1984]).

The first variant is obtained by relaxing the restrictive homogeneity assumption (Murray & Ginman, [1976]; Mutti, [1977]; Stern, Baum and Greene, [1979]; Volker, [1982]; and Warner and Kreinen, [1982]). This approach allows for separate price effects of domestically produced substitutes with prices P_{dt} and imports with prices P_{mt}. Thus (1) becomes

$$M_t = f(RY_t, P_{mt}, P_{dt}); \qquad (2)$$

---

[2] Khan and Ross [1977] and Boylan et al [1980] employed the Box-Cox procedure to choose among alternative functional forms. In this approach a group of alternative applications are nested in a general function and statistical inference determines the most appropriate functional form. Both these studies found that the log linear functional form was preferred to the linear model.

yielding a form corresponding to (1b).

$$\log M_t = b_0 + b_1 \log RY_t + b_2 \log P_{mt} + b_3 \log P_{dt} + v_t \qquad (2a)$$

where b_1, b_2 and b_3 are the income, import price and domestic price elasticities respectively. Again $v_t \sim NID(0, \sigma^2)$. Zero homogeneity in prices[3] implies that $b_2 + b_3 = 0$ or $b_2 = -b_3$.

The second variant arises from a failure of equation (1) to make a distinction between the effects of cyclical and secular factors on the level of imports, since real income appears as the only demand variable in the equation. To capture the influence of secular and cyclical factors in the determination of import demand, Branson [1968], Marston [1971], Artus [1973], Khan and Ross [1975], Deppler [1977], Wilson and Tackacs [1979], Morris, Khan and Officer [1980] and Haynes and Stone [1982] split the income variable into its cyclical and secular components. Corresponding to (2), then, is

$$M_t = f(RY_t/RY_t^*, \; RY_t^*, \; P_{mt}/P_{dt}), \qquad (3)$$

where RY_t^* is trend or potential real income at time t, RY_t is actual

---

[3] Murray and Ginman [1976] have tested the homogeneity postulate for the U.S.A., Canada and Japan. They found that the empirical results rejected the homogeneity postulate of the traditional import demand function for all three countries. Goldstein, et al. [1980] have also tested this assumption for the United Kingdom. The likelihood ratio test and the t test were performed and both rejected the homogeneity restriction.

real income at the same time and RY_t/RY^*_t is regarded as the cyclical component of income at time t.

The third variant of (1) introduces some dynamic behaviour into the import demand relation as follows:

$$M_t = f(P_{mt}/P_{dt}, RY_t, M_{t-1}). \tag{4}$$

The relationship given by equation (1) is taken as an equilibrium relationship and thus implies instantaneous adjustment on the part of importers to changes in the relative price of imports and real income. Since there may be costs involved in the adjustment of actual imports to the desired flow (Khan [1974], Khan and Ross [1977]) or imports may be linked to contracts extending over a period of time (Argus, [1973]), there is likely to be a delayed response. This restrictive assumption of continuous equilibrium can be relaxed by specifying, for example, a partial-adjustment mechanism for imports in which the deviation of equilibrium imports from their previously observed level is a proportion of the difference between the demand for imports in period t and the corresponding actual level in the previous period. An alternative specification could be justified in terms of adaptive expectations. The point is that the justification for M_{t-1} appearing in (4) is slow adjustment to equilibrium; moreover, partial adjustment is not the only form of slow adjustment that could be considered (but it is undoubtedly the simplest).

The estimates for these models for the United Kingdom are examined in the next section.

2.2.2 Estimates for the United Kingdom

Marston [1971] estimated the linear form of equations (3) and (4). The trend and cyclical income coefficients were consistent with their theoretical specification and statistically significant for both equations. The secular income parameter estimates were 1.69 (0.07) and 0.99 (0.40) while those of the cyclical component of income were 1.55 (0.38) and 1.38 (0.39) respectively. The coefficient of the lag variable in equation (4) was also significant. The import price coefficients for both equations were incorrectly signed and statistically insignificant for both equations. Ross and Khan [1975] estimated the log-linear form of equation (3) using semi-annual data for the period 1960 to 1972. They found that both the trend income elasticity and current real income elasticity were positive and statistically significant, the former having a value of 0.89 (0.39) and the latter 0.94 (0.27). The relative price elasticity was found to be positive and statistically significant at the 10% level of significance. Goldstein and Khan [1976] used quarterly data for the period of 1955 to 1973 to estimate the log-linear form of equation (1) and equation (4). They found that the estimated price elasticity for both equations took the wrong sign and was not significantly different from zero. Income elasticity took the expected sign and was also significant at the 1% level. The coefficient of lagged imports in equation (4) was not significantly different from zero. Wilson and Takacs [1979] estimated the log-linear form of equation (2) for the period 1957-71 using quarterly data. They found that the estimates of the price parameters both took the wrong sign and were statistically insignificant. The income coefficient, on the other hand, was positive and significant. Goldstein, Khan and Officer [1980] estimated the log-linear form of equation (3) for the period 1951-1973. They found that the estimate of the import price elasticity took the wrong sign and was statistically insignificant. The cyclical income elasticity was positive and significantly different from zero. The trend income elasticity also had a positive sign but was not statistically significant. Thursby and Thursby [1984] estimated all four specifications for the period 1957.1 to 1977.3. They found that the import price variable did not take the anticipated sign and was statistically insignificant for all four models.

From the previous analysis, two shortcomings are worth noting. First, the fitted equations are not derivable from an underlying model of optimal behaviour, except in some vague sense. The inclusion of additional explanatory variables is purely in response to criticisms of the implicit restrictive assumptions of the basic model and thus lacks a solid theoretical foundation. Second, in all the empirical work of U.K. aggregate import demand functions, the coefficient of the import price variable consistently took a positive sign, implying an upward sloping demand schedule. Thursby and Thursby [1984] and Khan et al [1985] attributed this phenomenon to the presence of simultaneous equations bias in these models.

2.3 Import Demand as a Demand for Intermediate Goods

2.3.1 Preamble

More recently, import demand has been modelled as a demand for intermediate goods within a general theoretical framework. The treatment of imports as an input is justified on the grounds that most internationally traded goods are intermediate goods, and moreover, finished imports are generally still subject to domestic handling and transporation before reaching final demand (Kohli, 1982). This approach has been used by many authors (e.g. Kohli [1978, 1981, 1982, 1983]; Mohabbat and Dalal [1983]; Mohabbat et al [1984]; Mountain [1986]; Diewert and Morrison [1986]) to examine the foreign sectors of many economies. These authors have confined their scope of inquiry within a cost or profit function framework. A detailed discussion of these studies is given in the next section.

2.3.2 Selected Studies using the Translog Method

The cost function approach and the profit function approach are two means through which substitution possibilities between domestic inputs and outputs have been modelled. The cost function C(Q;W) is stated as follows:

$$\ln TC = a + \alpha_Q \ln Q + \sum_j \alpha_j \ln W_j + (1/2)\, B_{QQ} (\ln Q)^2 + 1/2 \sum_j \sum_k \alpha_{jk} \ln W_j \ln W_k + \sum_j B_{jQ} \ln Q \ln W_j \tag{5}$$

where TC = Total Cost, Q = output (exogenous) W_j= price of input j (exogenous).

The profit function $\pi(P;X)$ is stated as follows:

$$\begin{aligned} \ln \pi = {} & \alpha_o + \sum_{i}^{s} \alpha_i \ln P_i + \sum_{j}^{n} B_j \ln X_j \\ & + 1/2 \sum_{i}^{s} \sum_{h}^{s} \delta_{ih} \ln P_i \ln P_h \\ & + 1/2 \sum_{j}^{n} \sum_{k}^{n} \gamma_{jk} \ln X_j \ln X_k \\ & + \sum_{i}^{s} \sum_{j}^{n} \rho_{ij} \ln P_i \ln X_j \qquad (6) \end{aligned}$$

where π = profit, P_i = price of output i, X_j = quantity of input j.

From these equations, the share equations have been derived and estimated simultaneously. The parameter estimates are then used to compute various elasticities.

Table 1 provides a survey of selected studies on factor substitution in the context of the translog function. As shown in the table, different authors use different assumptions, specifications and data, and obtain different results. Burgess [1974b], Applebaum and Kohli [1979], Kohli [1982] and Diewert and Morrison [1986] suggest that imports and capital are complements in production whereas labour is a substitute for both imports and capital. On the other hand Burgess [1974a], Mohabbat and Dalal [1983], Mohabbat et al. [1984] and Mountain [1986] find that imports, capital and labour are substitutes for each other in production. Kohli [1983] suggests that imports are complements to capital and labour and Kohli [1978] finds, *inter alia*, imports to be labour intensive and export to be capital intensive.

Table 2.1: Overview of Selected Studies on Factor Substitution

Author	Country and Industry	Data	Assumptions and Cost or Profit Funcion	Type of Equation and Method of Estimation	Main Results
Burgess (1974a)	U.S. Economy	Time Series 1947-1968	linear homogenous and separable. Cost function (K,L,M)	SUE I3SLS	(K:L), K:M), (L:M) = substitutes
Burgess (1974b)	U.S. Economy	Time Series 1929-1969	linear homogenous and separable. Cost function (K,L,M)	SUI IZEF I3SLS	(L:M), (L:K) = sustitutes (K:M) = complements
Berndt & Wood (1975)	U.S. Manufacturing	Time Series 1947-1971	linear homogenous and separable. Cost function (K,L,E,M,T)	SUE I3SLS	(K:L), (K:MT), (L:E), (L:MT), (E:MT) = substitutes (K:E) = complements
Kohli (1978)	Canada Economy	Time Series (1949-1972)	linear homogenous and separable. Profit function (K,L,M)	SUE IZEF	(K:L), (K:M) = substitutes (L:M) = complements
Applebaum & Kohli (1979)	Canada Economy	1951-1972	linear homogenous and separable. Profit function (K,L,M)	SUE IZFF	(K:M) = complements (L:K), (L:M) = substitutes
Victor (1981)	U.S. Urban Transportation	Cross Section 1958	homothetic and separable. Cost function (R,L,F)	SUE IZEF	(L:F) = substitutes
Kohli (1982)	Switzerland Economy	Time Series (1948-1976)	linear homogenous and separable. Cost function & profit function (K,L,M)	SUE IZEF	(M:L), (K:L) = substitutes (M:K) = complements
Berndt & Wood (1982)	U.S. Manufacturing	Time Series (1948-1971)	linear homogenous and separable. Cost function (K,L,E)	SUE IZEF	(K:L), (L:E) = substitutes (K:E) = complements
McKay et al (1983)	Australia Agricultural Sector	Time Series (1952-1977)	linear homogenous and separable. Profit function (K,L,A)	SUE IZEF	(K:L) = substitutes

Mohabbat & Dalal (1983)	South Korea Economy	Time Series (1960-1973)	linear homogenous and separable. Cost function (K,L,M)	SUE IZEF	(M:L), (M:K), (K:L) = substitutes
Kohli (1983)	Australia Economy	Time Series (1960-1978)	linear homogenous and separable. Profit function (K,L,M)	SUE IZEF	(K:L) = substitutes (K:M), (L:M) = complements
Hunt (1984)	U.K. Industrial Sector	Time Series (1960-1980)	linear homogenous and separable. Cost function (K,L,E)	SUE IZEF	(K:L), (L:E) = substitutes (K:E) = complements
Mohabbat et al (1984)	India Economy	Time Series (1960-1975)	linear homogenous and separable. Cost function (K,L,M)	SUE IZEF	(K:L), (K:M), (L:M) = substitutes
Diewert & Morrison (1986)	U.S. Economy	Time Series (1945-1972)	linear homogenous and separable. Cost function (K,L,M)	SUE IZEF	(K:L), (L:M), (K:M) = substitutes
Chung (1987)	U.S. Manufacturing	Time Series (1947-1971)	non-homogenous and separable. Cost function (K,L,E,M,T)	SE IZEF	(K:L), (K:E), (K:MT), (L:E), (L:MT), (E:MT) = substitutes
Diewert & Wales (1987)	U.S. Manufacturing	Time Series (1947-1971)	linear homogenous and separable. Cost funtion (K,L,E)	SUE IZEF	(L:K) = substitutes

Notes:

Type of equation:

SUE = Seeming Unrelated Equations

SE = Single Equation

Method of Estimation:

I3SLS = Iterative three Stage Least Square Method

IZEF = Zellner's Iterative Efficient Method

Variable:

K = capital
L = labour
LD = land
E = energy
F = fuel
MT = material
M = imports

2.4 Research and Development and Human Capital

2.4.1 General

Over the last few years much research has been undertaken on the effects of R&D and scientific knowledge on the dynamic development of an economy. For example: Rosenberg [1982] has emphasised the relevance of learning as a means of increasing productivity, Krugman [1987] and Krugman and Baldwin [1988] have analysed the implications of learning for the international specialisation of countries; Kline and Rosenberg [1988] have highlighted the pervasive role of scientific knowledge on innovation, Metcalf and Gibbons [1988] and Malerba [1992] have pointed to the role of knowledge in the absorption and generation of new technologies by firms In these studies, learning has enhanced the stock of knowledge and hence the technological capabilities of firms. One aspect of this thesis is to look at the implications of the aggregate stock of knowledge on production and trade for the United Kingdom. Kaldor [1980] and Katrak [1982] have suggested that the United Kingdom is suffering from a low technology syndrome which affects her international competitiveness. A low technology syndrome implies that the United Kingdom has fallen behind its main competitors because it has failed to increase R&D fast enough. A detailed theoretical and empirical discussion of the roles of human capital and research and development within the neo-factor endowment and neo-technology framework is undertaken here.

2.4.2 The Neo-factor-endowment and Neo-technology Theories

The human capital or neo-factor endowment theory explains trade determination by recognising human capital as an important component of a country's capital endowment. The theory has its origin in the Leontief Paradox. Leontief [1956] found that U.S. imports tended to be more capital intensive than its exports. Since capital was relatively abundant in the U.S. this finding was contrary to Hecksher-Ohlin predictions. Johnson [1970,p14] attributed the Leontief Paradox "to a misspecification, based on the identification of 'captial' with capital equipment and 'labour' with human bodies regardless of skills." Johnson suggested that the paradox could be removed "by extending the concept of capital to include the capitalised value of productive knowledge created by research and development expenditures" [Johnson 1970,p14]. Leontief himself advocated the inclusion of human capital as a possible resolution of the paradox.

The neo-factor endowment theory, which assumes that techniques of production are the same across countries, postulates that a country that has an abundant supply of skilled labour will export products intensive in skilled labour and will import products intensive in unskilled labour (Kenen [1965], [1968], Kessing [1968], [1971], Hufbauer [1970]).

The neo-factor endowment theory does not consider changing technology. Technological knowledge is assumed identical across countries. The relative endowments of capital, skilled and unskilled labour in different countries determine production location. Inter-country shifts in production cannot be predicted. Factor endowments are usually considered fixed. The theory does not explain how these may change over time. "The inadequacies of the human-skills theory lie, therefore, in its failure to allow for a dynamically developing technology" (Hughes [1986] p22).

The neo-technology theory of trade, on the other hand, emphasises changes in technology and differences in technological knowledge in trade determination. The theory provides a framework that can, in principle, give an explanation as to how product and process innovation may create trade. The theory assumes that technical knowledge is not a costless or universally available good. The possession of such knowledge creates a temporary advantage for the country that has it (i.e. the exporting country). The neo-technology theory comprises two components: the technology-gap theory and the product life-cycle theory. The technology-gap theory (Posner [1961] and Vernon [1966]), postulates that a country that develops a new product (or process) may have a temporary monopoly in the relevant technological expertise. Consequently, it will increase exports of that item and/or will decrease imports of competing products. Imitation of the new product or process involves time and cost. During this time lag the innovative country will gain an advantage in production raising the demand for its product at home and abroad. Posner emphasises the imitation lag in trade creation. The imitation lag of a new product or process is predicated on the time required to start production and on the size of the learning gap. If there are many dynamic learning effects, it could take a long time before knowledge is identical across countries. The ability to imitate an innovation also depends on the stock of R&D knowledge that the imitator possesses. A technology-gap trade between the innovator and countries without R&D stocks will persist for a longer period than between the innovator and countries with R&D stocks (Keesing [1967], Mansfield, Romeo & Wagner [1979], Walker [1979]).

The product life-cycle theory (Hirsch [1965], Vernon [966]) originated in part as a consequence of the technology-gap theory's "rather naive view of the mechanism behind the transfer of production from one country to another; imitation was over-emphasised, capital mobility (and monopoly powers) underemphasised. As a consequence, the theory lacks precision in its prediction of the timing and direction of production transfers" (Walker [1979, p18]). The product life-cycle theory had been developed with reference to the U.S. market. In the initial stages of production of a new product, production will be located in the home market for two reasons. First, there is a high income group which may easily accept the new product. Second, a pool of skilled labour and of specialised scientific and engineering knowledge exists. Vernon [1966] stresses that production techniques of a new product are likely to be at an experimental stage and may undergo frequent changes in design and specification at this early stage. Thus the factor combination may include relatively large amounts of skilled labour and small amounts of physical capital. As the product attains a mature stage, the production process will have become more stable. Production-runs will become longer. The requirements of skilled labour will decline while those of physical capital may rise. Shifts in production occurs at this stage in order to take advantage of lower factor costs. Production may also be started by competitors. While the technology-gap theory stresses imitation lags, the product life cycle theory "emphasises the transition from product differentiation to product standardisation" (Haufbauer [1970, p190]).

There are, therefore, potential roles for skill and technology in explaining trade. These factors may give alternative or complementary explanations of trade flows. For example, R&D and skill are complementary in transforming scientific knowledge into a marketable product or they may provide an explanation of the trading patterns of different industries and between different countries. However, it is obvious that once technology difference is recognised the human-skills theory is inadequate and a more dynamic theory is required.

Thus, there are two principal differences between the neo-technology and the neo-factor endowment theories, as discussed above. First, the neo-factor endowment theory assumes the technology of an industry or country to be fixed. The technology-gap and life-cycle theories in contrast, stress changing technology and changing products. Second, the neo-factor proportions theory postulates that production location is determined by the relative amounts of skilled and non-skilled labour and of capital, in different countries. The theory cannot explain shifts in production from one country to another. Its inability to do so stems from the fact that it fails to take into account technology changes. The neo-technology theory, by contrast, does not take the rate of technological change as given; it depends on current and previous innovative effort determining inter-industry and inter-country differences in technology. Shifts in production from one country to another are explained through imitation and product standardisation.

2.4.3 Empirical Evidence

Empirical studies investigating the role of human capital in international trade flows have defined a human capital variable in one of two ways. First, wage differentials are used to reflect differences in human capital per person, presumably on the assumption that a difference in human capital is functionally related to a wage difference. The procedure is to calculate wage differentials relative to unskilled (or uneducated) labour and to capitalise these differentials at some appropriate discount rate. Second, inter-industry employment of different kinds of labour are used to reflect skill differentials. The empirical correlate of technological ability in these studies is R&D activity, defined either as the number of scientists and engineers in R&D activity as a percentage of the labour force of each industry or as R&D expenditures as a percentage of sales (or value added) for each industry.

These studies will be grouped into two categories. The first relates to the low technology syndrome and the second to the confirmation of the neo-factor endowment theory or the neo-technology theory of trade.

Pavitt [1981] reports, on the basis of industry-wide data on R&D and international patenting, that the United Kingdom has in recent years been lagging behind its international competitors in innovative activity. Katrak [1982] analyses the skill, R&D and capital intensities of exports, imports and foreign investment inflows and outflows. He finds that the skill intensity of exports is greater than that of imports in 1968 and 1978 and that the ratio becomes smaller in 1972.

Similar results are found for R&D in 1972 and 1978. He also finds that capital intensity has risen in both exports and imports but relatively more in exports. Katrak's prediction for direct investment also receives support. Most of the changes in the ratios reported are small and there is no test of their significance. Pavitt [1987, p.20] argues that "the main factor behind U.K.'s relatively slow rate of growth of industry-financed R&D has been the unwillingness or inability of British firms to commit an increasing share of output or profits to R&D at the same rate as foreign competitors". This implies that United Kingdom share of manufactured products has declined sharply as indicated by Dosi et al. [1990] who analysed U.K. market shares in world trade from 1899 to 1980.

With respect to skill intensities, the United Kingdom's performance has been equally disappointing. Albu [1980] observes that in the supply of well-qualified engineers and technologists the United Kingdom compares unfavorably with Japan and West Germany. Prais [1981] reaches a similar conclusion in a more detailed comparative study of United Kingdom and West Germany. Daly et al. [1985] have analysed the skill intensities of workers in the metal working trades for the United Kingdom and Germany. Steedman and Wagner [1987] have done likewise for the furniture industry while Prais and Wagner [1988] and Prais and Wagner [1993] have compared the skills intensities for mechanical fitters and electricians in the manufacturing sectors. In all these studies the skill intensities have been higher in Germany indicating that United Kingdom has lagged behind Germany in vocational training. The results are similar when the United Kingdom is compared to France.

Steedman [1987], Steedman [1988] and Steedman, Mason and Wagner [1991] have demonstrated that skill intensities of mechanical and electrical engineering, supervisory and technician skills are higher in France than in the United Kingdom.

These studies therefore suggest that the skill and R&D content of exports may be important in indicating sources of U.K. comparative advantage and that these might be changing over time. Nevertheless there are no direct tests of these hypotheses.

Cable and Rebelo [1980] provide a detailed study of U.K. trade in manufactured goods. These authors have found some evidence for the neo-technology theory. Their technology variable, measured as the ratio of R&D expenditures to sales, is positive and statisticallly significant for the export equations involving less developed countries, Japan, U.S., the E.E.C. and the world as a whole. R&D, however, is insignificant in the world export equation when a skill variable defined as the proportion of skilled and semi-skilled workers in the labour force is included. The latter variable is significant. Using measures of revealed comparative advantage, R&D was not significant. Cable & Rebelo conclude that their overall results indicate some support for both technology and skill as an explanation of trade flows.

Smith et al. [1982] have conducted a similar study but with different results. Three different skilled labour variables: managerial, professional and technical, and skilled manual have been used to test the skill theory. The technology theory is tested using R&D expenditures as a proportion of output. Other independent variables are capital intensity, concentration, average plant size and the proportion of foreign-owned firms. Many measures are used for the dependent variable: the ratio of the trade balance to consumption [(X-M)/C], exports/sales (X/S), and imports/consumption (M/C), all for 1979. Unlike the results of Cable and Rebelo, the R&D variable is siginificant in only one equation, which excludes the professional and technical labour variable. Managerial and skilled manual labour are statistically insignificant in net trade, export and import equations. The professional and technical skill (PT) is found to be positive and statistically significant, while managerial and skilled manual labour are not significant in the net trade equation. The conclusion of the study implies that PT is a major influence on trade, while R&D has no effect.

Lyons [1983] finds a positive role for the R&D variable. He estimates imports and exports sales ratios in 1963 and 1980 for trade with the world, the EEC and non-EEC countries. R&D is measured as a percentage of sales. Two measures of skill are used: those with A-level (i.e. the Advanced level of the General Certificate of Education, equivalent to a national examination at the end of two years of CEGEP) and post A-level qualifications as a proportion of the work force, and average wages and salaries per employee. Lyons finds that the skill variable reflecting the A-level qualification has a positive effect on both exports and imports. The average wage variable is insignificant. R&D also has a positive influence on exports and imports. When looking at non-EEC exports, R&D was no longer significant, nor is it significant for EEC imports.

Hughes [1985] investigates the roles of R&D expenditures and skilled labour in determining U.K. exports for 1978. Hughes finds both aspects of the effects of technology, the intensity of R&D and the gap between U.K. and foreign R&D, have positive effects on exports. Her two human skills variables, skilled manual labour and skilled non-manual labour, have positive coefficients but only skilled manual labour is significant. Greenhalgh [1990], in analysing the relationship between trade performance and innovation for 31 industrial groups, finds support for the neo-technology theory of trade.

2.5 Summary and Objectives

It is clear from the discussion in Section 2.2 above that single-equation studies of the demand for imports, treated as a demand for final goods, are somewhat simplistic and lack an appealing theoretical foundation. Moreover, it is not clear how the theory could be extended to examine the role of R&D and human capital in import demand. The alternative approach, treating import demand as a demand for intermediate goods, allows a richer theoretical formulation which is sufficiently adaptable to permit the incorporation of human capital and R&D into the analysis. For these reasons, the approach to U.K. import demand in this thesis is based on the notion of treating imports as a demand for intermediate goods. As a consequence of using this approach it is quite natural, in a more general setting, to regard imports into the United Kingdom as an input into U.K. technology, represented by a variable profit function, and exports as an output of U.K. technology. Such treatment of imports and exports in regard to U.K. trade has not been undertaken before and hence represents one contribution of this thesis.

Another contribution of the thesis lies in the explicit introduction of the endowment of human capital and of R&D into the model: these factors are defined in the stock dimension and have not been modelled in this way before.

The model to be derived in Chapter 3 is a five-input, three-output, variable profit function model. The inputs are capital, labour, human capital, R&D and imports. The treatment of imports as an input is justified on the grounds that most internationally traded goods are intermediate goods and moreover, finished imports are generally still subject to domestic handling and transportation before reaching final demand (Kohli [1982]). The outputs of the model are exports, consumption goods and investment goods. The inputs, labour, non-human capital, R&D and human capital are fixed in the short-run and the prices of imports, exports, investment goods and consumption goods are exogenous. This representation of technology is thus similar to Samuelson's [1953-54] gross national product function. From this GNP function, the import demand and export supply functions, the supply equations for investment goods and consumption goods, the inverse demand functions for labour, non-human capital, human capital and R&D can be derived as the partial derivatives of the function with respect to its arguments. The entire system may then be estimated simultaneously using U.K. data and the parameter estimates used in the computation of the following partial elasticites:

a) The elasticities of transformation between variable outputs and their corresponding partial price elasticities, particularly with referece to imports and exports.

b) The elasticities of complementarity between fixed inputs and their corresponding partial inverse price elasticities, particularly with respect to human capital and R&D.

c) The elasticities of intensity and their corresponding two sets of partial elasticities linking variable outputs with fixed inputs, particularly with respect to exports, imports, R&D and human capital.

Information on these elasticities is essential to assess quantitatively the effects of price and policy changes. The ultimate objective of this thesis is to compute and analyse these elasticities for the United Kingdom for the period 1960-1986. No study of this nature has ever been undertaken for United Kingdom before. Thus the third contribution of the thesis is to bridge the gap in empirical knowledge on a wide range of elasticities relevant to the analysis of U.K. trade.

Chapter 3

THEORETICAL MODEL AND ITS FUNCTIONAL FORM

3.1 Introduction

This chapter presents the theoretical derivation of the model and discusses its functional form. A multi-input, multi-output variable profit function is assumed to represent the production technology in the United Kingdom. For a given technology and a given endowment of fixed factors of production, the variable profit function expresses the optimum level of profit of a firm in terms of the fixed factors, the prices of outputs and variable inputs. A brief exposition of the theory of the profit function demonstrating how the supply functions and the factor demand functions may be derived from an arbitrary profit function is presented in Section 3.2.

With respect to the functional form of the model, the translog function is chosen over other alternatives: the Cobb-Douglas, the Constant Elasticity of Substitution (CES), the Generalized Leontief (GL) and the Generalized Cobb-Douglas (GCD). The Cobb-Douglas and CES are too restrictive in their assumptions, while empirical evidence suggests that the translog represents a better specification of the technology than the GL and the GCD (Berndt et al.[1977]). This is discussed in Section 3.3.1. In Section 3.3.2., the profit function and the share equations are formulated within the translog framework. The elasticities of transformation, complementarity and intensity, with their corresponding partial price and quantity elasticities, are also derived and discussed.

3.2 The Theoretical Model

It is assumed that import and export decisions are undertaken by profit-maximizing firms which face competitive commodity and factor markets; thus the firms take input and output prices as exogenous. These firms choose their output combination and their input requirements to maximize profits, subject to a vector of output and input prices and the economy's fixed endowment of labour, physical (or non-human) capital, human capital and research and development (R&D). Imports enter as an input into U.K. technology and are modelled as a variable quantity. The treatment of imports as an input is justified on the grounds that most internationally traded goods are intermediate goods and, moreover, finished imports are generally still subject to domestic handling and transportation before reaching final demand (Burgess [1974], Kohli [1978, 1982]).

Let Y_1, $Y_2, \ldots, Y_N$ denote N distinct commodities which are the variable outputs and inputs to be considered. Let $Y = (Y_1, \ldots, Y_N)$, where Y_i is positive for an output and negative for an input, $i = 1, 2, \ldots, N$. Let there be J fixed inputs X_1, $X_2, \ldots, X_J$, defined by $X = (X_1, \ldots, X_J)$, $j = 1, 2, \ldots, J$. Thus Y is an N-tuple and X a J-tuple. Combining them, we get $Z = (Y, X)$, a $1 \times (N+J)$ vector of all inputs and outputs. The vector of output prices is denoted by $P = (P_1, \ldots, P_N)$ and the vector of fixed input prices by $W = (W_1, \ldots, W_J)$, with all prices being positive. The restricted profit function may be expressed as follows:

$$\pi(P; X, t) = \max_{(Y)} \{PY' : (Y; X, t) \in T\}, \qquad (7)$$

where π is variable or restricted profit, t is a proxy for technical progress, T is the set of production possibilitics and $P \gg 0_N$ and $X \leq 0_J$. $P \gg 0_N$ means that every element of the vector P is greater than zero. $X \leq 0_J$ means that every element of the vector X is equal or less than zero.

McFadden [1966,1970], Gordon [1968], Diewert [1974] and Lau [1978] have shown that the restrictions imposed on T determine the properties of the variable profit function. The following represents a standard set of assumed regularity conditions on T:

(A.1) T is a closed, non-empty subset of $\mathbb{R}^{N+J}$.

(A.2) T is a convex set. Convexity implies that if Z and Z^* are elements of T, then a linear combination of Z and Z^* will belong to T, that is , $\lambda Z + (1-\lambda)Z^* \epsilon T$ for $0 \leq \lambda \leq 1$.

(A.3) T is monotonic. If Z is an element of T and $Z^* \geq Z$, then $Z^* \epsilon T$.

(A.4) If $(Y;X,t) \epsilon T$, then the components of Y are bounded from above for X fixed i.e. the set of outputs is finite.

When T satisfies restrictions (A.1) to (A.4) above, the variable profit function $\pi(P;X,t)$ will have the following properties:

(A.5) $\pi(P;X,t)$ is a non-negative real valued function defined for all $P \gg 0_N$ for any X_j.

(A.6) $\pi(P;X,t)$ is homogeneous of degree one in P, i.e. for every λ 0, $\pi(\lambda P;X,t) = \lambda\pi(P;X,t)$.

(A.7) $\pi(P;X,t)$ is convex in P for every fixed X.
Let $(P^*;X,t) = (\lambda P + (1-\lambda)\tilde{P};X,t)$, then
$\pi(P^*;X,t) \le \lambda\pi(P;X,t) + (1-\lambda)\ \pi(\tilde{P};X,t)$.

(A.8) $\pi(P;X,t)$ is concave in X for every fixed P. Let
$(P;X^*,t) = (P;\lambda X + (1-\lambda)\tilde{X},t)$,
then $\pi(P;X^*,t) \ge \lambda\pi(P;X,t) + (1-\lambda)\ \pi(P;\tilde{X},t)$.

(A.9) $\pi(P;X,t)$ is homogeneous of degree one in X. For every $\lambda > 0$,
$\pi(P;\lambda X,t) = \lambda\pi(P;X,t)$.

(A.10) $\pi(P;X,t)$ is non-decreasing in X for every fixed P.

(A.11) $\pi(P;X,t)$ is montonically increasing or decreasing with respect to P, depending on whether the corresponding quantity is a variable output or input.

The production possibilities set T which corresponds to π can be defined as

$$T = \{(Y;X,t): P'Y \le \pi(P;X,t)\ \forall\ P \gg 0_N,\ \forall\ X \le 0_J\}. \qquad (8)$$

When π satisfies conditions (A.5) - (A.11) then T defined above will satisfy conditions (A.1) - (A.4) and the variable profit function corresponding to T will coincide with π. This implies that the variable profit function contains enough information for a complete characterisation of the production technology and hence the production set (Diewert [1974]; Woodland [1976]; McKay et al [1983]). When the variable profit function satisfies conditions (A.5) to (A.11) and is, in addition, 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 the process of differentiation, a result known as Hotelling's [1932] lemma. Thus

$$\partial\pi(P;X,t)/\partial P_i = Y_i(P;X,t), \quad i = 1,2,\ldots,N, \tag{9}$$

where $Y_i(P;X,t)$ is the profit maximizing output supply (input demand) if i is an output (a variable input). When $\pi(P;X,t)$ satisfies conditions (A.5) to (A.11) and is differentiable with respect to components of X, the inverse demand functions for the fixed inputs can be derived as

$$\partial\pi(P;X,t)/\partial X_j = W_j(P;X,t), \quad j = 1,2,\ldots,J, \tag{10}$$

where W_j is the shadow price of fixed input j (Diewert [1974]).

By formulating a functional form of the variable profit function, a system of demand and supply equations can be derived by applying Hotelling's lemma. The parameters of the equations can be estimated jointly using conventional multivariate regression techniques.

3.3 Functional Form

3.3.1. Selection of the Translog Function

For the purpose of estimation, a specific functional form of the variable profit function is employed. A highly general functional form, one that places no a priori restrictions on the Allen partial elasticities of substitution and one that can be interpreted as a second order approximation to an arbitrary twice differentiable profit function, is specified. The Cobb-Douglas and the Constant Elasticity of Substitution (CES) do not fall into this category. These functional forms are globally well-behaved but impose strong separability. This causes unit elasticities of substitution for the Cobb-Douglas and constant and equal elasticities of substitution for the CES. Thus the existence of complementarity is ruled out a priori for a multi-input, multi-output profit function in these cases.

There are however, a variety of functional forms available that do not impose strong separability and hence do not rule out complementarity. These are the Generalised Leontief, the Generalised Cobb-Douglas and the Translog functions; all accommodate complementarity. Berndt et al [1977] fitted these functional forms to Post-War Canadian data and found the translog to be the most preferred form. Applebaum [1979] and Berndt and Khaled [1979] developed generalised Box-Cox forms, containing the translog (TL), the Generalised Leontief (GL) and the Generalised Square Root Quadratic Form (GSRQ) as special cases. Using 1929-1971 U.S. manufacturing data, Applebaum found that the GL and GSRQ represented a better specification of technology than the TL. Using 1947-1971 U.S. manufacturing data, Berndt and Khaled rejected the GSRQ, but the results were inconclusive for the TL. These findings, together with the fact that the majority of studies of this nature (see Chapter 2) have used the Translog model, have led to the adoption of the Translog specification for the variable profit function in this thesis.

3.3.2. The Translog Variable Profit Function

Christensen, Jorgenson and Lau (CJL) [1971] introduced the translog function as a second order approximation to any twice differentiable production or cost function. A second order approximation at the expansion point of the variable profit function $\pi(P;X,t)$ can be obtained by a logarithmic Taylor series expansion:

$$\begin{aligned}
\ln\pi &= \ln\pi(0) + \sum_i (\partial \ln \pi/\partial \ln P_i) \ln P_i \\
&+ \sum_j (\partial \ln \pi/\partial \ln X_j) \ln X_j + (\partial \ln \pi/\partial \ln t) \ln t \\
&+ 1/2 \sum_{ih} (\partial^2 \ln \pi/\partial \ln P_i\, \partial \ln P_h) \ln P_i \ln P_h \\
&+ 1/2 \sum_{jk}\ \partial^2 \ln \pi /\partial \ln X_j\, \partial \ln X_k) \ln X_j \ln X_k \\
&+ 1/2\, (\partial^2 \ln \pi / \partial \ln t^2)\, (\ln t)^2 \\
&+ 1/2 \sum_{ij} (\partial^2 \ln \pi/\partial \ln P_i\, \partial \ln X_j) \ln P_i \ln X_j \\
&+ 1/2 \sum_i (\partial^2 \ln \pi/\partial \ln P_i\, \partial \ln t) \ln P_i \ln t \\
&+ 1/2 \sum_j (\partial^2 \ln \pi/\partial \ln X_j\, \partial \ln t) \ln X_j \ln t. \qquad (11)
\end{aligned}$$

Equation(11) can be written in a more convenient form as follows:

$$\begin{aligned}\ln \pi = {} & \alpha_0 + \sum_i \alpha_i \ln P_i + \sum_j \beta_j \ln X_j + \alpha_t \ln t \\ & + 1/2 \sum_i \sum_h \gamma_{ih} \ln P_i \ln P_h + 1/2 \sum_j \sum_k \phi_{jk} \ln X_j \ln X_k \\ & + \alpha_{tt}(\ln t)^2 + 1/2 \sum_i \sum_j \delta_{ij} \ln P_i \ln X_j \\ & + 1/2 \sum_i \alpha_{it} \ln P_i \ln t + 1/2 \sum_j \beta_{jt} \ln X_j \ln t. \qquad (12)\end{aligned}$$

This specification of the translog variable profit function is similar to that given by Diewert [1974] with time being included as a proxy for technical progress as in Berndt and Woods [1982] specification of the translog cost function.

The chosen translog variable profit function implies various restrictions on its parameters. First, the symmetry of the matrix of second-order derivatives requires

$$\left.\begin{aligned}\gamma_{ih} &= \gamma_{hi} \quad \text{for } i,\ h = 1,2,\ldots,N, \\ \phi_{jk} &= \phi_{kj} \quad \text{for } j,\ k = 1,2,\ldots,J.\end{aligned}\right\} \qquad (13)$$

Second, since the variable profit function is linear homogeneous in P by assumption, we have

$$\begin{aligned}&\ln \pi(\lambda P_1,\ldots,\lambda P_N;\ X_1,\ldots X_J,t) = \ln \pi(P_1\ldots,P_N; \\ &X_1\ldots X_J,t) + \ln \lambda. \qquad (14)\end{aligned}$$

Equation (14) implies the following restrictions on the parameters of the translog variable profit function:

$$\left.\begin{aligned}
&\sum_{i=1}^{N} \alpha_i = 1, \qquad \sum_{i=1}^{N} \gamma_{ih} = 0 \text{ for } h = 1,2,\ldots,N;\\
&\sum_{i=1}^{N} \delta_{ij} = 0 \qquad \text{for } j = 1,2,\ldots J;\\
&\sum_{i=1}^{N} \alpha_{it} = 0.
\end{aligned}\right\} \tag{15}$$

Third, since $\pi(P;X,t)$ is also linear homogeneous in X, then

$$\ln \pi(P_1,\ldots,P_N;\ \lambda X,\ldots \lambda X_J, t) = \ln\pi(P_1,\ldots P_N;\ X_1,\ldots X_J, t) + \ln \lambda. \tag{16}$$

Equation (16) implies the following additional restrictions on the translog parameters:

$$\left.\begin{aligned}
&\sum_{j=1}^{J} \beta_j = 1;\\
&\sum_{k=1}^{J} \phi_{jk} = 0 \text{ for } j = 1,\ldots,J;\\
&\sum_{j=1}^{J} \delta_{ij} = 0 \text{ for } i = 1,\ldots N.\\
&\sum_{j=1}^{J} \beta_{jt} = 0
\end{aligned}\right\} \tag{17}$$

A profit function is usually considered well-behaved only if it satisfies the conditions of monotonicity and convexity. The translog function does not satisfy these conditions globally. On the other hand, there are regions in the price and input frontier where these conditions may be satisfied. These well-behaved regions may be large enough for the estimated translog function to satisfy the monotonicity and convexity requirements. For any set of parameters, inputs, and price levels, these conditions can be easily checked (Berndt and Christensen [1973]), as will now become apparent. Monotonicity for the variable profit function requires that

$$\partial\pi(P;X,t)/\partial P_i > 0; \quad i = 1,\ldots,N, \tag{18}$$

$$\partial\pi(P;X,t)/\partial X_j > 0; \quad j = 1,\ldots,J. \tag{19}$$

Since P_i, X_j and π are positive, an equivalent set of conditions is

$$S_i = \partial \ln \pi/\partial \ln P_i = (\partial\pi/\partial P_i)(P_i/\pi) > 0, \tag{20}$$

$$S_j = \partial \ln \pi/\partial \ln X_j = (\partial\pi/\partial X_j)(X_j/\pi) > 0. \tag{21}$$

Differentiating the function the monotonicity conditions to be verified are

$$S_i = \alpha_i + \sum_h \gamma_{ih} P_h + \sum_j \delta_{ij} \ln X_j + \alpha_{it} \ln t > 0, \tag{22}$$

$$S_j = \beta_j + \sum_k \phi_{jk} \ln X_k + \sum_i \delta_{ij} P_i + \beta_{jt} \ln t > 0. \qquad (23)$$

It is these conditions that may be checked once the estimates of the coefficients have been obtained, for a range of values of P, X and t.

The curvature conditions require that the variable profit function be convex in prices and concave in fixed quantities. A necessary and sufficient condition for the former is that the Hessian $\partial^2\pi/\partial P_i \partial P_h$ is positive semi-definite; for the latter the Hessian $\partial^2\pi/\partial X_j \partial X_k$ must be negative semi-definite.

Assuming, then, that the translog variable profit function satisfies, at least locally, the regularity conditions (A.5) to (A.11), Hotelling's lemma can be applied to it to yield the following system of supply share equations:

$$\begin{aligned} S_i &= P_i Y_i/\pi(P;X,t) = \partial \ln \pi(P;X,t)/\partial \ln P_i = \alpha_i \\ &+ \sum_h \gamma_{ih} \ln P_h + \sum_j \delta_{ij} \ln X_j \\ &+ \alpha_{it} \ln t; \; i = 1,2\ldots,N, \end{aligned} \qquad (24)$$

where S_i is the share of output i in variable profit. Linear homogeneity in prices implies that $\sum_i S_i = 1$. Similarly the marginal productivity relation or the share equation of fixed input j can be derived as follows:

$$V_j = WX/\pi(P;X,t) = \partial \ln \pi(P;X,t)/\partial \ln X_j = \beta_j$$
$$+ \sum_i \delta_{ij} \ln P_i + \sum_k \phi_{jk} \ln X_j$$
$$+ \beta_{jt} \ln t; \; j = 1,2,\ldots,J, \tag{25}$$

where $\sum_j V_j = 1$ due to linear homogeneity in fixed quantities.

3.3.3. *Elasticities.*

A useful interpretation of the translog parameters is obtained by defining a share elasticity. The first derivative of ln π with respect to ln P_i or ln X_j is the corresponding share elasticity. The cross-partial derivative $\{\partial^2 \ln \pi/\partial \ln P_i \partial \ln P_h\}$ is a constant share elasticity equal to γ_{ih}. Thus the translog parameter summarises the response of value share S_i to a change in ln P_i. A positive share elasticity implies that the corresponding value share increases with an increase in ln P_i or ln X_j; a negative share elasticity implies that the value share decreases with an increase in ln P_i or ln X_j, a share elasticity equal to zero implies that the value share is independent of price or domestic input (Jorgenson and Fraumeni [1981], Berndt and Wood [1982]). α_{it} and β_{jt} give the effect of technical progress on output supply and input demand. A qualitative direction of technical progress is simply obtained as the sign of the coefficient of ln t in each of the share equations. Technical progress is said to be favourable to output i when $\alpha_{it} > 0$, unfavourable when $\alpha_{it} < 0$ and neutral when $\alpha_{it} = 0$. It is also said to be input j-using when $\beta_{jt} > 0$, input j-saving when $\beta_{jt} < 0$ and input j-neutral when $\beta_{jt} = 0$.

The relationships between the various outputs and inputs are also reflected in the parameter estimates of the set of derived share equations (McKay et al [1983]). Diewert [1974] has described these in terms of the elasticities of transformation, complementarity and intensity developed as an extension to the notion of an Allen [1938] elasticity of substitution. For the variable profit function these elasicities may be defined as follows.

(a) The elasticity of transformation, θ_{ih}, is defined as the elasticity of the variable output i with respect to the price P_h:

$$\theta_{ih} = \pi(\delta^2\pi/\delta P_i \delta P_h)/(\delta\pi/\delta P_i)\ (\delta\pi/\delta P_h). \tag{26}$$

Written in share form, equation (26) becomes

$$\theta_{ih} = \left\{ \begin{array}{ll} \dfrac{\gamma_{ih} + S_i S_h}{S_i S_h}, & i,h = 1,2,\ldots,N,\ i \neq h \\ \dfrac{\gamma_{ii} + S_i^2 - S_i}{S_i^2}, & i = 1,2,\ldots,N. \end{array} \right\} \tag{26a}$$

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

(b) The elasticity of complementarity, ω_{jk}, is defined as the inverse price elasticity of fixed input j with respect to a change in the quantity of fixed input k:

$$\omega_{jk} = \pi(\delta^2\pi/\delta X_j\delta X_k)/(\delta\pi/\delta X_j)(\delta\pi/\delta x_k). \tag{27}$$

Written in share form, equation (27) becomes

$$\omega_{jk} = \left\{ \begin{array}{ll} \dfrac{\phi_{jk} + V_jV_k}{V_jV_k}, & j,k = 1,2,\ldots,J, \ j \neq k \\ \dfrac{\phi_{jj} + V_j^2 - V_j}{V_j^2}, & j = 1,2,\ldots,J. \end{array} \right\} \tag{27a}$$

ω_{jk} summarizes the relations between the quantity of k input and the price of input j. If $\omega_{jk} > 0$, inputs k and j are substitutes while if $\omega_{jk} < 0$, inputs k and j are complements.

(c) The elasticity of intensity, ψ_{ij}, is defined as the elasticity of the variable quantity Y_i with respect to the fixed quantity X_j:

$$\psi_{ij} = \pi(\delta^2\pi/\delta P_i\delta X_j)/(\delta\pi/\delta P_i)(\delta\pi/\delta X_j). \tag{28}$$

Written in share form, equation (28) becomes

$$\psi_{ij} = \frac{\delta_{ij} + S_iV_j}{S_iV_j}, \quad i = 1,2,\ldots,N; \ j = 1,2,\ldots,J. \tag{28a}$$

ψ_{ij} summarises the relationship between the price of the i output and the quantity of the j input. It gives the factor intensity of each output.

Diewert [1974] has shown that the elasticity of transformation, the elasticity of complementarity and the elasticity of intensity are analytically related respectively to the conventional price elasticity of supply (demand), the elasticity of the shadow price of fixed inputs and the two separate sets of partial elasticities of intensity linking variable outputs with fixed inputs. The price elasticity of supply is

$$\varepsilon_{ih} = \begin{cases} \theta_{ih}S_h \\ \theta_{ii}S_i \end{cases}, \quad i,h = 1,\dots,N \quad i \neq h; \; i = 1,\dots,N. \qquad (29)$$

ε_{ih} measures the percentage change in the quantity of output i due to a percentage change in the price of output h for i = h and i ≠ h[4]. The inverse price elasticity of demand for domestic factors is

$$\eta_{jk} = \left\{ \begin{array}{ll} \omega_{jk}V_k & j,k = 1,2,\dots,J \; j \neq k; \\ \omega_{jj}V_j \, , & j = 1,2,\dots,J. \end{array} \right\} \qquad (30)$$

η_{jk} measures the percentage change in the price of input j due to a percentage change in the quantity of input k. The two elasticities of intensity are the partial cross-quantity elasticities defined as

$$\xi_{ij} = \psi_{ij}Vj \quad , \quad i = 1,2,\dots,N; \; j = 1,2,\dots J; \qquad (31)$$

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[4] The partial elasticity of output Y_i with respect to price P_h is the proportional change in Y_i due to a one percentage change in P_h: $(\partial Y_i/\partial P_h)\,(P_h/Y_i)$

and the partial cross-price elasticity defined as

$$\rho_{ji} = \psi_{ij} S_i \quad i = 1,2,\ldots,N. \; j = 1,2,\ldots,J. \tag{32}$$

ξ_{ij} measures the percentage change in the quantity of output i due to a percentage change in the quantity o. input j. ξ indicates the relative effect of a change in the endowment of a domestic fixed factor on the supply (demand) of a variable quantity. ρ_{ji} measures the percentage change in the price of input j due to percentage change in the price of output i. ρ indicates the relative effect of a change in the prices of the variable quantities on the domestic factor rental prices.

The various elasticities can be grouped together in two matrices of elasticities. These are the substitution matrix and the matrix of variable-quantity price elasticities and input elasticities. These are defined below.

(A) The substitution matrix:

$$\Sigma = \begin{bmatrix} \Sigma_{pp} & \Sigma_{px} \\ \Sigma_{xp} & \Sigma_{xx} \end{bmatrix},$$

where Σ_{pp} is the matrix of the elasticities of transformation with elements $P_1, P_2, \ldots, P_N$; Σ_{xx} is the matrix of the elasticities of complementarity with elements $X_1, X_2, \ldots, X_J$; and $\Sigma_{xp} = \Sigma_{px}$ is the matrix of the elasticities of intensity with elements $P_1, P_2, \ldots, P_N$ and X_1, $X_2, \ldots, X_J$. The symmetry of Σ is implied by the symmetry of the Hessian of the profit function. In addition, the curvature properties of the restricted profit function imply that Σ_{pp} is posit've semi-definite and

Σ_{xx} is negative semi-definite.

(B) The matrix of variable quantity price elasticities and input elasticities:

$$E = \begin{bmatrix} E_{pp} & E_{px} \\ E_{xp} & E_{xx} \end{bmatrix} = \begin{bmatrix} \begin{Bmatrix} \text{output own/cross} \\ \text{price elasticities} \end{Bmatrix} & \begin{Bmatrix} \text{output-input cross} \\ \text{elasticities} \end{Bmatrix} \\ \begin{Bmatrix} \text{input-output cross} \\ \text{price elasticities} \end{Bmatrix} & \begin{Bmatrix} \text{input inverse own/} \\ \text{cross price} \\ \text{elasticities} \end{Bmatrix} \end{bmatrix}$$

where E_{pp} is the matrix of the partial price elasticities of output supply of elements $P_1, P_2, \ldots, P_N$; E_{xx} the matrix of the inverse price elasticities of the demand for domestic inputs of elements $X_1, X_2, \ldots, X_J$; E_{px} the matrix of the partial cross-quantity elasticities of elements $P_1, P_2, \ldots, P_N$ and elements $X_1, X_2, \ldots, X_J$; and E_{xp} the matrix of the partial cross-price elasticities of elements $X_1, X_2, \ldots, X_J$ and $P_1, P_2, \ldots, P_N$.

3.3.4. Application and Interpretation.

The hypothesis that the United Kingdom suffers from a low technology syndrome will be tested by the elasticities of intensity. This group of elasticity will also confirm or reject the neo-factor endowment theory and the neo-technology theory of trade in explaining the U.K.'s trade patterns. The slope of the demand curve for imports is given by the partial price elasticity of import demand. The relationship of imports and exports to the supply of consumption goods and investment goods is provided by the elasticities of transformation. The effects of changes in the endowment of labour, capital, human capital and R&D on the trade balance are indicated by the partial cross-quantity elasticities. The partial cross-price elasticities between outputs and inputs quantify the effects of changes in the price of imports and exports on the returns to the factors of production.

3.4. Summary

In this chapter a system of import and export functions have been developed in a general theoretical framework and the translog functional form can be used for the variable profit function. The elasticity matrices to be estimated are also presented and interpretation discussed. In the next chapter sources and construction of the series of human capital and R&D are discussed.

Chapter 4

HUMAN CAPITAL AND RESEARCH AND DEVELOPMENT

4.1 Introduction

Market values of the stocks of human capital and research and develoment (R&D) for the United Kingdom are not available, because these series are not calculated by the Central Statistical Office. In this chapter an attempt is made to compute these series for the sample period 1960 to 1986. The construction of the series for the stock and value of human capital is given in Section 4.2. Section 4.3 is concerned with the construction of the series for the stock and value of R&D. This is followed by a commentary in Section 4.4 and a summary in Section 4.5.

4.2 Construction of the Stock and Value of Human Capital

Human capital expenditures include the cost of formal education and the foregone earnings of students of working age.

The cost of formal education is obtained by adding the current educational expenses of primary and secondary schools, colleges, institutes and universities of England and Wales, Scotland and N. Ireland. The series begins in financial year 1909-1910 and ends in the financial year 1986-1987[5]. Information on this series is unavailable for the years 1913-14 to 1917-18 for England and Wales, due to the

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[5] The series begins in 1909-10, since it is assumed that human capital assets have a 50 year life expectancy.

suspension of compilation of these statistics during World War I. A straight line interpolation is used to obtain them. There is also no information for Ireland for the years 1920-21 and 1921-22. Again a straight line interpolation is used for these years. Data for U.K. expenditures on university education are also not available for the period 1909-10 to 1919-20, since the recording of such expenditures only began in the financial year 1920-21. The growth rate of university expenditures during the 1920's, which is 7% per annum, is used to extrapolate the data for that period. The series from 1909-1910 to 1919-1920 are then summed and converted from financial years to calendar years. For the rest of the series, the 1920 to 1965 figures are taken from Vaizey [1965, 1968, Table 3 and Table 10] and from 1966 to 1986 the data are extracted from the *Unesco Yearbook* [1980-1992]. Real current expenditures in 1980 values are obtained by deflating the series by the consumer price index.

To compute the foregone earnings of students at colleges and universities the following are required: enrollment of students in colleges and universities, the number of weeks per year in school, and student compensation. Student enrollment is divided into two categories: full-time students and part-time students in colleges and universities. University enrollment is not available for the period 1909-1910 to 1918-1919 and so the growth rate of university student enrollment for the year 1920-1921, which is 7%, is used to extrapolate for these years. For the rest of the series, data are obtained from the *Annual Abstract of Statistics* [1940-1992].

The number of part-time students in colleges and universities is computed next. A part-time student is a day student enrolled in a programme. Part-time student enrollment is converted into full-time student enrollment according to the rule that two part-time students are equivalent to one full-time student (Becker [1975 p.110], Kendrick [1976], and Eisner [1980] all use the same conversion ratio).

In regard to the length of stay in school, the information provided by the Central Statistical Office is used. Students at colleges and universities are in school for 32 weeks (C.S.O.[1980 p.138]). For student compensation, the average weekly earnings for unskilled labour from 1910 to 1986 is used.

The product of student enrollment, weeks in school and average weekly compensation yields the foregone earnings of students. The series thus constructed is then deflated by the consumer price index to obtain the real foregone earnings of students.

Gross real stocks of the cost of formal education and foregone earnings of students are computed using the perpetual inventory method. This is expressed in the following equation:

$$GK_t = GK_{t-1} + I_t - R_t , \tag{32}$$

in which

GK_t = end of year gross real stock in year t;

GK_{t-1} = end of year gross real stock for the year preceeding year t;

I_t = gross real investment in year t;

R_t = retirement of real stock in year t.

According to this method gross real stock is equal to accumulated expenditures less retirements.

Net real stock is obtained as follows :

$$NK_t = NK_{t-1} + I_t - D_t , \qquad (33)$$

in which

NK_t = end of year net real stock in year t ,

NK_{t-1} = end of year net real stock for the year preceeding year t,

I_t = gross real investment in year t

D_t = depreciation in year t.

The method of uniform straight line depreciation is used. Since human capital assets are assumed to have a life expectancy of fifty years, the rate of depreciation is two percent per year . Both Kendrick [1976] and Eisner [1980] have used this method. To obtain the current value of net real stock of human capital, the procedure is as follows. First, net real stock of education expenditures is reflated by the consumer price index to obtain current net stock of educational expenditures. Second, the net real stock of foregone earnings of students is reflated by the consumer price index to arrive at net current stock of foregone earnings. Third, corresponding years of current net stock of educational expenses and current net stock of foregone earnings of students are summed together to arrive at the current value of net human capital stock. These series are given in Tables 4.1 and 4.2 and graphed in Figures 3.1 to 3.3.

An examinatiom of the series reveals that current net stock of Government expenditures on education rises, on average, by 18.4% from 1960 to 1972 and 52.9% from 1972 to 1986. A large part of the increase is attributed to price changes, since, in real terms, the corresponding growth rates are 7% and 6.2%. Current net stock of foregone earnings of students, over the same periods, increases by 26.7% and 62% and in real terms by 11.3% and 8.2%.

4.3 Construction of the Stock and Value of Research and Development

In general, R&D is defined as any creative, systematic activity undertaken in order to increase the stock of knowledge, and the use of this knowledge to devise new applications. It includes fundamental research, applied research and experimental development. The U.K. Department of Trade and Industry (HMSO [1976 p.2]) defines these as follow:

1) Fundamental research is the "original investigation undertaken in order to gain new scientific knowledge and understanding. It is not primarily directed to any specific practical aim or application".

2) Applied research is "also original investigation undertaken in order to gain new scientific or technical knowledge. It is, however, directed primarily towards a specific practical aim or objective".

TABLE 4.1 NET STOCKS OF HUMAN CAPITAL FOR THE UNITED KINGDOM IN CURRENT VALUES, 1960-86

YEAR	CQGE	CQFF	WHC
	£b	£b	£b
1960	11.685	0.659	12.344
1961	12.587	0.718	13.306
1962	13.707	0.789	14.496
1963	14.668	0.852	15.520
1964	15.913	0.938	16.851
1965	17.579	1.055	18.634
1966	19.298	1.186	20.484
1967	20.833	1.314	22.147
1968	22.975	1.495	24.471
1969	25.555	1.712	27.267
1970	28.645	1.969	30.614
1971	33.018	2.324	35.342
1972	37.471	2.694	40.165
1973	43.296	3.174	46.470
1974	53.641	3.958	57.599
1975	70.894	5.247	76.141
1976	87.303	6.491	93.794
1977	106.014	7.938	113.953
1978	120.051	9.085	129.136
1979	142.272	10.893	153.166
1980	175.072	13.528	188.600
1981	197.834	15.457	213.291
1982	221.476	17.505	238.981
1983	237.051	18.954	256.004
1984	270.490	21.858	292.348
1985	295.423	24.168	319.591
1986	314.922	26.040	340.962

Notes:

CQGE = Current net stock of expenditures on education

CQFF = Current net stock of foregone earnings of students

WHC = CQGE + CQFF = Current value of net stock of human capital.

TABLE 4.2: NET STOCKS OF HUMAN CAPITAL FOR THE UNITED KINGDOM, IN CONSTANT (1980) £b's, 1960-1986.

YEAR	CNQGE	CNQFF	QHC
	£b	£b	£b
1960	62.489	3.521	66.010
1961	65.218	3.722	68.940
1962	68.193	3.926	72.119
1963	71.553	4.155	75.708
1964	75.061	4.423	79.485
1965	79.186	4.752	83.937
1966	83.541	5.132	88.673
1967	88.277	5.568	93.845
1968	93.018	6.053	99.071
1969	97.913	6.559	104.473
1970	103.412	7.108	110.519
1971	108.972	7.669	116.640
1972	115.295	8.290	123.584
1973	121.960	8.941	130.901
1974	130.197	9.607	139.805
1975	138.735	10.268	149.003
1976	146.728	10.909	157.637
1977	153.644	11.505	165.149
1978	160.711	12.163	172.873
1979	167.774	12.846	180.620
1980	175.072	13.528	188.600
1981	182.335	14.246	196.581
1982	189.296	14.962	204.257
1983	196.397	15.703	212.100
1984	202.766	16.386	219.151
1985	208.780	17.080	225.859
1986	215.258	17.799	233.057

Notes:

NQGE = Constant net stock of expenditures on education.

CNQFF = Constant net stock of foregone earnings of students.

QHC = CNQGE + CNQFF = Constant net stock of human capital.

FIGURE 4.1: GRAPHS OF CURRENT NET STOCK (CQGE) AND REAL NET STOCK (NQGE) OF EXPENDITURES ON EDUCATION

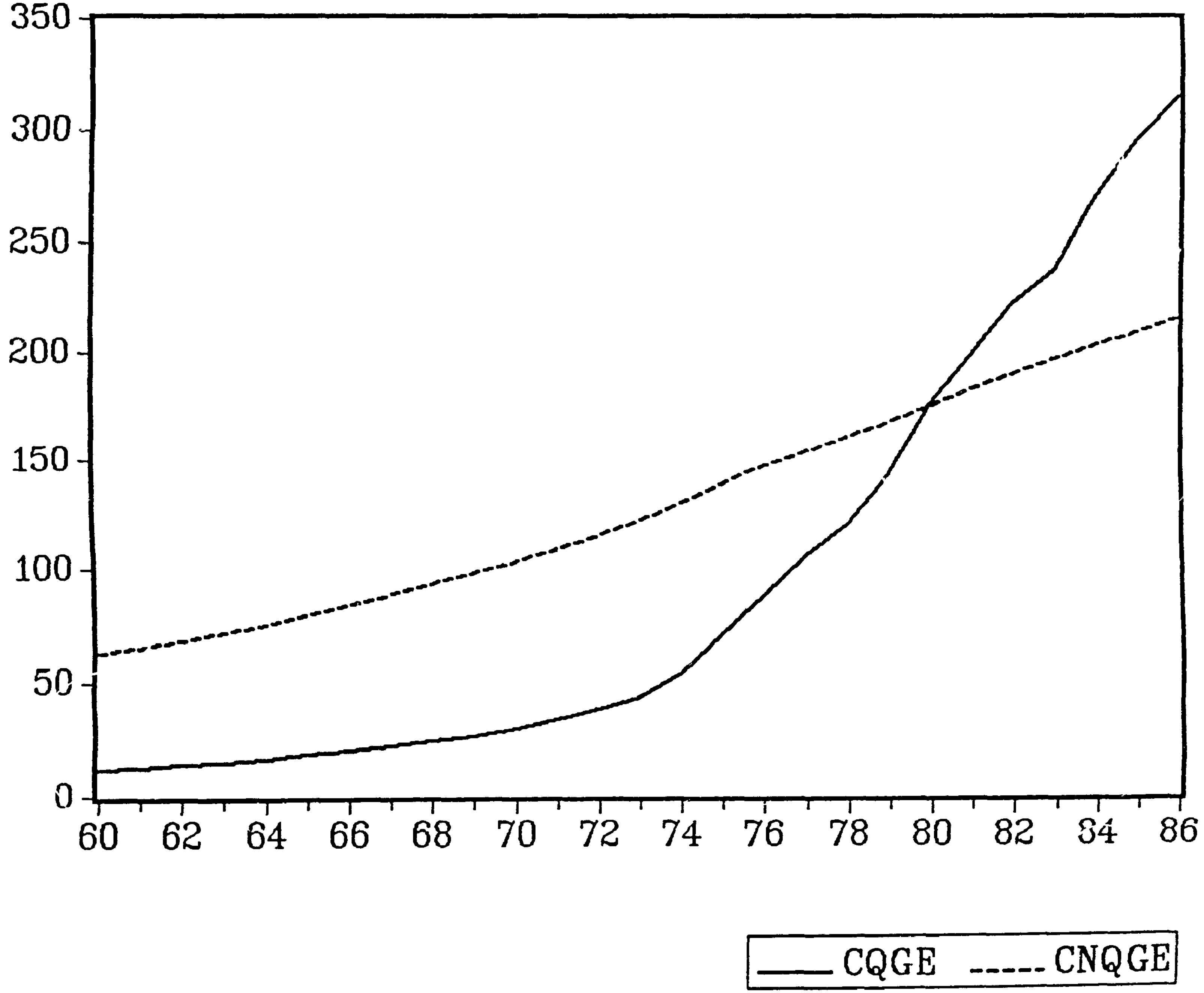


FIGURE 4.2: GRAPHS OF CURRENT NET STOCK (CQFF) AND REAL NET STOCK (CNQFF) OF FOREGONE EARNINGS OF STUDENTS

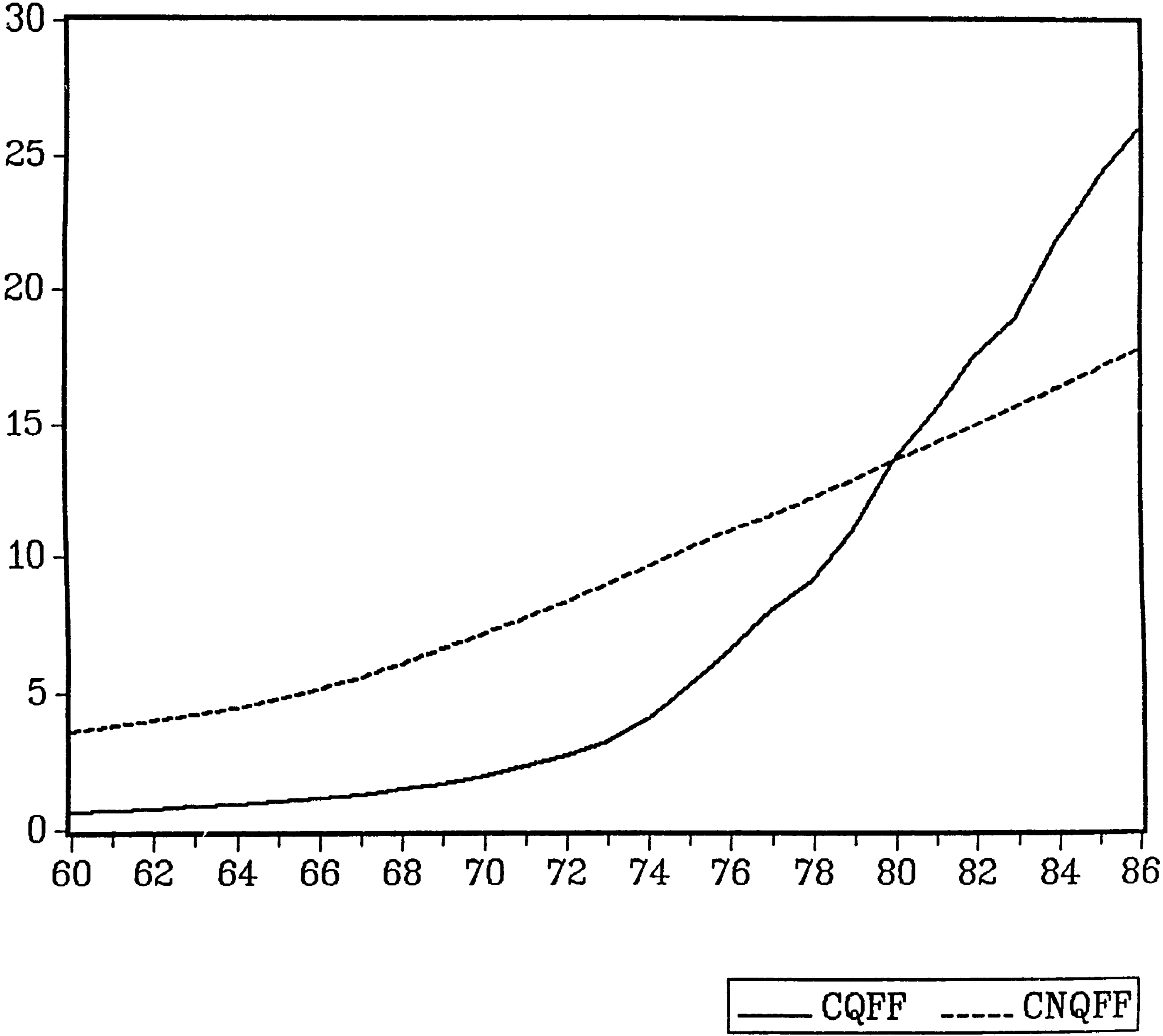
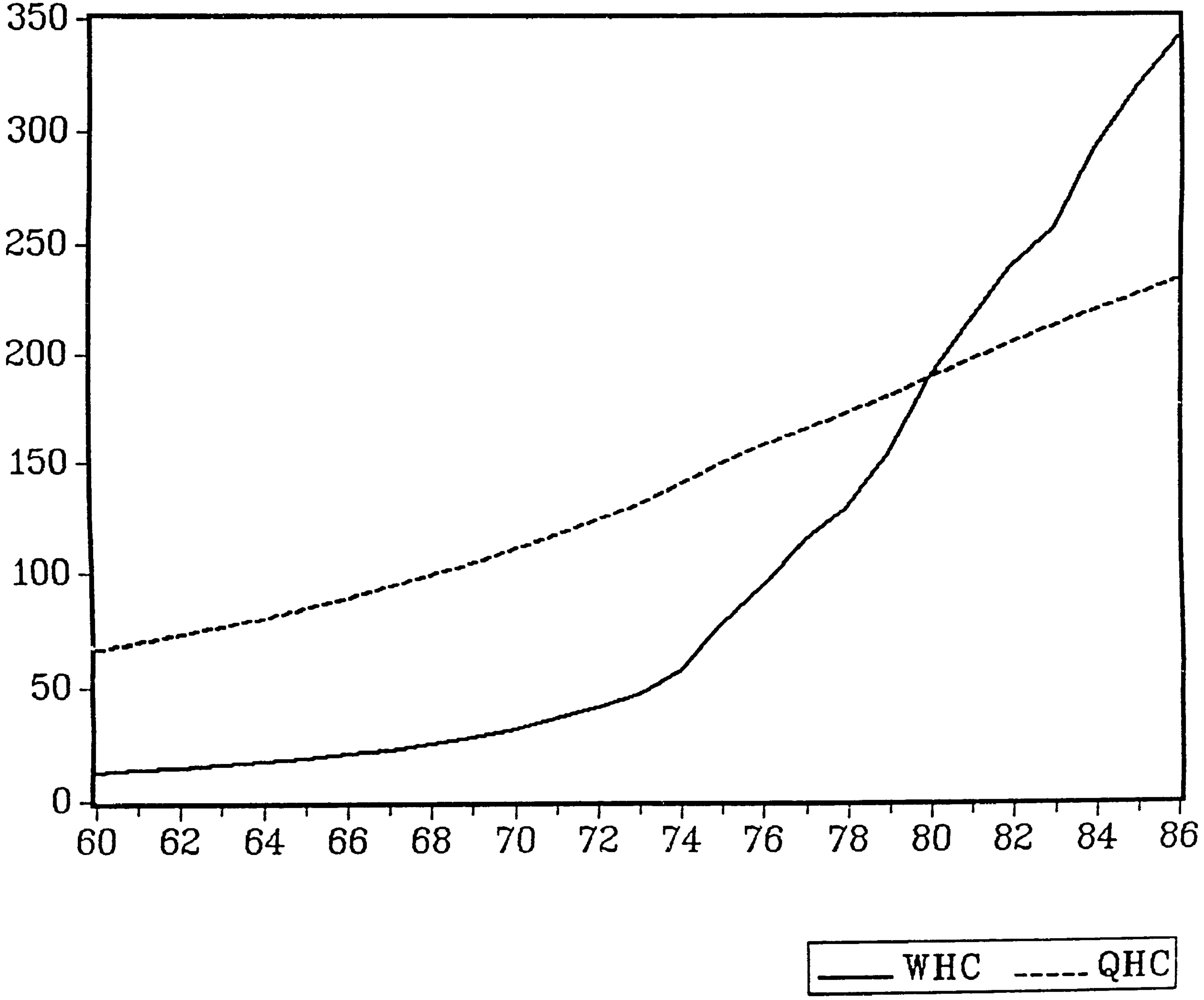


FIGURE 4.3: GRAPHS OF CURRENT VALUE (WHC) AND REAL VALUE (QHC) OF NET

STOCK OF HUMAN CAPITAL



3) Experimental development is "the use of scientific knowledge in order to produce new or substantially improved materials, devices, products, processes, systems or services".

The earliest year for which recorded information on U.K. R&D expenditures is available is the financial year 1939-1940 (OECD [1968 p.6]). Government expenditures on civil R&D is $3.6m in that year. Such information is also available for the years 1945-46, 1950-51, 1956-57 and 1961-62. Total R&D expenditure for the financial year 1961-62 is also reported for the first time. The 1961-62 ratio of government expenditure on civil R&D to total R&D expenditures is used to convert government civil R&D to total R&D expenditures for the years 1939-40, 1945-46, 1950-51 and 1956-57. A straight-line interpolation is used to compute R&D expenditures for the intervening years. These figures are then converted from financial to calendar years for the years 1940 to 1960. Total R&D expenditures are also available for the calendar years 1961 (OECD [1975, p.2]), 1964, 1966, 1967, 1968, 1969, 1972, 1975 (Arrundale [1979, p.100], Table A provides values for R&D for 1964, 1966-1969, 1972 and 1975), 1978 (Arrundale [1980 p.99], Bowles [1981 p. 105]), 1981 (Bowles [1984 p.81]), 1983, 1985, and 1986 (D.I.T.[1988 p.82]) Industrial R&D expenditures are available for calendar years 1964, 1966, 1967, 1969, 1972, 1975 (D.T.I.[1977 p.640]), 1978, 1981 (D.T.I.[1983 p.115]), 1983 and 1985 (HMSO [1988 p.140]). U.K. Government expenditures on R&D are available annually from 1966 to 1986 in the U.K. Yearbook (HMSO [1967-1989]).

Total R&D expenditures for 1962, 1963 and 1965 are obtained by straight-line interpolation from the 1961 and 1964 and 1966 total R&D

expenditures respectively. Similarly, total R&D expenditures for 1970, 1971, 1973, 1974, 1976, 1977, 1979, 1980, 1982 and 1984 are obtained by the same procedure. The R&D expenditure series from 1940 to 1986 is then divided into fundamental, applied and developmental R&D by using the shares of government basic research expenditures, government applied research expenditures and government developmental research to total government R&D expenditures. From 1940 to 1963, and in 1965, this break-down is not available and the 1964 break-down ratios are used for these years. The series are then deflated by the consumer price index to obtain their corresponding real magnitudes.

The gross real stock of R&D is computed using the perpetual inventory method. Following Kendrick [1976], fundamental research is not retired on the ground that this type of research adds to accumulated knowledge which is never lost and hence continues to be available throughout time. Applied research and development research, on the contrary, have a finite life and are eventually supplanted by new knowledge which overrides what was previously available, previous knowledge becoming obsolete. Kendrick [1976] could not separate applied research from development R&D and thus he grouped them together in one category and adopted a ten-year life service based on information he obtained from a questionaire he sent to some U.S. firms. Eisner [1980] adopted Kendrick's life expectancy for developmental R&D but used a twenty year life span for applied R&D in his study of real changes in the value of capital in the United States. In the series constructed here, Kendrick's ten-year life service for developmental R&D and Eisner's twenty-year life expectancy for applied R&D are used.

To compute the net real stock of R&D, basic research was not depreciated, developmental R&D followed a uniform ten-year straight-line depreciation, while applied R&D followed a uniform twenty-year straight-line depreciation (Eisner [1980]). Finally, the current value of R&D stock is obtained by reflating the net real R&D stocks of basic research, applied research and developmental research by the consumer price index and summing the resulting series. These stock series are given in Tables 4.3 and 4.4 and graphed in Figures 4.4–4.7.

Nominal stock of basic R&D increases, on average, by 27.4% from 1960 to 1972 and by 53.4% from 1972 to 1986. In real terms, the growth rates are 12.2% and 6.3% for the corresponding periods. Over the same periods, current net stock of applied R&D rises by 17.6% and 45.4% , and current net stock of developmental R&D by 16.1% and 32.8% In real terms, the growth rates for the net stock of applied R&D are 6.5% and 4.5% and for the stock of developmental R&D, these are 5.8% and 1.7%. Here again, inflation accounts for a greater part of the increases in the nominal growth rates.

4.4 Commentary

The series are, at least, constructed on the basis of unbiased methods that have the authority of leading names in the field. In this sense, they are not intentionally or even inadvertently inaccurate. The series, however, exclude certain factors that should be included. For example, high school students beyond school-leaving age should be included in the human capital series but are omitted due to data unavailability. Such exclusion leads to systematic bias but even here the inaccuracy is consistent throughout. In spite of these arguments, the series cannot be claimed to be 100% accurate. Yet there is no guide whatsoever to the series in the literature. Thus their comparison with an accurate version is not possible and in any case these are the 'best available'.

It is quite possible that the series contain the random errors that arise in any measuring procedure. These are the errors with which the statisticians deal and they can play havoc with estimation. A comment on such errors will be made at a later stage.

4.4. Summary

In this chapter, the series of the stock and value of human capital and R&D are computed along lines suggested by leading authors in the field such as Kendrick and Eisner. A discussion on the series is also given. In the next chapter, the empirical model and its estimates are presented.

TABLE 4.3 : CURRENT NET R&D STOCKS FOR THE UNITED KINGDOM IN £b, 1960-1986.

	BRD	ARD	DRD	WRD
	£b	£b	£b	£b
1960	1.074	1.186	1.238	3.498
1961	1.217	1.317	1.368	3.902
1962	1.381	1.464	1.508	4.353
1963	1.535	1.595	1.638	4.768
1964	1.726	1.760	1.803	5.288
1965	1.956	1.955	1.997	5.908
1966	2.195	2.148	2.188	6.530
1967	2.409	2.306	2.337	7.052
1968	2.699	2.524	2.546	7.769
1969	3.040	2.784	2.755	8.879
1970	3.476	3.007	3.009	9.492
1971	4.059	3.357	3.344	10.760
1972	4.603	3.678	3.641	11.923
1973	5.357	4.201	4.061	13.618
1974	6.630	5.070	4.822	16.523
1975	8.660	6.419	6.115	21.193
1976	10.492	7.413	7.022	24.926
1977	12.720	8.627	8.255	29.603
1978	14.433	9.459	9.394	33.286
1979	17.239	10.889	11.306	39.433
1980	21.286	13.156	13.893	48.334
1981	24.861	15.400	15.946	56.207
1982	28.095	17.410	17.506	63.010
1983	30.547	18.893	18.470	67.910
1984	33.404	20.598	19.571	73.573
1985	36.485	23.971	20.103	80.559
1986	38.987	27.089	20.379	86.455

Notes:

BRD = Nominal stock of basic R&D;

ARD = Current net stock of applied R&D;

DRD = Current net stock of developmental R&D;

WRD = Current net value of R&D stock (WRD = BRD+ARD+DR).

TABLE 4.4: REAL NET R&D STOCK FOR THE UNITED KINGDOM IN £b, 1960-1986.

	RBRD	RARD	RDRD	QRD
	£b	£b	£b	£b
1960	5.744	6.344	6.618	18.706
1961	6.304	6.826	7.086	20.216
1962	6.872	7.282	7.504	21.658
1963	7.488	7.782	7.989	23.258
1964	8.140	8.301	8.503	24.944
1965	8.810	8.806	8.995	26.611
1966	9.501	9.296	9.470	28.267
1967	10.209	9.771	9.909	29.889
1968	10.928	10.218	10.309	31.454
1969	11.648	10.665	10.555	32.869
1970	12.549	10.854	10.863	34.266
1971	13.397	11.080	11.036	35.512
1972	14.164	11.318	11.203	36.685
1973	15.089	11.833	11.440	38.362
1974	16.092	12.307	11.705	40.103
1975	16.946	12.561	11.967	41.474
1976	17.633	12.459	11.801	41.893
1977	18.435	12.504	11.964	42.903
1978	19.321	12.663	12.576	44.560
1979	20.329	12.841	13.332	46.501
1980	21.285	13.156	13.893	48.334
1981	22.217	13.762	14.250	50.229
1982	23.123	14.329	14.408	51.860
1983	24.034	14.865	14.532	53.431
1984	25.040	15.441	14.671	55.153
1985	25.785	16.941	14.207	56.933
1986	26.649	18.516	13.930	59.095

Notes:

RBRD = Real Stock of Basic R&D.

RARD = Net Real Stock of Applied R&D.

RDRD = Net Real Stock of Developmental R&D.

QRD = Net Real Stock of R&D.

FIGURE 4.4: GRAPHS OF CURRENT STOCK (BRD) AND REAL STOCK (RBRD)

OF BASIC R&D

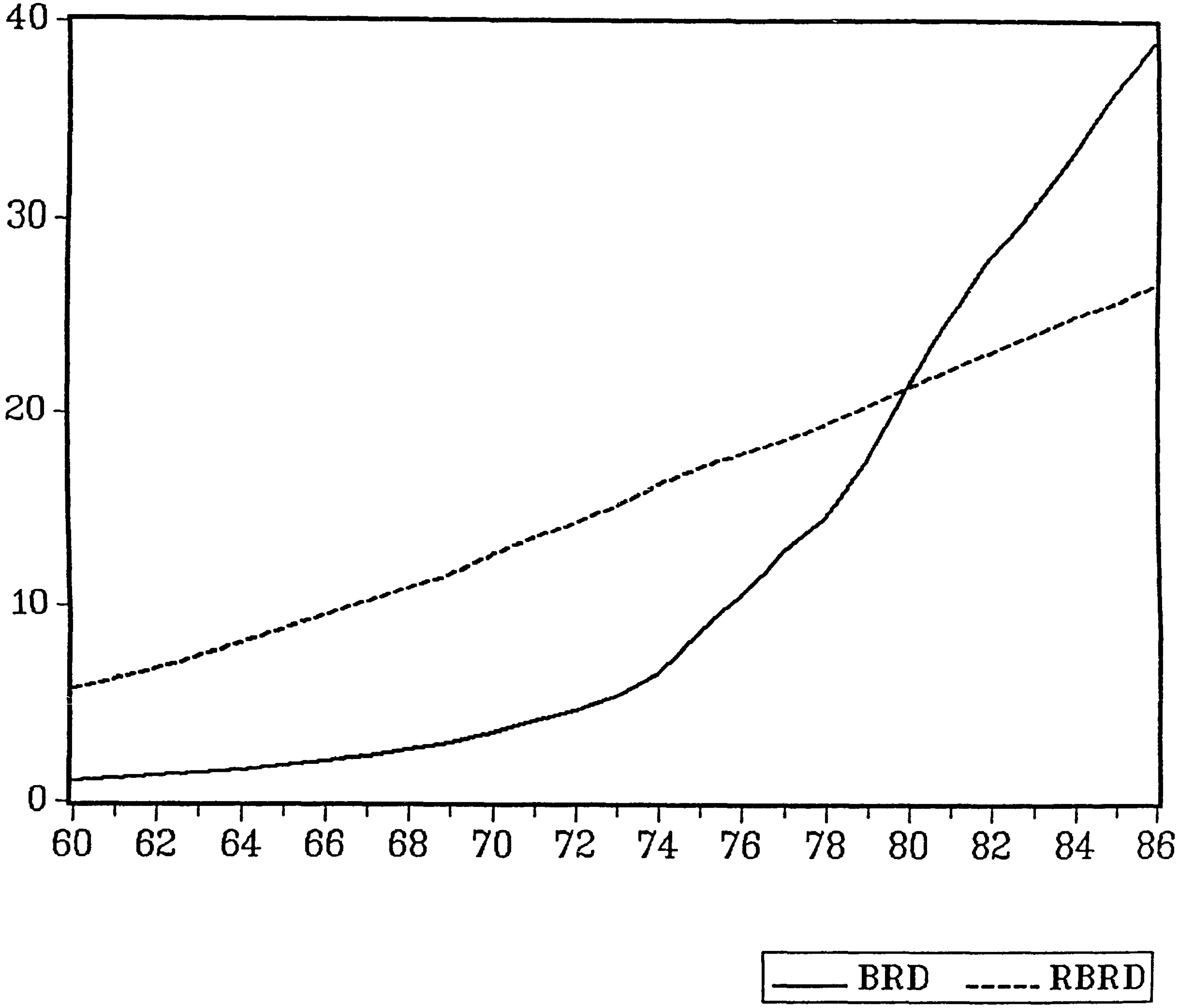


FIGURE 4.5: GRAPHS OF CURRENT NET STOCK (ARD) AND REAL NET STOCK (RARD)

OF APPLIED R&D

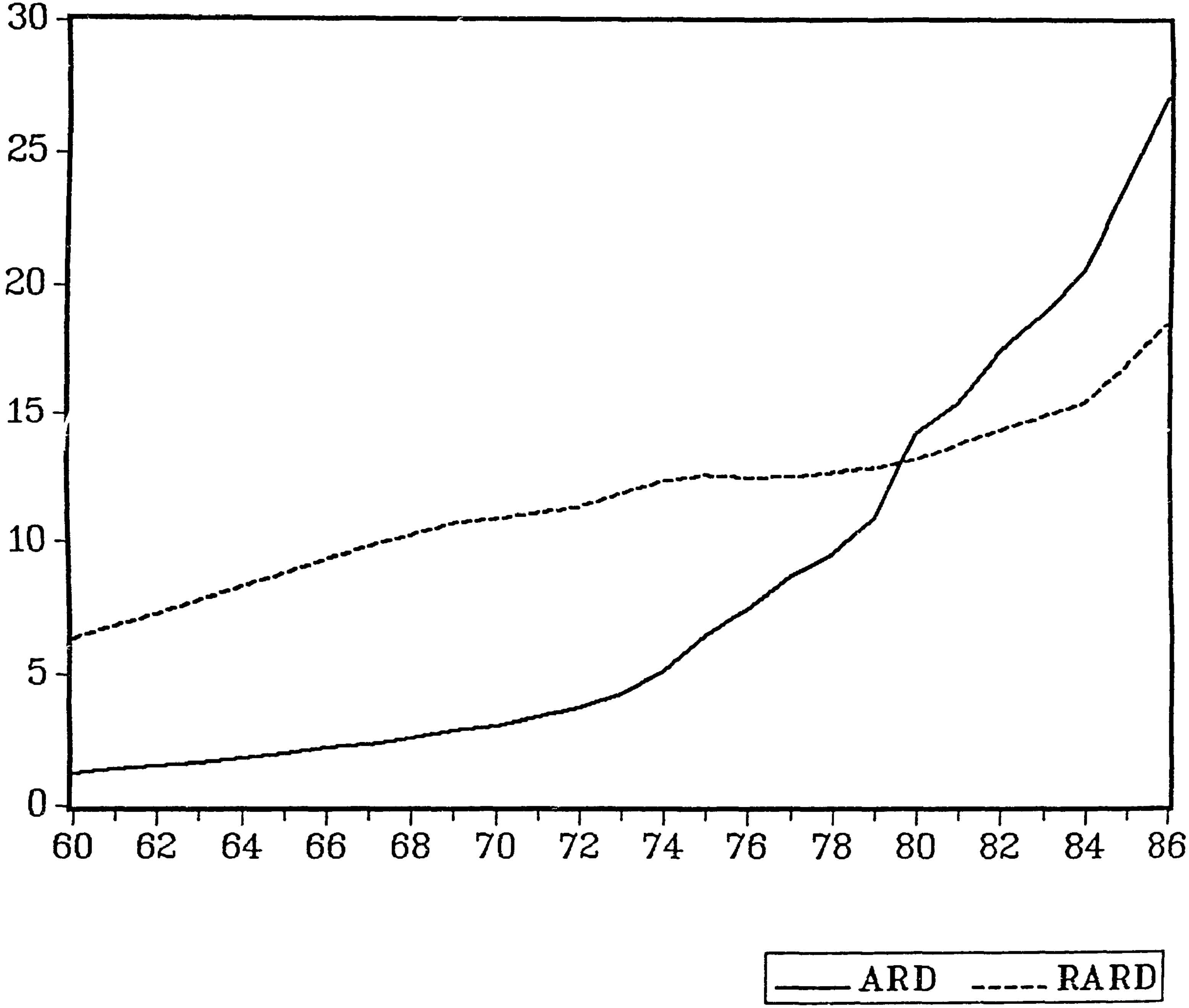


FIGURE 4.6: GRAPHS OF CURRENT NET STOCK (DRD) AND REAL NET STOCK (RDRD) OF DEVELOPMENTAL R&D

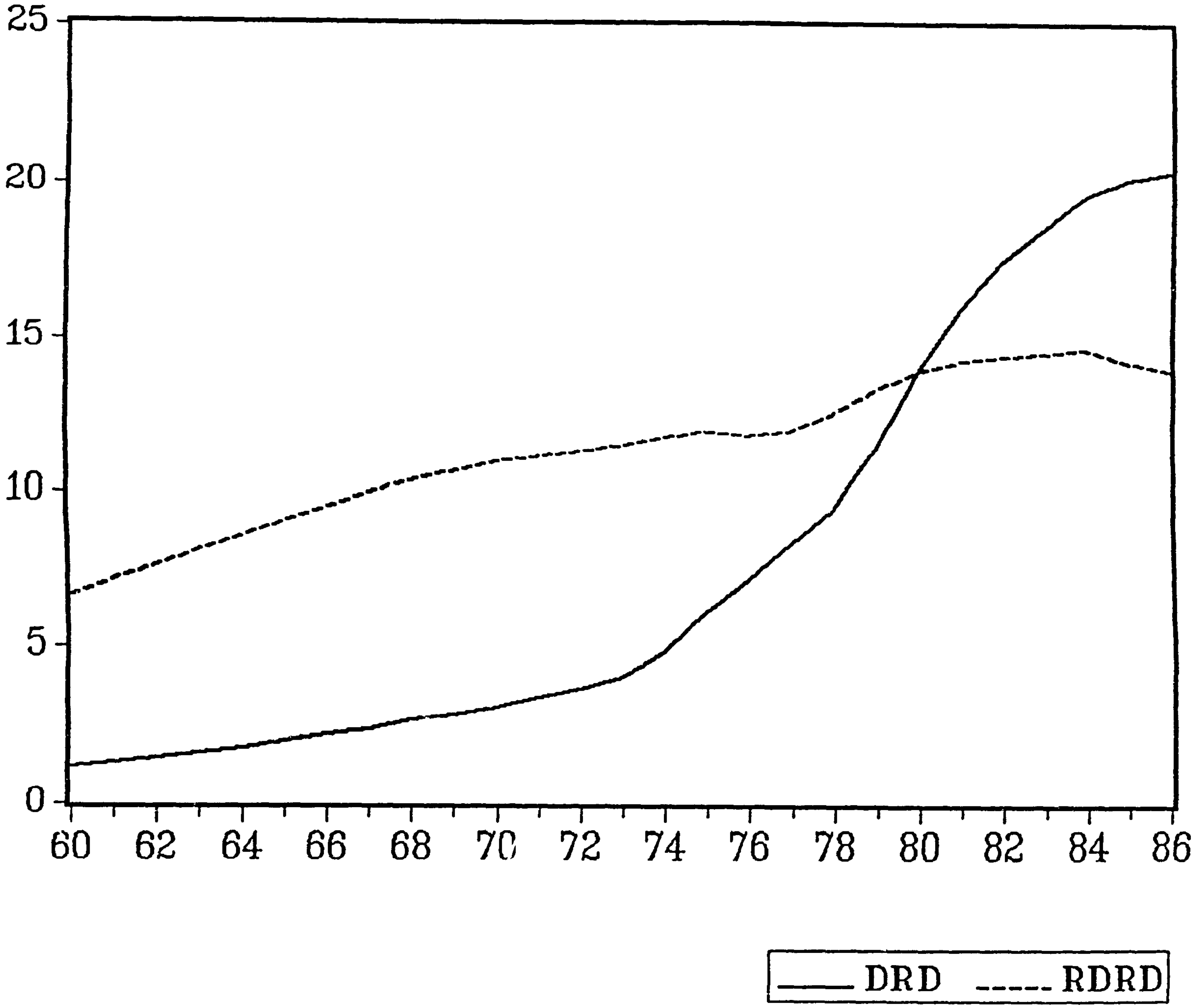
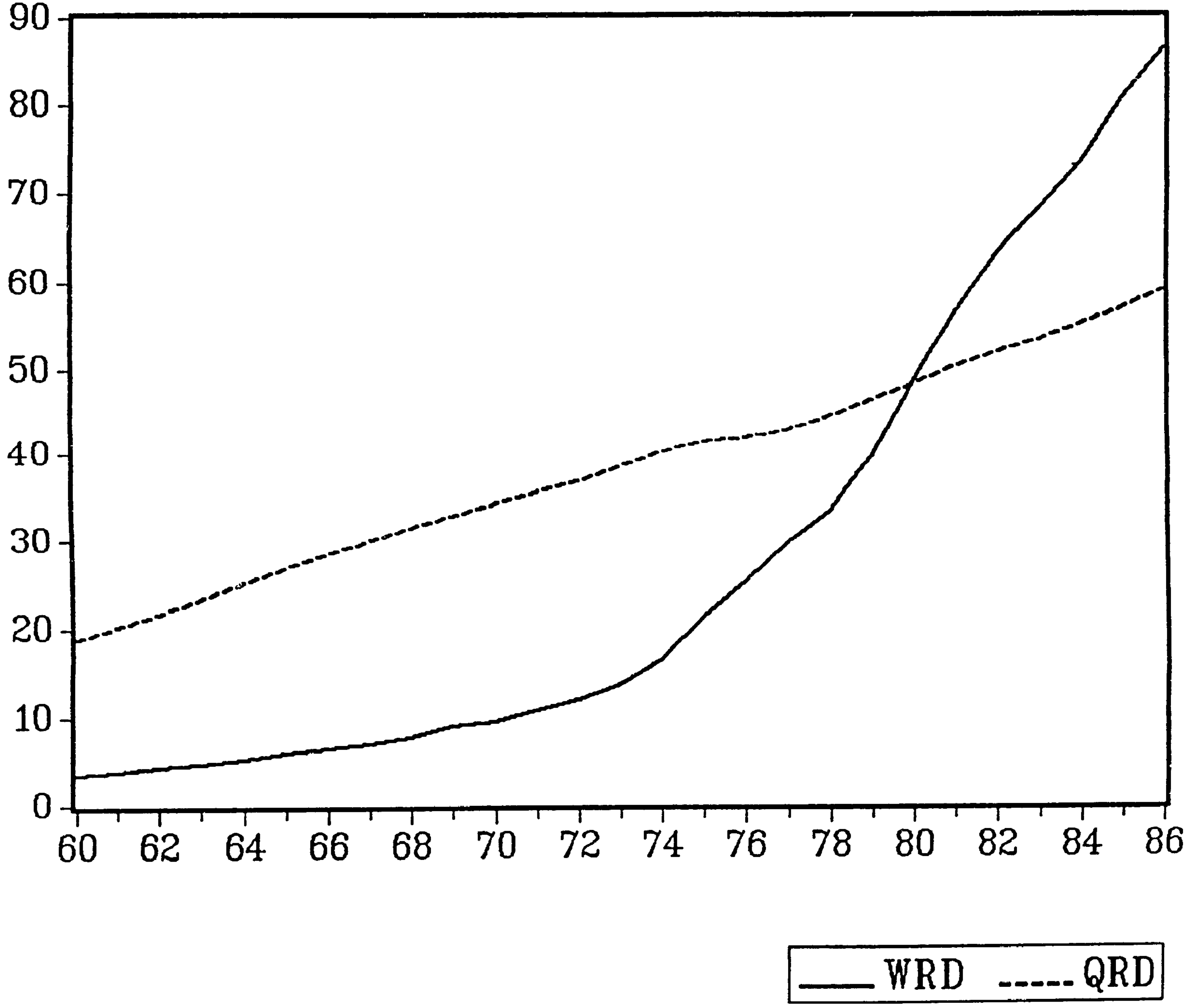


FIGURE 4.7: GRAPHS OF CURRENT NET VALUE (WRD) AND REAL NET VALUE (RWRD)

OF R&D STOCK



Chapter 5

THE EMPIRICAL MODEL AND ITS ESTIMATES

5.1 Introduction

The theoretical model is expressed here in its empirical form for estimation purposes. Such an empirical implementation requires that the share equations are embedded within a stochastic framework. Since it is assumed that the deviations of the shares from their logarithmic derivatives of the profit function are the result of random errors in profit-maximizing behaviour, an additive disturbance term is appended to each share equation. Since the output shares and input shares each sum to unity at every observation, the variance-covariance matrix of the errors for the whole system of equations, is singular. To accommodate this singularity problem, in the estimation procedures, the import demand share equation from the supply side and the capital share equation from the demand side are dropped for the purpose of computation and estimated as residuals. Thus if there are M equations in the system, (M-2) of them are independently estimated by the method of instrumental variables. This choice of estimation method is based principally on the view that the prices of outputs are endogenous.

The chapter is divided into six Sections. The empirical model is presented in Section 5.2. Section 5.3 is devoted to the construction and sources of data. This is followed by a discussion of the stochastic specification of the model and the estimation technique to be applied in Section 5.4. Model validation and empirical results are reported in Section 5.5. Section 5.6 contains a summary.

5.2 The Empirical Model

In the model, there are four outputs, and hence four output prices: consumption (Y_C), investment (Y_I), exports (Y_X), and imports (Y_M). The set of subscripts {C, I, X, M} will be denoted by Δ and a representive element of Δ by a lower case Roman letter like i. Thus the notation $\sum_{i\in\Delta} Y_i$ is taken to mean $Y_C + Y_I + Y_X + Y_M$. It should be noted that Y_M is a negative output. Y without a subscript denotes the 4x1 column vector of elements Y_C, Y_I, Y_X, Y_M; P denotes the corresponding 4x1 price vector of elements P_i, $i\in\Delta$. Y is assumed to lie in a subset y of $\mathbb{R}^4$.

There are also four inputs in the model: these are the quantities of labour (X_L), of human capital (X_H), of research and development (X_R), and of physical or non-human capital (X_K), each with a corresponding price W_L, W_H, W_R, and W_K. The set of subscripts {L, H, R, K} is denoted by Π and, as before, a small Roman letter will denote a representative element of Π, say $j\in\Pi$. X is the 4x1 vector of elements X_j and W the 4x1 vector of elements W_j, $j\in\Pi$.

The transpose of a vector is denoted by a prime; thus $Y' = [Y_C, Y_I, Y_X, Y_M]$ is a 1x4 vector. It follows that the value of total output is $P'Y$ or $Y'P$. Finally, let T denote the set of available technologies. The variables X and Y are always combined together consistently with the available technology of production which is assumed to vary with time, t. If X, Y and t are observed, then the set of them must be consistent with the available technology, i.e. $\{Y, X, t\} \in T$. Given this, the variable profit function is:

$$\pi(P;X,t) = \max_{Y} \; \{P'Y : (Y;X,t) \in T\}.$$

The demand equations for imports and the supply equations for consumption goods, investment goods and exports are derived as partial derivatives of the variable profit function. Thus

$$\partial\pi/\partial P_i = Y_i(P,X,t), \quad i \in \Delta.$$

The inverse input demand equations for labour, non-human capital, human capital and R&D can also be derived as partial derivatives of the variable profit function:

$$\partial\pi/\partial X_j = W_j(P,X,t), \quad j \in \Pi.$$

The translog variable profit function may now be written, for $h, i \in \Delta$, $j, k, \in \Pi$, as

$$\begin{aligned} \ln \pi = {} & \alpha_0 + \sum \alpha_i \ln P_i + 1/2 \sum_i \sum_h \gamma_{ih} \ln P_i \ln P_h \\ & + \sum_i \alpha_{i\tau} \ln t \ln P_i + \sum_j \beta_j \ln X_j \\ & + 1/2 \sum_j \sum_k \phi_{jk} \ln X_j \ln X_k + \sum_i \sum_j \delta_{ij} \ln P_i \ln X_j \\ & + \sum_j \beta_{j\tau} \ln t \ln X_j + \alpha_\tau \ln t \\ & + 1/2 \, \alpha_{\tau\tau} (\ln t). \end{aligned} \qquad (31)$$

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

$$\begin{aligned}\partial \ln \pi/\partial \ln P_C = SC = {} & \alpha_C + \gamma_{CC} \ln P_C + \gamma_{CI} \ln P_I \\ & + \gamma_{CX} \ln P_X + \gamma_{CM} \ln P_M + \delta_{CL} \ln X_L + \delta_{CH} \ln X_H \\ & + \delta_{CR} \ln X_R + \delta_{CK} \ln X_K + \alpha_{C\tau} \ln t. \end{aligned} \tag{32}$$

$$\begin{aligned}\partial \ln \pi/\partial \ln P_I = SI = {} & \alpha_I + \gamma_{IC} \ln P_C + \gamma_{II} \ln P_I \\ & + \gamma_{IX} \ln P_X + \gamma_{IM} \ln P_M + \delta_{IL} \ln X_L + \delta_{IH} \ln X_H \\ & + \delta_{IR} \ln X_R + \delta_{IK} \ln X_K + \alpha_{I\tau} \ln t. \end{aligned} \tag{33}$$

$$\begin{aligned}\partial \ln \pi/\partial \ln P_X = SX = {} & \alpha_X + \gamma_{XC} \ln P_C + \gamma_{XI} \ln P_I \\ & + \gamma_{XX} \ln P_X + \gamma_{XM} \ln P_M + \delta_{XL} \ln X_L + \delta_{XH} \ln X_H \\ & + \delta_{XP} \ln X_R + \delta_{XK} \ln X_K + \alpha_{X\tau} \ln t. \end{aligned} \tag{34}$$

$$\begin{aligned}\partial \ln \pi/\partial \ln P_M = SM = {} & \alpha_M + \gamma_{MC} \ln P_C + \gamma_{MI} \ln P_I \\ & + \gamma_{MX} \ln P_X + \gamma_{MM} \ln P_M + \delta_{ML} \ln X_L + \delta_{MH} \ln X_H \\ & + \delta_{MR} \ln X_R + \delta_{MK} \ln X_K + \alpha_{M\tau} \ln t. \end{aligned} \tag{35}$$

The above equations are assumed to be homogeneous in P. Linear homogenity in P implies the following:

(a) $$\frac{\delta \ln \pi}{\delta \ln P_C} + \frac{\delta \ln \pi}{\delta \ln P_I} + \frac{\delta \ln \pi}{\delta \ln P_X} + \frac{\delta \ln \pi}{\delta \ln P_M} = 1$$

(b) $\alpha_C + \alpha_I + \alpha_X + \alpha_M = 1,$

(c) $\sum \gamma_{ih} = 0$, $h, i \in \Delta$, and

(d) $\sum \delta_{ij} = 0$, $i \in \Delta$; $j \in \Pi$.

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

$$\begin{aligned}\partial \ln \pi / \partial \ln X_L = SL = {} & \beta_L + \delta_{CL} \ln P_C + \delta_{IL} \ln P_I \\ & + \delta_{XL} \ln P_X + \delta_{ML} \ln P_M + \phi_{LL} \ln X_L + \phi_{LH} \ln X_H \\ & + \phi_{LR} \ln X_R + \phi_{LK} \ln X_K + \beta_{L\tau} \ln t. \end{aligned} \tag{36}$$

$$\begin{aligned}\partial \ln \pi / \partial \ln X_H = SHC = {} & \beta_H + \delta_{CH} \ln P_C + \delta_{IH} \ln P_I \\ & + \delta_{XH} \ln P_X + \delta_{MH} \ln P_M + \phi_{HL} \ln X_L + \phi_{HH} \ln X_H \\ & + \phi_{HR} \ln X_R + \phi_{HK} \ln X_K + \beta_{H\tau} \ln t. \end{aligned} \tag{37}$$

$$\begin{aligned}\partial \ln \pi / \partial \ln X_R = SRD = {} & \beta_R + \delta_{CR} \ln P_C + \delta_{IR} \ln P_I \\ & + \delta_{XR} \ln P_X + \delta_{MR} \ln P_M + \phi_{RL} \ln X_L + \phi_{RH} \ln X_H \\ & + \phi_{RR} \ln X_R + \phi_{RK} \ln X_K + \beta_{R\tau} \ln t. \end{aligned} \tag{38}$$

$$\begin{aligned}\partial \ln \pi / \partial \ln X_k = SK = {} & \beta_K + \delta_{CK} \ln P_C + \delta_{IK} \ln P_I \\ & + \delta_{XK} \ln P_X + \delta_{MK} \ln P_M + \phi_{KL} \ln X_L + \phi_{KH} \ln X_H \\ & + \phi_{kR} \ln X_R + \phi_{KK} \ln X_K + \beta_{K\tau} \ln t. \end{aligned} \tag{39}$$

Linear homogeneity in X implies the following:

$$(e)\ \frac{\delta \ln \pi}{\delta \ln X_L} + \frac{\delta \ln \pi}{\delta \ln X_H} + \frac{\delta \ln \pi}{\delta \ln X_R} + \frac{\delta \ln \pi}{\delta \ln X_K} = 1$$

$$(f)\ \beta_L + \beta_H + \beta_R + \beta_K = 1,$$

$$(g)\ \sum \phi_{jk} = 0; \quad j,\ k \in \Pi,$$

$$(h)\ \sum\ \delta_{ij} = 0; \quad i \in \Delta,\ j \in \Pi.$$

The parameter estimates from equations (32) to (39) will be used to compute various partial elasticites, the analysis of which will provide insights into the substitution possibilities inherent in U.K. technology.

5.3 Construction and Sources of Data

The basic data employed consist of 27 annual observations on the price and quantity of three outputs (consumption goods, investment goods and exports), one variable input (imports) and four fixed domestic inputs (labour services, physical capital, human capital and research and development) for the period 1960 to 1986.

The consumption figures include current sales by business to both individuals and Government, including consumption expenditures on durables, nondurables, services and Government expenditures. Investment includes both gross private capital formation and inventory accumulation. Imports and exports are quantities of goods and services imported and exported respectively. Aggregation has been carried through by computing Divisia indices. The Divisia index is flexible because it is based on a homogeneous production function which provides a second-order approximation to a arbitrary production function at any given point (Christensen, Jorgenson and Lau [1973]). The output and variable input price series have been normalised to one for 1980.

The human capital input variable is the Divisia quantity index of real net human capital stock and the value of human capital is the sum of the current values of the stocks of education expenditures and the foregone earnings of students.

The capital input variable is the Divisia quantity index of net real total capital stock. The value of capital is calculated as the sum of current values of the various components (parts and machinery, vehicles, ships, aircrafts, dwellings and other buildings) of capital stock. These series are published by the Central Statistical Office in the *Annual Abstract of Statistics*.

The measure of the labour input variable is the Divisia quantity index of total man-hours of the employed labour force. The value of labour services is taken to be total compensation to employees. These series are also published in the *Annual Abstract of Statistics*.

The R&D input variable is computed as the Divisia quantity index of net real R&D stock and the value of R&D services as the product of net real R&D stock and the consumer price index.

5.4 Stochastic Specification and Estimation Technique

The translog variable profit function is assumed to be an exact representation of U.K. technology and any derivations of the observed output and input shares from their logarithmic derivatives are the result of random errors in profit-maximizing behaviour. Thus a vector of random disturbances for any time period t is specified for the share equations.

$$e_t' = (e_{1t}, \ldots, e_{(N+J)t}). \tag{40}$$

such that

$$\sum_{i\in\Delta} e_{it} = 0 \text{ and } \sum_{j\in\Pi} e_{jt} = 0, \quad t=1,2,\ldots\ldots,n \tag{41}$$

where n is the number of observations.

The disturbances are allowed to be contemporaneously correlated, since the covariance between the error term of a variable quantity share equation and the stochastic term of a fixed quantity share equation may be non-zero, but they are specified to be temporally independent. In this case the variance covariance matrix of $\epsilon' = (e_C, e_I, e_X, e_M, e_H, e_R, e_K)$ is

$$\Omega = I_n \otimes \begin{bmatrix} \sigma_{CC} & \sigma_{CI} & \sigma_{CX} & \sigma_{CM} & \sigma_{CL} & \sigma_{CH} & \sigma_{CR} & \sigma_{CK} \\ \sigma_{IC} & \sigma_{II} & \sigma_{IX} & \sigma_{IM} & \sigma_{IL} & \sigma_{IH} & \sigma_{IR} & \sigma_{IK} \\ \sigma_{XC} & \sigma_{XI} & \sigma_{XX} & \sigma_{XM} & \sigma_{XL} & \sigma_{XH} & \sigma_{XR} & \sigma_{XK} \\ \sigma_{MC} & \sigma_{MI} & \sigma_{MX} & \sigma_{MM} & \sigma_{ML} & \sigma_{MH} & \sigma_{MR} & \sigma_{MK} \\ \sigma_{LC} & \sigma_{LI} & \sigma_{LX} & \sigma_{LM} & \sigma_{LL} & \sigma_{LH} & \sigma_{LR} & \sigma_{LK} \\ \sigma_{HC} & \sigma_{HI} & \sigma_{HX} & \sigma_{HM} & \sigma_{HL} & \sigma_{HH} & \sigma_{HR} & \sigma_{HK} \\ \sigma_{RC} & \sigma_{RI} & \sigma_{RX} & \sigma_{RM} & \sigma_{RL} & \sigma_{RH} & \sigma_{RR} & \sigma_{RK} \\ \sigma_{KC} & \sigma_{KI} & \sigma_{KX} & \sigma_{KM} & \sigma_{KL} & \sigma_{KH} & \sigma_{KR} & \sigma_{KK} \end{bmatrix}$$

where I_n is the identity matrix of order n.

Since the output and input shares each sum to unity at every observation, the disturbance covariance matrix is singular. This problem can be overcome by dropping one variable output share equation from the supply side and one fixed input share equation from the demand side. When the estimation method presumes homogeneity and symmetry, the choice of equations to be dropped is arbitrary and estimates of the parameters of these omitted equations can be derived from the homogeneity and symmetry restrictions (Barten [1969]). In this study the import share equation is dropped from the supply side and the capital share equation from the demand side; in addition, the right hand side variables are expressed as ratios in the following system of estimating share equations:

$$\begin{aligned} SC = P_C Y_C/\pi &= \alpha_C + \gamma_{CC} \ln (P_C/P_M) + \gamma_{CI} \ln (P_I/P_M) \\ &+ \gamma_{CX} \ln (P_X/P_M) + \delta_{CL} \ln (X_L/X_K) + \delta_{CH} \ln (X_H/X_K) \\ &+ \delta_{CR} \ln (X_R/X_K) + \alpha_{C\tau} \ln t + e_C. \end{aligned} \qquad (42)$$

$$SI = P_I Y_I/\pi = \alpha_I + \gamma_{CI} \ln (P_C/P_M) + \gamma_{II} \ln (P_I/P_M) + \gamma_{IX} \ln (P_X/P_M) + \delta_{IL} \ln (X_L/X_K) + \delta_{IH} \ln (X_H/X_K) + \delta_{IR} \ln (X_R/X_K) + \alpha_{I\tau} \ln t + e_I. \qquad (43)$$

$$SX = P_X Y_X/\pi = \alpha_X + \gamma_{CX} \ln (P_C/P_M) + \gamma_{IX} \ln (P_I/P_M) + \gamma_{XX} \ln (P_X/P_M) + \delta_{XL} \ln (X_L/X_K) + \delta_{XH} \ln (X_H/X_K) + \delta_{XR} \ln (X_R/X_K) + \alpha_{X\tau} \ln t + e_X. \qquad (44)$$

$$SL = W_L X_L/\pi = \beta_L + \delta_{CL} \ln (P_C/P_M) + \delta_{IL} \ln (P_I/P_M) + \delta_{XL} \ln (P_X/P_M) + \phi_{LL} \ln (X_L/X_K) + \phi_{LH} \ln (X_H/X_K) + \phi_{LR} \ln (X_R/X_K) + \beta_{L\tau} \ln t + e_L. \qquad (45)$$

$$SHC = W_H X_H/\pi = \beta_H + \delta_{CH} \ln (P_C/P_M) + \delta_{IH} \ln (P_I/P_M) + \delta_{XH} \ln (P_X/P_M) + \phi_{LH} \ln (X_L/X_K) + \phi_{HH} \ln (X_H/X_K) + \phi_{HR} \ln (X_R/X_K) + \beta_{H\tau} \ln t + e_h. \qquad (46)$$

$$SRD = W_R X_R/\pi = \beta_R + \delta_{CR} \ln (P_C/P_M) + \delta_{IR} \ln (P_I/P_M) + \delta_{XR} \ln (P_X/P_M) + \phi_{LR} \ln (X_L/X_K) + \phi_{HR} \ln (X_H/X_K) + \phi_{RR} \ln (X_R/X_K) + \beta_{R\tau} \ln t + e_R \qquad (47)$$

The system of share equations (42)-(47) has parameter restrictions and contemporaneous correlation in the disturbances across equations.

An estimation method is therefore required that will take these features into consideration. Such a method is Zellner's iterative efficient estimation procedure (IZEF). This method takes into account only the parameter constraints across equations. The procedure involves a number of steps until convergence is achieved. First, the system of equations using constrained coefficients are estimated. Using the residuals from this first step we then obtain an estimate of the variance-covariance matrix $\hat{\Omega}^{(1)}$. Using $\hat{\Omega}^{(1)}$ we obtain a second set of parameters using GLS. If we now use the residuals from the second stage, we can obtain a second estimate of $\Omega^{(2)}$. This method continues until convergence is achieved. The procedure is deemed to have converged when both of the following hold: the parameter changes are less than some pre-specified value (usually .01) and the product of the inverse of the covariance matrix from the previous iteration and the covariance matrix from the current iteration is 'close to' unity.

IZEF is predicated on the assumption that the right-hand side variables are exogenous. It may be reasonable to assume that U.K. firms operate in competitive product and factor markets and therefore that output prices and the prices of inputs can be taken as fixed. At the more aggregate economy level, however, input prices and hence output prices are less likely to be exogenous; moreover, the United Kingdom is not a small open economy and therefore does not act as a price taker in both import and export markets. Thus it may be inappropriate to assume that output supply prices are exogeneous and that the variable quantity price regressors in equations (42) to (47) are uncorrelated with the disturbances. If the estimation procedure is to provide consistent parameter estimates in equations (42) to (47) this possible simultaneity must be taken into account. Thus IZEF is an inappropriate estimation method from this point of view, but it can be adapted to handle the situation by revamping the procedure in terms of instrumental variables. This method will be termed MIZEF. The instruments used are precisely those used by Berndt and Christensen [1973b, 1974] and by Berndt and Wood [1975] for the U.S. These are: U.K. population, U.K. population of working age, effective rate of sales and excise taxation, property taxes, Government purchases of labour services, Government purchases of non-durables, Government purchases of durable goods, U.K. net capital stock lagged one period, real exports of goods lagged one period and real exports of services at the end of the previous year which are in addition to the instrumental (exogenous) variables already in the equations. Specifically, since linear homogeneity in prices is imposed, $\ln(P_C/P_M)$, $\ln(P_I/P_M)$ and $\ln(P_X/P_M)$ are regressed on the instrumental variables and their fitted values are used to estimate equations (42) to (47). The R^2 estimates from these first-stage regressions are 0.824, 0.873 and 0.812 respectively. The entire system is then estimated by the MIZEF method, iterated until the estimated coefficients and the residual covariance matrix converge. The MIZEF estimator, being a member of the class of generalized instrumental variable estimators (GIVE), is a best asymptotic normal estimator, for the class of instruments used. The MIZEF procedure used in this thesis is precisely that used by Berndt & Christensen [1974] and Berndt & Wood [1975].

The final set of variables used in the estimation of the model are SE, SI, SX, SL, SHC, SRD, S1, S2, S3, Z4, Z5, and Z6 and the following set of exogoneous variables:

$$SE = C/GNP$$

$$SI = I/GNP$$

$$SX = X/GNP$$

$$SL = W_L L/WC$$

$$SHC = W_H H/WC$$

$$SRD = W_R R/WC$$

$$WC = W_L L + W_H H + W_R R + W_K K$$

$$S1 = \ln (X_L/X_K)$$

$$S2 = \ln (X_H/X_K)$$

$$S3 = \ln (X_R/X_K)$$

$$Z4 = \ln (P_C/P_M)$$

$$Z5 = \ln (P_I/P_M)$$

$$Z6 = \ln (P_X/P_M)$$

where

GNP = Gross National Product in nominal terms

C = Consumption Expenditures in nominal terms

I = Investment Expenditures in nominal terms

X = Exports in nominal terms

WC = total value of the fixed factors of production

$W_L L$ = Employee compensation

$W_H H$ = value of human capital

$W_R R$ = value of research and development

$W_K K$ = value of capital services

P_C = Divisia price index of consumption goods

P_I = Divisia price index of investment goods

P_M = Divisia price indes of imports

P_X = Divisia price index of exports

X_L = Divisia quantity index of labour service

X_K = Divisia quantity index of physical capital services

X_H = Divisia quantity index of human capital

X_R = Divisia quantity index of R&D

See Tables 5.3 to 5.7.

5.5 Model Validation and Empirical Results

5.5.1 Introduction

There are 80 parameters in the system described by equations (32) to (39). Since some of the γ's and δ's appear more than once, they have to be restricted to a unique value which imposes 27 symmetry constraints. In addition since the variable profit function is linear homogeneous in prices and quantities by definition, the share equations are homogeneous of degree zero in both prices and quantities. This leads to 20 homogeneity constraints, leaving 33 parameters to estimate.

5.5.2 Model Validation

It is necessary, first, to seek to validate the maintained hypothesis of the translog model. In this respect, there are five types of test to be undertaken. First, tests which seek to confirm the assumed error structure. Here we shall be especially concerned with normality of the residuals and serial correlation. Second, there are tests that seek to confirm the assumed conditions of monotonicity and convexity/concavity of the translog model. Third, there are tests that seek to confirm the stability of the coefficients and the cross-equation restrictions of the translog model.

Normality of the residuals is necessary for conducting statistical tests of significance on the parameter estimates. Normality may arise by virtue of an original assumption or via a central limit theorem. If normality of the residuals is violated, then the statistical reliability of tests of significance must be called into question. A formal way of checking for departure from normality is the Jarque-Bera test[1]. According to this test, the test statistic under the null hypothesis has a chi-square distribution with two degrees of freedom. The chi-square statistic ranges from 0.305 for the consumption share equation to 4.01 for the human capital share equation. The 5% critical value from the chi-square table for two degrees of freedom is 5.99. These results lend weight to the view that the residuals do not depart significantly from normality.

In considering serial correlation there is good reason, a priori,

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[1]

$$LM = n \left[\frac{b_1}{6} + \frac{(b_2 - 3)^2}{24} \right] \sim \chi^2(2),$$

where b_1 is the shewness coefficient defined as $\sqrt{b_1} = \frac{u_3}{u_2^{3/2}}$ and b_2 is

the coefficient of Kurtosis defined as $b_2 = \frac{u_4}{u_2^2}$, where u_r $(r = 2,3,4)$

is the rth moment about the mean. A test for normality is a test of the null hypotheses: $H_o: b_1 = 0$ and $b_2 = 3$ against an alternative hypothesis that H_o is not true.

to suspect its presence since the data are time series and ecomomic time series are characteristically serially correlated. Judge et al. [1985] have suggested the use of the conventional single-equation Durbin-Watson d-statistic to check for autocorrelation in a simultaneous equation model of the kind examined in this chapter. The test is performed on the equations individually and the Durbin-Watson d-statistics are: 1.08 for SE, 1.64 for SE, 1.87 for SX, 1.33 for SL, 0.75 for SHC and 0.68 for SRD, indicating that there is no conclusive evidence of autocorrelation (since the values fall within the inconclusive range). If first-order autoregressive (AR1) errors are presumed and the equations transformed by the Cochrane-Orcutt procedure, the resulting d-statistics cannot sustain significant serial correlation, yet, even if such serial correlation were sustainable, the second-order condition for the export shares and ' ` the human capital shares is not then satisfied. Thus correcting for AR1 residuals evidently renders the model less appropriate than when such correction is not undertaken. Moreover, no strong case can be made at the outset for presuming AR1 residuals. Thus the balance of the evidence, such as it is, favours excluding AR1 residuals from consideration.

A further test on the translog specification is to assess whether the monotonicity and convexity conditions are satisfied for the estimated parameters. The monotonicity conditions [A.6 and A.9] are satisfied since the estimated share of imports is negative and those of outputs and fixed inputs are positive at each annual observation. The curvature conditions (convexity in P [A.7] and concavity in X [A.8]) are also satisfied, since the own partial elasticitics are greater than zero for outputs and less than zero for inputs for each observation. It is therefore concluded that the translog profit function is economically well-behaved in the neighbourhood covered by the set of U.K. data used in the calculations.

Another concern is structural instability, because Winters [1984] and Thursby and Thursby [1984] have found evidence of structural instability for the import demand function when the United Kingdom joined the EEC in 1972. The implication of this change, is that the coefficients of the model for the 1960-72 period could be different from the coefficients for the 1972-86 period. A Chow test was employed to test for structural instability[2]. The null hypothesis is that the structural coefficients are stable against the alternative that their values are different in the two periods. The residual sum of squares for the first period (1960-72) is computed as the sum of the residual sum of squares for the six equations. The residual sum of squares for the second period (1973-86) is calculated analagously. The sum of these two is the residual sum of squares for the unrestricted model. The residual sum of squares for the restricted model is the sum of the residual sum of squares for the six equations for the entire sample period. The calculated F ratio is 0.847. The critical F ($V_1 = 48$, $V_2 = 66$) at 5% is 1.56. Since the calculated F ratio is less than the

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[2] The Chow test is $F = \frac{(SSR(R)-SSR(U))/6K}{SSR(U)/6n+6m - 12k}$, with degrees of freedom 6k and $6m_1 + 6m_2 - 12k$, where m_1 and m_2 are the observations in the first and second periods respectively.

tabular F the null hypothesis cannot be rejected. The evidence, then, does not support the hypothesis of structural change.

The last test to be undertaken is on the symmetry of the translog model. A likelihood ratio test of the following kind is used[3]. Two models are estimated: a constrained model in which there are the required cross-equation restrictions and an unconstrained model in which the coefficients are not constrained. Both models are estimated and the likelihood ratio test statistic is computed and compared with the critical value of $\chi^2(r)$, r being the number of restrictions imposed. At the 0.05 level of significance, the calculated chi-square statistic of 19.8 is less than the 0.05 critical value of 67.5 Thus the evidence does not support rejecting the null hypothesis. On the basis of the evidence, the symmetry conditions would seem to be compatible with the data.

In summary, the evidence available, implies first, that normality of the residuals cannot be rejected; second, that the null hypothesis of serially uncorrelated residuals cannot be rejected; third, that, at each data point, the model is consistent with the monotonicity condition A.6 and with convexity in P (A.7) and concavity in X (A.8); fourth, that there is no strong support for the structural change hypothesis

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[3] Let L_r = likelihood function for the restricted version with r restrictions and L_u = likelihood function for the unrestricted version. Then $LR = L_r/L_u$, and $-2 \ln LR$ is distributed as $\chi^2(r)$.

discovered by Winters [1984] and Thursby and Thursby [1984]; and, finally, that the data are consistent with a symmetric translog model. In many ways, these five results represent a happy state of affairs, since the evidence lends credence to the view that the original model is well specified; and therefore that an application of the model to an analysis of U.K trade is in order. The last statement would certainly seem to be irrefutable on the basis of the evidence presented. Yet it is inappropriate, on knowledge of the data, especially the data constructed by the author, to display such confidence in the model and the data, for two reasons.

In the first place, there is not a great deal of evidence. The model is fitted to a mere 27 observations while the tests used have, generally speaking, only an asymptotic justification. Typically in cases of this kind, the nominal size of a test (α^*) very much understates its true size (α); which is to say that a corresponding confidence region of a particular parameter is nominally high (95%), while in fact being rather low [$(1-\alpha) \ll 95\%$]. In short, although the evidence of the tests lends support to going forward with the applications in view, it must be admitted that, in all likelihood, the confidence level of the parameter values is very much smaller than would seem to be the case based on nominal size.

In the second place, and potentially more important for the present discussion, the basic data must surely suffer from the ubiquitous problem of errors-in-variables. In a recent lecture, Cragg [1994] has made clear that errors in the variables can cause havoc with the interpretation of traditionally estimated econometric models. For example, while symmetry ought to hold for the translog model estimate with error-free data, symmetry would not hold if the data are prone to random errors with zero means. Thus, except under special circumstances, and if the data contain errors, estimates of the model should not be expected *inter alia* to obey the symmetry conditions. Of course, to state that, say, symmetry ought not to be obeyed is not to say what should be obeyed or what is the appropriate procedure for dealing with the problem. Indeed, it is not known at this time, what would be an appropriate analysis of U.K. trade in the presence of errors in the variables and to begin to undertake such a study is certainly, at the very least, beyond the scope of this thesis.

5.5.3 Empirical Results

The parameter estimates are presented in Tables 5.1 and 5.2. The R^2 figures are 0.25 (SC), 0.50 (SI), 0.27 (SX), 0.95 (SL), 0.83 (SHC) and 0.60 (SRD). The observed and fitted values of the shares are graphed in Figures 6.1 to 6.8. The plots show a reasonable fit of the various relationships. The estimates and fitted values will be used to compute the various partial elasticities which will be presented and analysed in the next chapter. Nearly all of the parameter estimates are significantly different from zero. From the estimates of $\alpha_{i\tau}$, technical change has been biased in favor of investment goods and imports and against the production of consumption goods and exports. The estimates of $\beta_{j\tau}$ indicate that technical change is labour-using, capital-using but R&D-saving and human-capital-saving. A further more detailed analysis of the results and their implications is given in Chapter 6.

TABLE 5.1: MIZEF ESTIMATES OF THE TRANSLOG PROFIT FUNCTION. U.K. ECONOMY, 1960-1986. ASYMPTOTIC STANDARD ERRORS ARE GIVEN IN PARENTHESES.

<u>Outputs</u>

Consumption	Investment	Exports	Imports
γ_{CC} = 0.273 (0.101)	γ_{II} = 0.187 (0.048)	γ_{XX} = 0.212 (0.107)	γ_{MM} =-0.064 (0.027)
γ_{CI} = -0.171 (0.056)	γ_{IC} =-0.171 (0.056)	γ_{XC} =-0.161 (0.093)	γ_{MC} = 0.060 (0.036)
γ_{CX} = -0.161 (0.093)	γ_{IX} =-0.036 (0.042)	γ_{XI} =-0.036 (0.042)	γ_{MI} = 0.020 (0.027)
γ_{CM} = 0.060 (0.036)	γ_{IM} = 0.020 (0.027)	γ_{XM} =-0.015 (0.035)	γ_{MX} =-0.015 (0.035)
α_{CT} = -0.018 (0.007)	α_{IT} = 0.018 (0.005)	α_{XT} =-0.002 (0.006)	α_{MT} = 0.002 (0.004)
δ_{CK} = -0.138 (0.070)	δ_{IK} = 0.068 (0.047)	δ_{XK} =-0.050 (0.063)	δ_{MK} = 0.076 (0.040)
δ_{CL} = 0.015 (0.025)	δ_{IL} = 0.030 (0.016)	δ_{XL} =-0.026 (0.023)	δ_{ML} =-0.018 (0.010)
δ_{CH} = -0.102 (0.039)	δ_{IH} =-0.077 (0.027)	δ_{XH} = 0.017 (0 034)	δ_{MH} =-0.041 (0.018)
δ_{CRD}= 0.022 (0.012)	δ_{IRD} =-0.020 (0.007)	δ_{XRD}= 0.015 (0.012)	δ_{MRD}=-0.016 (0.005)

TABLE 5.2: MIZEF ESTIMATES OF THE TRANSLOG PROFIT FUNCTION. U.K. ECONOMY, 1960-1986. ASYMPTOTIC STANDARD ERRORS ARE GIVEN IN PARENTHESES.

Demands

Labour	Human Capital	R&D	Capital
$\phi_{LL} = 0.011$ (0.010)	$\phi_{HH} = 0.051$ (0.026)	$\phi_{RDRD} = 0.028$ (0.009)	$\phi_{KK} = -0.171$ (0.081)
$\phi_{LH} = -0.076$ (0.014)	$\phi_{HL} = -0.076$ (0.014)	$\phi_{RL} = -0.022$ (0.005)	$\phi_{KL} = 0.087$ (0.027)
$\phi_{LK} = 0.087$ (0.027)	$\phi_{HK} = 0.058$ (0.045)	$\phi_{RK} = 0.027$ (0.013)	$\phi_{KH} = 0.058$ (0.045)
$\phi_{LR} = -0.022$ (0.005)	$\phi_{HR} = -0.033$ (0.008)	$\phi_{RH} = -0.033$ (0.008)	$\phi_{KR} = 0.027$ (0.013)
$\beta_{LT} = 0.002$ (0.006)	$\beta_{HT} = -0.013$ (0.004)	$\beta_{RT} = -0.002$ (0.001)	$\beta_{KT} = 0.012$ (0.007)
$\delta_{LM} = -0.018$ (0.010)	$\delta_{HM} = -0.041$ (0.018)	$\delta_{RM} = -0.016$ (0.005)	$\delta_{KM} = 0.076$ (0.040)
$\delta_{LC} = 0.015$ (0.025)	$\delta_{HC} = 0.102$ (0.039)	$\delta_{RC} = 0.021$ (0.012)	$\delta_{KC} = -0.138$ (0.070)
$\delta_{LI} = 0.037$ (0.016)	$\delta_{HI} = -0.077$ (0.027)	$\delta_{RI} = -0.20$ (0.007)	$\delta_{KI} = 0.068$ (0.047)
$\delta_{LX} = -0.026$ (0.023)	$\delta_{HX} = 0.101$ (0.039)	$\delta_{RX} = 0.015$ (0.012)	$\delta_{KX} = -0.005$ (0.064)

5.6 Summary

In this chapter an empirical version of the theoretical model of Chapter 3 has been developed and its stochastic specification explained The sources of the data used to estimate the model have also been described. Following these matters of specifications, the model has been fitted to the data using a particular restricted form of generalized instrumental variable estimation which is applicable to systems of simultaneous equations Various pre-test methods provided evidence to 'support' the view that the original empirical specification is broadly satisfactory, and hence the empirical estimates may be applied to an analysis on U.K. trade. This is carried out in Chapter 6.

The perceptive reader may notice in the discussion of the empirical model and its estimates, that the methodology applied has been to give greatest weight to the null hypothesis, unless evidence can be found to the contrary. This can be said to be a standard approach to econometric analysis and the author makes no apology for using it. However, it should also be recognized that, in the presence of errors-in-the-variables, much of the standard econometric conditions (e.g. symmetry) on which the empirical work has been carried out, will not be met in the empirical estimates (Cragg [1994]). In fact, it would take a very highly detailed analysis to cope with the consequences of errors-in-the-variables, and such an analysis would amount to another Ph.D. Thesis and probably several more. Seen in this light, the analysis presented here may be viewed as seeking to establish an approach and a model of U.K. trade, along with their quantitative implications, and that critical appraisals of such an approach and model must wait upon the establishment of an empirical basis for the analysis of U K trade such as is presented in this thesis. As will become clear in Chapter 6, the implications of the empirical analysis are both interesting and reasonable, and in this sense, worthwhile, even though later analysis, assuming errors-in-the-variables, may provide modifications to some of the conclusions.

TABLE 5.3: DATA FOR ESTIMATION OF MODEL - OUTPUT SHARES

YEAR	SC	SI	SX	SM
1960	.82368	.18309	.28149	-.28826
1961	.81642	.17967	.28583	-.28193
1962	.82613	.16579	.27800	-.26993
1963	.82510	16640	.28592	-.27741
1964	.81123	.19504	.27987	-.28614
1965	.80908	.18718	.27632	-.27259
1966	.80950	.18301	.26993	-.26243
1967	.80700	.19448	.26848	-.26996
1968	.80288	.19822	.27271	-.26381
1969	.79177	.19364	.27986	-.26527
1970	.78827	.19378	.28001	-.26207
1971	.79110	.18632	.27983	-.25725
1972	.81258	.18138	.26666	-.26062
1973	.79628	.21098	.27422	-.28148
1974	.81795	.18947	.28167	-.28910
1975	.82648	.18386	.26061	-.27096
1976	.80280	.19825	.28686	-.28791
1977	.79555	.19765	.29852	-.29172
1978	.78911	.19457	.28610	-.26978
1979	.79458	.19753	.28406	-.27617
1980	.81975	.17142	.27685	-.26801
1981	.82883	.16266	.27431	-.26580
1982	.83118	.16189	.27003	-.26311
1983	.82806	.16449	.27563	-.26818
1984	.81892	.17023	.29571	-.28487
1985	.80915	.17085	.29779	-.27778
1986	.82615	.17066	.27009	-.26689

Notes:

SC = C/GNP

SI = I/GNP

SX = X/GNP

SM = M/GNP

TABLE 5.4: DATA FOR ESTIMATION OF MODEL - INPUT SHARES

YEAR	SL	SK	SRAD	SHC
1960	0.16871	0.62394	0.04578	0.16157
1961	0.16804	0.62484	0.04697	0.16015
1962	0.16059	0.63037	0.04828	0.16076
1963	0.16385	0.63057	0.04831	0.15726
1964	0.16529	0.62690	0.04964	0.15817
1965	0.16540	0.62318	0.05090	0.16052
1966	0.17130	0.61921	0.05065	0.15885
1967	0.16718	0.61975	0.05146	0.16161
1968	0.16538	0.61611	0.05266	0.16585
1969	0.16136	0.61839	0.05271	0.16754
1970	0.16087	0.62138	0.05154	0.16621
1971	0.15362	0.62726	0.05114	0.16798
1972	0.15428	0.63591	0.04802	0.16179
1973	0.14474	0.65883	0.04452	0.15190
1974	0.14278	0.66688	0.04243	0.14791
1975	0.14017	0.65255	0.04513	0.16215
1976	0.14234	0.64130	0.04543	0.17093
1977	0.13651	0.63505	0.04711	0.18134
1978	0.13521	0.63830	0.04642	0.18008
1979	0.13941	0.63647	0.04589	0.17823
1980	0.13748	0.62429	0.04860	0.18962
1981	0.13588	0.63629	0.04752	0.18032
1982	0.13805	0.62165	0.05014	0.19016
1983	0.13342	0.62076	0.05154	0.19428
1984	0.13414	0.61353	0.05073	0.20160
1985	0.13138	0.61181	0.05170	0.20511
1986	0.13512	0.60544	0.05248	0.20696

Notes:

$SL = W_L L/WC$ $SRAD = W_R R/WC$

$SHC = W_H H/WC$ $SK = W_K K/WC$

TABLE 5.5: DATA USED FOR ESTIMATION OF MODEL - FITTED VALUES OF PRICE RATIOS, AND FACTOR RATIOS

YEAR	Z4	Z5	Z6	S1	S2	S3
1960	-.23296	-.33034	-.12108	0.50025	-0.51443	-0.41174
1961	-.22985	-.35838	-.12265	0.47765	-0.50857	-0.37181
1962	-.20912	-.42597	-.11881	0.42952	-0.48495	-0.32447
1963	-.20437	-.31681	-.12335	0.42818	-0.44911	-0.26597
1964	-.18726	-.29610	-.12057	0.42301	-0.41682	-0.21254
1965	-.15576	-.27334	-.10449	0.37699	-0.40250	-0.18821
1966	-.14567	-.26677	-.08767	0.38152	-0.41754	-0.19796
1967	-.06991	-.19371	-.02904	0.34078	-0.39077	-0.17256
1968	-.02555	-.14296	.00567	0.31665	-0.35868	-0.14361
1969	.01148	-.08313	.02810	0.27615	-0.34587	-0.14017
1970	.04145	-.05619	.04711	0.26868	-0.27713	-0.08626
1971	.05321	-.02587	.06030	0.19723	-0.26318	-0.09067
1972	-.00775	-.05286	.00362	0.13976	-0.24384	-0.09682
1973	-.05824	-.08664	-.05770	0.13040	-0.22383	-0.08965
1974	-.08979	-.12365	-.07948	0.10885	-0.17957	-0.06678
1975	-.13999	-.15507	-.11241	0.08512	-0.12464	-0.04199
1976	-.16975	-.19450	-.12886	0.03569	-0.10259	-0.06622
1977	-.13028	-.17166	-.08693	0.01466	-0.08466	-0.07103
1978	-.17100	-.18005	-.14974	0.01226	-0.04887	-0.04309
1979	-.07849	-.09437	-.06661	0.01102	-0.02117	-0.01659
1980	.04343	.01771	.03495	0.00000	0.00000	0.00000
1981	-.03881	-.05184	-.04067	-0.14577	-0.04201	-0.04590
1982	.06748	-.01971	.00886	-0.17967	-0.02391	0.03320
1983	.05215	-.03862	.02915	-0.20537	-0.00005	-0.01712
1984	-.02519	-.11129	-.02905	-0.20893	-0.00244	-0.02048
1985	02707	-.05172	-.01520	-0.21454	0.00856	-0.00778
1986	.09238	.02203	.01388	-0.23237	0.01822	0.00784

Notes:

Z4 = Ln $(\hat{P}_C/P_M)$

Z5 = Ln $(\hat{P}_I/P_M)$

Z6 = Ln $(\hat{P}_X/P_M)$

S1 = Ln (X_L/X_K)

S2 = Ln (X_H/X_K)

S3 = Ln (X_R/X_K)

TABLE 5.6: EXOGENOUS VARIABLES

YEAR	SOML	UKP	UKWP	LNCS	GPL
1960	6.10	52.372	24.526	48.2	2.444
1961	6.50	52.807	24.774	49.1	2.632
1962	6.80	53.292	25.059	52.6	2.820
1963	7.00	53.625	25.163	56.6	3.007
1964	7.50	53.991	25.306	65.3	3.279
1965	7.98	54.350	25.513	71.7	3.551
1966	8.15	54.643	25.638	77.7	3.952
1967	8.30	54.959	25.504	83.3	4.353
1968	8.44	55.219	25.387	89.3	4.753
1969	8.78	55.461	25.375	97.6	5.154
1970	8.81	55.632	25.308	108.1	5.555
1971	9.64	55.907	25.122	122.9	6.523
1972	11.11	56.079	25.195	141.5	7.611
1973	12.66	56.210	25.546	169.0	8.635
1974	13.30	56.224	25.602	215.7	10.813
1975	14.74	56.215	25.877	275.7	15.179
1976	17.48	56.206	26.094	332.6	17.418
1977	19.47	56.179	26.209	381.8	18.764
1978	23.66	56.167	26.342	428.7	20.825
1979	27.54	56.227	26.609	498.7	23.822
1980	29.86	56.314	26.819	596.4	30.133
1981	31.04	56.379	26.718	731.7	34.347
1982	36.53	56.335	26.663	805.5	36.587
1983	40.66	56.377	26.586	830.4	39.888
1984	45.19	56.488	27.113	870.7	42.154
1985	52.16	56.618	27.593	928.8	44.619
1986	61.62	56.820	28.064	999.2	46.920

Notes:

SOML	Property taxes. It is denominated in £b.
UKP	U.K. population in millions.
UKWP	U.K. working population in millions.
LNCS	Net capital stock lagged one period, in £b.
GPL	Government purchases of labour services - in £b.

TABLE 5.7: EXOGENOUS VARIABLES

YEAR	GPDG	GPS	ETR	EG	ES
1960	.356	1.452	.10187	4.856	2.996
1961	.215	1.793	.10236	5.178	2.847
1962	312	1.792	.10324	5.829	2.943
1963	.331	1.849	.09887	6.126	3.201
1964	.355	1.902	.10025	6.409	3.492
1965	.371	2.125	.10422	6.741	3.560
1966	.397	2.228	.10621	8.352	2.522
1967	.420	2.421	.11202	9.037	2.869
1968	.416	2.426	.12051	9.815	3.308
1969	.504	2.315	.13017	10.504	3.926
1970	.556	2.598	.12786	11.752	4.371
1971	.634	2.883	.11630	12.399	4.826
1972	.728	3.196	.10710	13.945	6.553
1973	.904	3.777	.10136	15.864	8.143
1974	1.086	4.819	.09832	19.330	8.567
1975	1.358	6.569	.13112	25.191	11.569
1976	1.596	8.023	.12707	31.728	11.864
1977	1.785	8.736	.13583	35.063	10.260
1978	1.999	10.182	.13471	40.687	15.543
1979	2.461	12.042	.15041	47.422	15.453
1980	3.078	15.077	.18710	50.977	17.833
1981	3.496	16.561	.16674	55.565	18.455
1982	3.581	19.083	.16831	60.776	22.044
1983	3.713	21.647	.16184	70.365	25.542
1984	3.880	23.334	.16186	78.051	27.653
1985	4.151	24 846	.16005	72.843	29.678
1986	4.389	26.714	.16918	75.684	32.763

Notes:

GPDG	Government purchases of durable goods in £b.
GPS	Government purchases of non-durable goods and services in £b.
ETR	Effective rate of sales and excise taxation. It is expressed as total excise and sales taxes over GNP.
EG	Export of goods lagged one period in £b.
ES	Export of services lagged one period in £b.

FIGURE 5.1: GRAPHS OF ACTUAL (SC) AND FITTED (FSC) VALUES

OF CONSUMPION SHARE

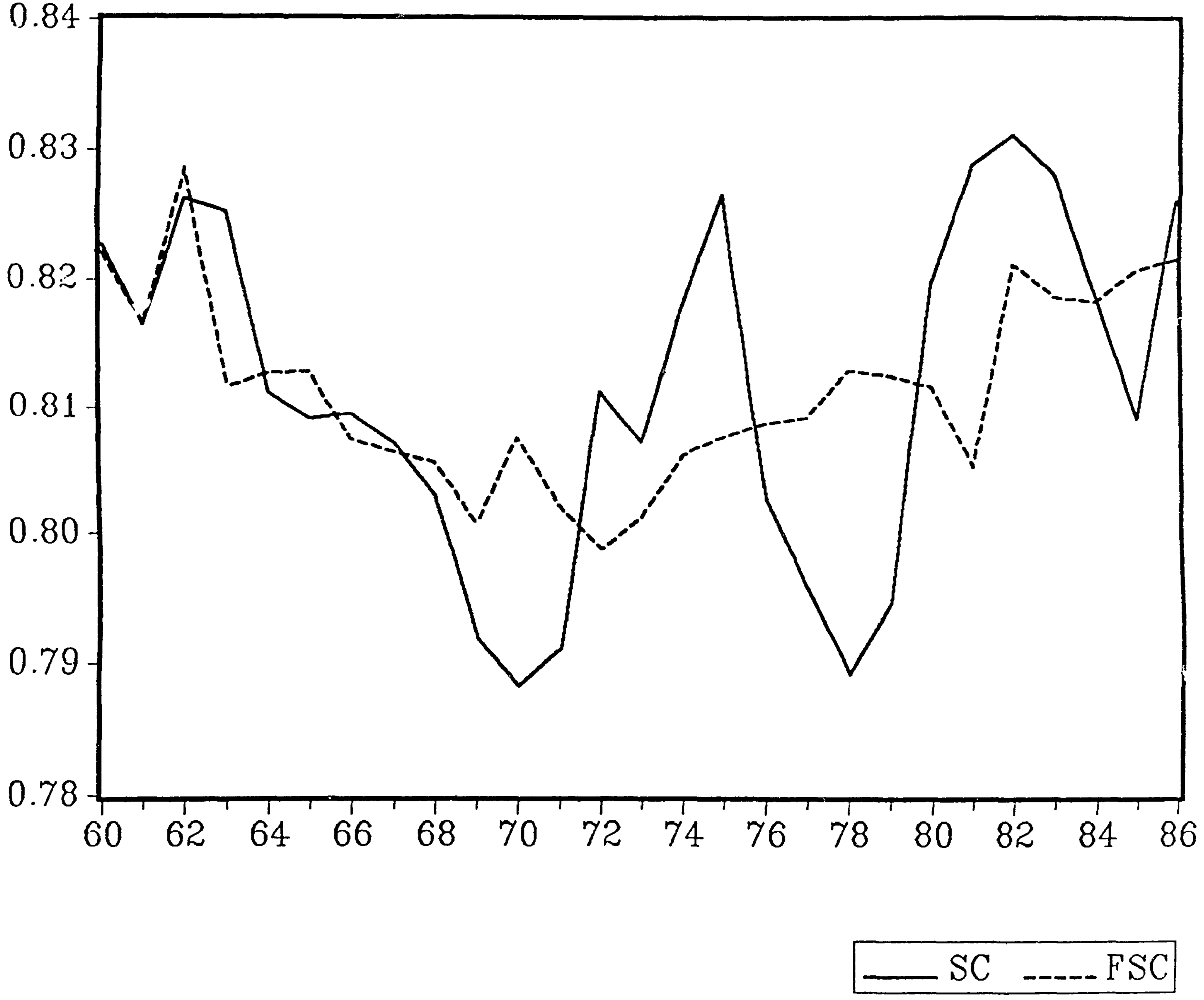

FIGURE 5.2: GRAPHS OF ACTUAL (SI) AND FITTED (FSI) VALUES

OF INVESTMENT SHARE

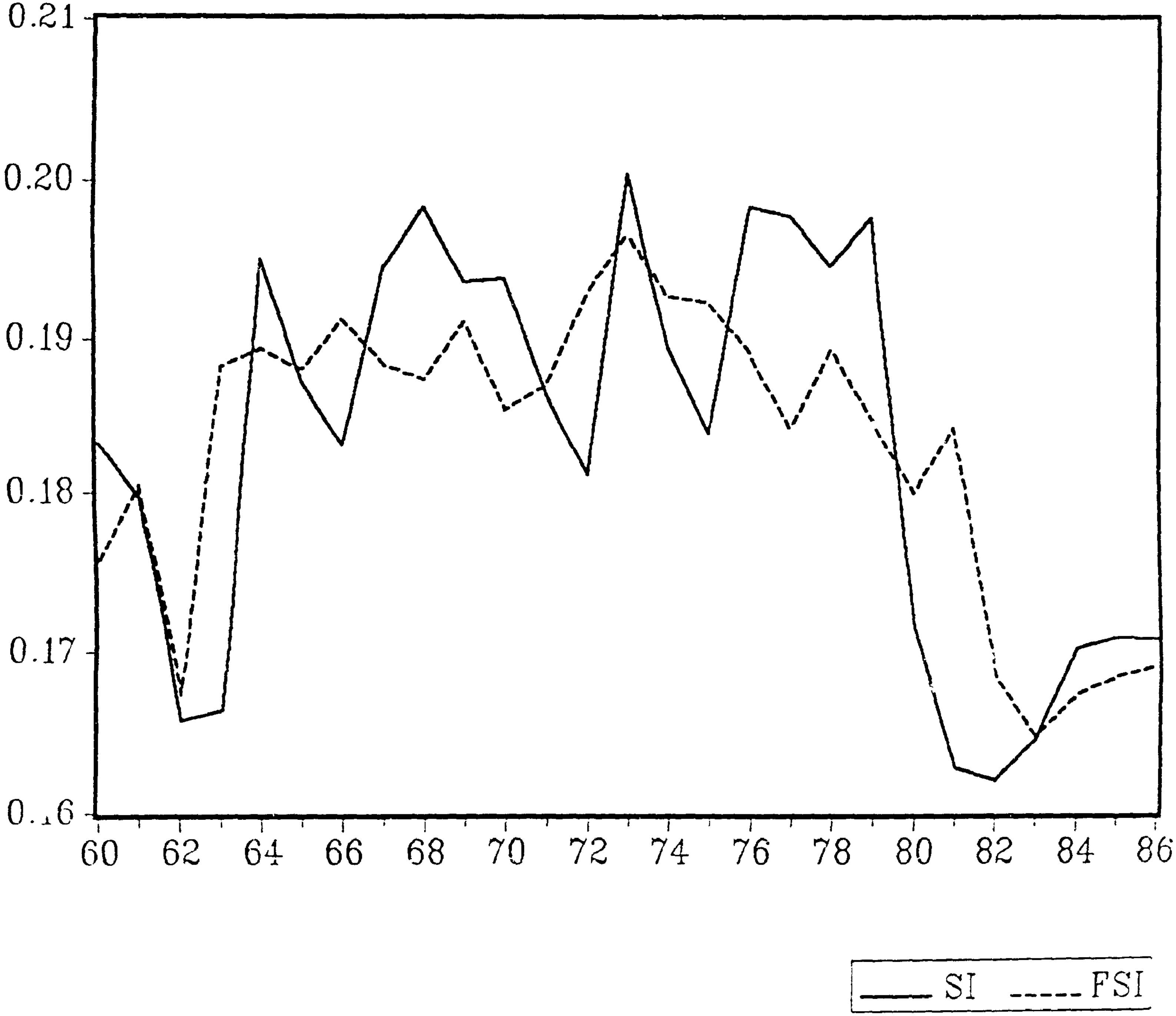

FIGURE 5.3: GRAPHS OF ACTUAL (SX) AND FITTED (FSX) VALUES OF EXPORT SHARE

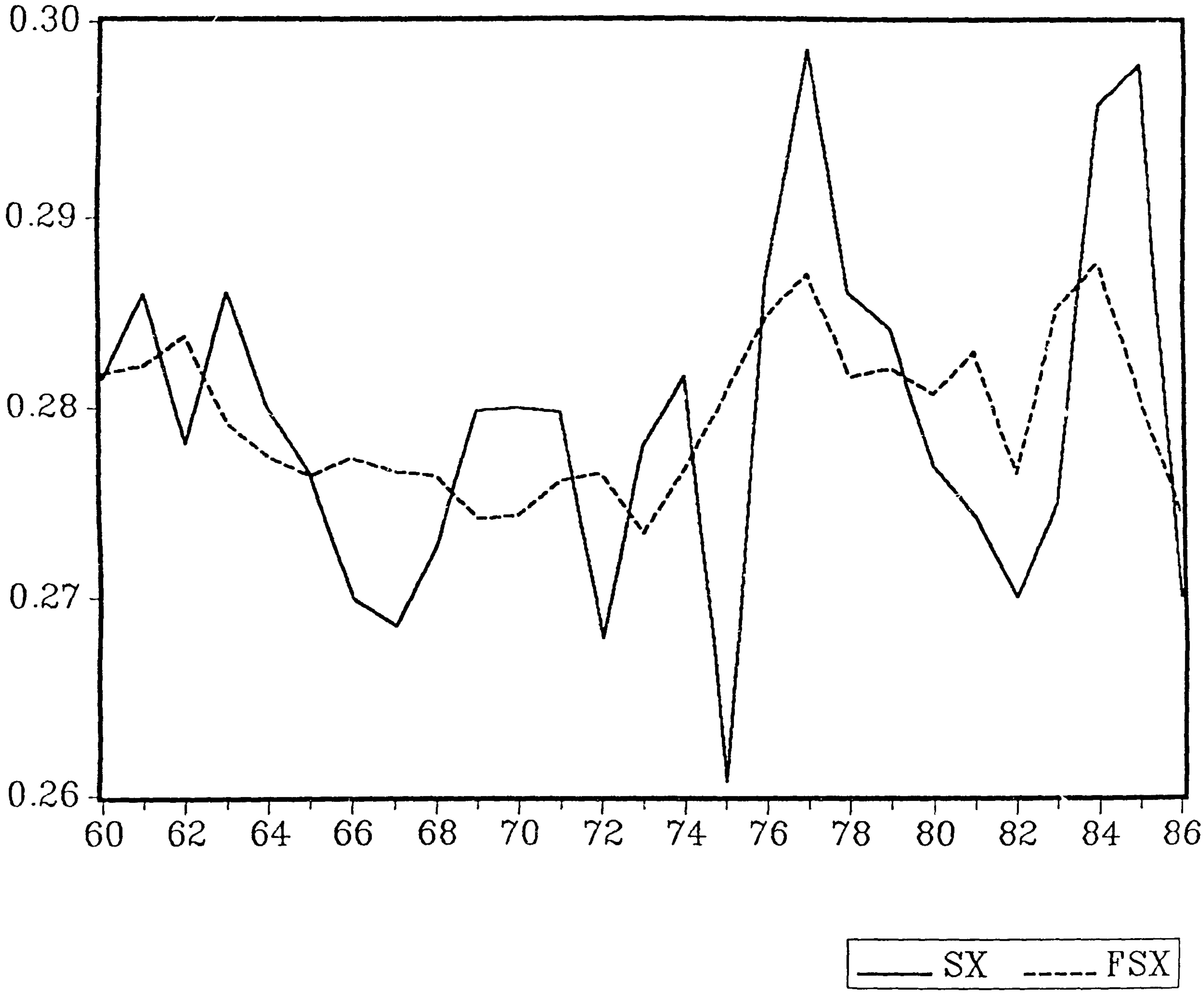

FIGURE 5.4: GRAPHS OF ACTUAL (SM) AND FITTED (FSM) VALUES

OF IMPORT SHARE

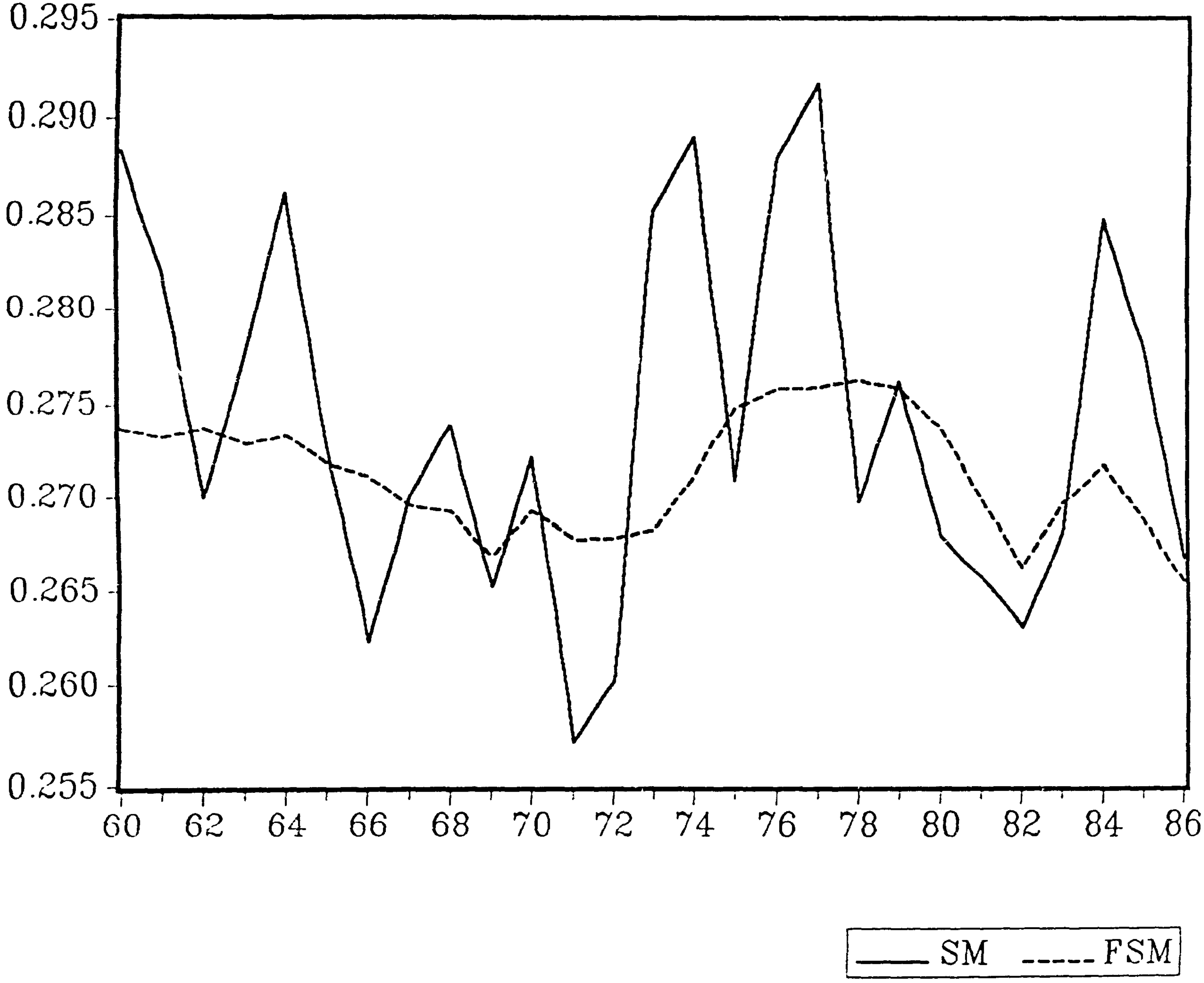

FIGURE 5.5: GRAPHS OF ACTUAL (SL) AND FITTED (FSL) VALUES

OF LABOUR SHARE

FIGURE 5.6: GRAPHS OF ACTUAL (SHC) AND FITTED (FSHC) VALUES

OF HUMAN CAPITAL SHARE

FIGURE 5.7: GRAPHS OF ACTUAL (SRD) AND FITTED (FSRD) VALUES

OF R&D SHARE

FIGURE 5.8: GRAPHS OF ACTUAL (SK) AND FITTED (FSK) VALUES

OF CAPITAL SHARE

Chapter 6

ANALYSIS OF THE ESTIMATED PARTIAL ELASTICITIES

6.1 Introduction

In this chapter, the various partial elasticities are calculated using the parameter estimates of the model (reported in the previous chapter) and the fitted shares. The yearly values of these elasticities are given in the Appendix. An analysis will also be undertaken.

There are seven sets of partial elasticities. The first set refers to those elasticities of transformation which provide information on the relationship among the outputs. Consumption goods are found to be substitutes for investment goods and complements for exports in production In contrast, imports are complements to consumption goods and exports. The second set of elasticities are elasticities of complementarity dealing with the substitutability relationship among fixed factors. Capital is found to be a substitute for labour, human capital and R&D. Labour is a complement for human capital and R&D. A complementarity relationship between human capital and R&D is also confirmed. The third set of elasticities refers to elasticities of intensity measuring the factor intensity of the outputs. Investment goods are found to be relatively labour intensive while consumption goods, exports and imports are relatively intensive in R&D. Both the neo-factor endowment theory of trade and the neo-technology theory receive confirmation as viable theories in the explanation of U.K. export trade patterns. The suggestion that the United Kingdom suffers from a low technology syndrome is also confirmed.

The partial price elasticities of supply and demand form the fourth set of elasticities while the fifth set comprises the partial price elasticities of fixed factors. Of course, the sign of the partial price elasticities yield the direction of slope of the corresponding curves. It is found that the supply curves for consumption goods, investment goods and exports are all upward-sloping while the slope of the demand curve for imports is downward-sloping. The slopes of the demand curve for labour, capital, human capital and R&D are all downward-sloping as well.

The partial cross quantity elasticities between outputs and fixed inputs form the sixth set of elasticities and these indicate the effects of changes in the endowment of fixed factors on the supply of outputs. An increase in the endowment of labour is found to have a positive effect on the supply of consumption goods and investment goods. Similarly, an increase in the endowment of human capital has a favourable effect on the production of consumption goods and exports but a negative effect on investment goods. As expected, an increase in the endowment of R&D has a positive effect on the production on consumption goods and exports while an increase in the endowment of capital has a positive effect on consumption goods, investment goods and exports.

Finally, the seventh set of elasticities comprises the partial price elasticities between outputs and inputs. These yield the distribution effects of changes in the prices of outputs on the prices of fixed inputs. It is found that an increase in the price of consumption goods will be more favourable to human capital and R&D while an increase in the price of investment goods will be more favourable to labour and capital. In contrast, a decrease in the price of imports will be more favourable to R&D and human capital while an increase in the price of exports will benefit human capital and R&D.

The actual estimates of these elasticities are developed in Section 6.2. An interpretation and analysis of the estimates is the subject of discussion in Section 6.3. This is followed, in Section 6.4, by a postscript.

6.2 Computation of Partial Elasticities

The elasticity of transformation between outputs i and h is calculated from the formalae

$$\theta_{ih} = \begin{cases} \dfrac{\gamma_{ih} + \bar{S}_i \bar{S}_h}{\bar{S}_i \bar{S}_h} & h, i \in \Delta, \quad h \neq i; \\[2ex] \dfrac{\gamma_{ii} + \bar{S}_i^2 - \bar{S}_i}{\bar{S}_i^2} & i \in \Delta; \end{cases} \tag{48}$$

where the bar over the share variable refers to its mean value over the sample. Since θ_{ih} is a function both of parameters and variables, it is necessary to choose a value of each relevant variable to get one estimate of the elasticity. The value chosen in each case is the arithmetic mean. Given this, the calculation of standard errors must also vary according to the values of the relevant variables. The standard errors here refer to the large-sample distribution of the estimated θ_{ih} at the means $\bar{S}_i$ and $\bar{S}_h$. The formula used is given in the following equation

$$SE(\theta_{ih}) = SE(\gamma_{ih})/\bar{S}_i\ \bar{S}_h \qquad i,\ h \in \Delta. \tag{49}$$

All calculations follow this form, namely, the elasticity corresponds to the value of the elasticity at the sample means of the variables while its standard error is obtained by a Taylor's series approximation and hence refers to the large-sample distribution of the elasticity at the means of the variables.

The elasticity of complementarity between inputs j and k is

$$\omega_{jk} = \begin{cases} \dfrac{\phi_{jk} + \bar{V}_j\bar{V}_k}{\bar{V}_k\bar{V}_j}, & j,k \in \Pi,\ j \neq k. \\[2ex] \dfrac{\phi_{jj} + \bar{V}_j^2 - \bar{V}_j}{\bar{V}_j^2}, & j \in \Pi. \end{cases} \tag{50}$$

The elasticity of intensity between output i and input j is

$$\psi_{ij} = \frac{\delta_{ij} + \bar{S}_i\bar{V}_j}{\bar{S}_i\bar{V}_j},\ i \in \Delta,\ j \in \Pi. \tag{51}$$

The price elasticity of supply is

$$\varepsilon_{ih} = \begin{cases} \theta_{ih}\,\bar{S}_h & i,\ h \in \Delta, \\ & i \neq h, \\ \theta_{ii}\,\bar{S}_i & i \in \Delta\ . \end{cases} \tag{52}$$

The inverse price elasticity of demand of fixed inputs is

$$\eta_{jk} = \begin{cases} \omega_{jk}\,\bar{V}_k, & j,\ k \in \Pi, \\ \omega_{jj}\bar{V}_j, & j \in \Pi. \end{cases} \tag{53}$$

The cross-quantity elasticity is

$$\xi_{ij} = \psi_{ij}\bar{V}_j\ , \quad i \in \Delta,\ j \in \Pi. \tag{54}$$

The cross-price elasticity is

$$\rho_{ji} = \psi_{ij}\bar{S}_i\ , \quad i \in \Delta,\ j \in \Pi. \tag{55}$$

The computed values of the elasticities of transformation, complementarity and intensity are given in Table 6.1. The estimates of the price elasticity of supply and the cross-quantity elasticity are reported in Table 6.2. In Table 6.3, the estimates of the inverse price elasticity of demand of fixed factors and the cross-price elasticity are presented.

TABLE 6.1

TABLE 6.1: ELASTICITIES OF TRANSFORMATION, COMPLEMENTARITY AND INTENSITY EVALUATED AT THE MEANS OF THE VARIABLES, FOR THE U.K. ECONOMY. ASYMPTOTIC ERRORS ARE GIVEN IN PARENTHESES.

Transformation	Complementarity	Intensity	
$\theta_{CI} = -0.151$ (0.375)	$\omega_{LH} = -1.932$ (0.553)	$\psi_{CL} = 1.122$ (0.205)	$\psi_{XL} = 0.372$ (0.553)
$\theta_{CX} = 0.289$ (0.014)	$\omega_{LRD} = -2.022$ (0.632)	$\psi_{CH} = 0.281$ (0.078)	$\psi_{XH} = 1.350$ (0.603)
$\theta_{CM} = 0.730$ (0.161)	$\omega_{LK} = 1.918$ (0.288)	$\psi_{CRD} = 1.543$ (0.312)	$\psi_{XRD} = 2.070$ (0.864)
$\theta_{IX} = 0.303$ (0.825)	$\omega_{HRD} = -2.892$ (0.892)	$\psi_{CK} = 0.730$ (0.138)	$\psi_{XK} = 0.971$ (0.358)
$\theta_{IM} = 0.601$ (0.549)	$\omega_{HK} = 1.534$ (0.412)	$\psi_{IL} = 2.082$ (0.578)	$\psi_{ML} = 1.449$ (0.256)
$\theta_{XM} = 1.200$ (0.459)	$\omega_{RDK} = 0.784$ (0.247)	$\psi_{IH} = -1.444$ (0.848)	$\psi_{MH} = 1.830$ (0.385)
		$\psi_{IRD} = -1.260$ (0.829)	$\psi_{MRD} = 2.210$ (0.382)
		$\psi_{IK} = 1.586$ (0.391)	$\psi_{MK} = 0.557$ (0.844)

6.3 Interpretation and Analysis

6.3.1 Elasticities of Transformation

An examination of the transformation elasticity estimates in Table 6.1 reveals that θ_{CI} is negative. This implies that consumption goods and investment goods are substitutes in production. θ_{CX}, θ_{CM}, θ_{IM}, θ_{IX} and θ_{XM} are all positive. The positive sign indicates that imports are complements to consumption goods, investment goods and exports; and exports are complements to investment goods and consumption goods. The evidence of substitutability or complementarity between any two outputs, however, must consider not only the sign of the estimate but its statistical significance as well. If the null hypothesis that $\theta_{ih} = 0$ is tested against the alternative hypothesis that $\theta_{ih} \neq 0$ at the 5% level, then θ_{CI} is not statistically significant from zero. This implies that no significant degree of substitution exists between consumption goods and investment goods. θ_{IX} and θ_{IM} are also not significantly different from zero. On the other hand, θ_{CX}, θ_{CM} and θ_{XM} are all significantly different from zero. This implies that a significant degree of complementarity exists between consumption goods and exports, consumption goods and imports, and exports and imports.

Given the results on the elasticities of transformation, the following observations can be made. First, the complementarity relationship between consumption goods and exports implies that when the prices of consumption goods increase faster than the price of exports, producers as a whole in the United Kingdom, will increase the production of exports, ceteris paribus. Second, a policy of trade liberalization will have a significantly positive effect on the consumption goods and exports sectors. The production of these goods are import intensive and a reduction in tariff rates will increase the demand for imports and hence a supply of consumption goods and exports. The effects of such a policy on investment goods, on the other hand, will be neglegible since changes in import prices have no significant effect on the supply of investment goods. Alternatively, an increase in U.K. tariff rates will have a significantly negative effect on the supply of exports and consumption goods, but essentially no effect on the supply of investment goods.

6.3.2 Elasticities of Complementarity

There are six elasticities of complementarity, and five of them are estimated here for the first time. These are ω_{LH}, ω_{LRD}, ω_{HRD}, ω_{HK} and ω_{RDK}; their computation and interpretation are considered a small contribution of the thesis.

The elasticity of complementarity between capital and labour (ω_{KL}) indicates that capital and labour are substitutes. The estimate of 1.92 is statistically significant from zero and is similar to what major empirical studies that have used the translog method have found[9]. Capital is also a substitute for human capital and R&D. These estimates are also significantly different from zero. This implies that when the price of human capital or R&D increases faster than the price of non-human capital, producers will substitute capital for R&D or human capital in the production process. Labour, in contrast, is complementary to human capital and R&D[10]. Human capital and R&D are also

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[9] For example, Diewert and Wales [1987] found ω_{KL} to be in the order of 0.6, Berndt and Wood [1975], Simos [1981] close to unity and Hunt [1984] 1.34

[10] Mohen et al. [1986] have empirically analysed the production of the manufacturing sector of the U.S., Japan and Germany. They have found that labour and R&D are substitutes in all three countries but capital and R&D are complements in the U.S. and Japan and substitutes in Germany.

complements ω_{LH}, ω_{LRD} and ω_{HRD} are all statistically different from zero.

Of particular importance among these elasticities is the elasticity of complementarity between R&D and human capital. A one percent increase in the R&D-human capital price ratio (W_{RD}/W_{H}) will lead to a 3% decrease in the human capital-R&D factor ratio (X_{H}/X_{RD}). The implication is that as the price of the R&D factor goes up in the relation to the price of human capital, investment in human capital decreases, since there is a need of human capital for R&D purposes. This further implies that when corporations cut R&D because of its high cost, they tend to employ less human-capital-intensive labour.

6.3.3 Elasticities of Intensity

An elasticity of intensity measures the relationship between a variable output and a fixed input, yielding the relative factor content of each output. Thus comparing any two elasticities of intensity we can determine whether output is factor X_1 intensive or factor X_2 intensive. There are four variable outputs (C, I, X, M) and four fixed inputs (H, K, L, R&D), thus we have four sets of elasticities to analyse. These are displayed in Table 6.1.

The first set of elasticities of intensity to be analysed involves consumption goods and the four fixed inputs. From Table 6.1, ψ_{CH}, ψ_{CRD}, ψ_{CL} and ψ_{CK} have estimated values that are statistically different from zero at the five percent level. This result indicates that consumption goods are intensive in labour, human capital, R&D and non-human capital. Since ψ_{CRD} is the largest in magnitude, consumption goods are relatively more R&D intensive.

The second set of elasticities of intensity is for investment goods. ψ_{IH} and ψ_{IR} are not statistically different from zero indicating that investment goods are not significantly intensive in human capital or R&D. The estimated values of ψ_{IL} and ψ_{IK}, in contrast, are significantly different from zero at the 5% level. This implies that investment goods are labour intensive and capital intensive, but since the estimated value of ψ_{IL} exceeds the estimated value of ψ_{IK} investment goods are relatively more labour intensive, on average.

The third set concerns exports. ψ_{XL} is statistically insignificant. ψ_{XRD}, ψ_{XH} and ψ_{XK} are statistically significant; thus exports are R&D intensive, human-capital intensive and capital-intensive. ψ_{XRD}, however, has an estimated value that exceeds the numerical value of ψ_{XK} and ψ_{XH}, implying that exports are relatively more R&D intensive.

Katrak [1982], Cable and Rebelo [1980], Smith et al [1982] and Hughes [1985] have found evidence that U.K. patterns of export trade may be explained by the human capital or neo-factor endowment theory. The results in this thesis lend support to their findings.

Lyons [1983] and Greenhalgh [1990], on the other hand, have argued, on the basis of their estimates, that the neo-technology theory of trade has a significant role in the explanation of U.K. export trade patterns. Here again, the results have substantiated their findings.

The last set of elasticities in this group involves imports. We observe that ψ_{MH}, ψ_{MRD} and ψ_{ML} are significantly different from zero while ψ_{MK} is not. This implies that imports are intensive in human capital, R&D and labour. Since ψ_{MRD} has the largest estimated value, imports are relatively more R&D intensive than human-capital-intensive and labour-intensive. Looking at the R&D intensities of both exports and imports we observe that U.K. exports and imports are significantly R&D intensive. However, when the magnitudes of these estimates are compared, it is found that U.K. imports are more R&D intensive than U.K. exports. This would seem to confirm the findings of Fagerberg [1988], Thirlwell [1986], Albu [1980], Pavitt [1981], Prais [1981] and Katrak [1982] who suggest, that the United Kingdom has fallen behind its main competitors in respect of R&D by failing to increase its investment in R&D fast enough relative to its competitors. The effect of this slower relative rate of increase in R&D is reflected in the composition of total exports, in particular, a dynamically decreasing proportion of R&D-intensive exports in total exports.

The empirical evidence shows that the United Kingdom is not very competitive in R&D intensive exports. In order to increase its international competitiveness in R&D intensive exports, the United Kingdom needs to devise a R&D policy that encourages producers to commit more resources to R&D and to speed up the diffusion of technical knowledge and new manufacturing techniques throughout the economy, especially to the nation's smaller manufacturers.

TABLE 6.2: ELASTICITIES OF THE DERIVED SUPPLY FOR CONSUMPTION, INVESTMENT, AND EXPORTS AND THE DEMAND FOR IMPORTS, EVALUATED AT THE MEANS OF THE VARIABLES. U.K. ECONOMY, 1960-1986. ASYMPTOTIC STANDARD ERRORS ARE GIVEN IN PARENTHESES.

<u>Outputs</u>

Consumption	Investment	Exports	Imports
$\varepsilon_{CC} = 0.148$ (0.125)	$\varepsilon_{II} = 0.203$ (0.264)	$\varepsilon_{XX} = 0.038$ (0.381)	$\varepsilon_{MM} = -1.035$ (0.100)
$\varepsilon_{CI} = -0.028$ (0.069)	$\varepsilon_{IC} = -0.122$ (0.304)	$\varepsilon_{XI} = 0.055$ (0.147)	$\varepsilon_{MC} = 0.592$ (0.131)
$\varepsilon_{CX} = 0.081$ (0.114)	$\varepsilon_{IX} = 0.085$ (0.231)	$\varepsilon_{XC} = 0.234$ (0.333)	$\varepsilon_{MI} = 0.110$ (0.100)
$\varepsilon_{CM} = -0.198$ (0.043)	$\varepsilon_{IM} = -0.163$ (0.149)	$\varepsilon_{XM} = -0.326$ (0.124)	$\varepsilon_{MX} = 0.335$ (0.128)
$\varepsilon_{CL} = 0.168$ (0.031)	$\varepsilon_{IL} = 0.313$ (0.087)	$\varepsilon_{XL} = 0.056$ (0.083)	$\varepsilon_{ML} = 0.218$ (0.038)
$\varepsilon_{CH} = 0.048$ (0.021)	$\varepsilon_{IH} = -0.249$ (0.146)	$\varepsilon_{XH} = 0.233$ (0.111)	$\varepsilon_{MH} = 0.315$ (0.066)
$\varepsilon_{CRD} = 0.075$ (0.015)	$\varepsilon_{IRD} = -0.062$ (0.040)	$\varepsilon_{XRD} = 0.101$ (0.042)	$\varepsilon_{MRD} = 0.107$ (0.019)
$\varepsilon_{CK} = 0.456$ (0.087)	$\varepsilon_{IK} = 0.998$ (0.246)	$\varepsilon_{XK} = 0.611$ (0.223)	$\varepsilon_{MK} = 0.350$ (0.531)

TABLE 6.3: ELASTICITES OF THE DERIVED DEMAND OF LABOUR, HUMAN CAPITAL, R&D AND CAPITAL EVALUATED AT THE MEANS OF THE VARIABLES. U.K. ECONOMY 1960-1986. ASYMPTOTIC STANDARD ERRORS ARE GIVEN IN PARENTHESES.

Demands

Labour	Human Capital	R&D	Capital
ε_{LL} =-0.775	ε_{HH} =-0.534	ε_{RDRD}=-0.375	ε_{KK} =-0.643
(0.069)	(0.151)	(0.177)	(0.123)
ε_{LH} =-0.333	ε_{HL} =-0.290	ε_{RDL} =-0.304	ε_{KL} = 0.288
(0.094)	(0.082)	(0.177)	(0.043)
ε_{LRD}=-0.099	ε_{HRD} =-0.141	ε_{RDH} =-0.498	ε_{KH} = 0.264
(0.031)	(0.044)	(0.154)	(0.043)
ε_{LK} = 1.207	ε_{HK} = 0.965	ε_{RDK} = 1.176	ε_{KRD} = 0.091
(0.181)	(0.259)	(0.269)	(0.021)
ε_{LC} = 0.911	ε_{HC} = 0.221	ε_{RDC}= 1.252	ε_{KC} = 0.591
(0.166)	(0.025)	(0.253)	(0.112)
ε_{LI} = 0.381	ε_{HI} = -0.265	ε_{RDI}=-0.232	ε_{KI} = 0.290
(0.106)	(0.155)	(0.151)	(0.072)
ε_{LX} = 0.104	ε_{HX} = 0.377	ε_{RDX}= 0.580	ε_{KX} = 0.218
(0.154)	(0.197)	(0.242)	(0.079)
ε_{LM} =-0.393	ε_{HM} = -0.497	ε_{RDM}=-0.598	ε_{KM} =-0.151
(0.069)	(0.104)	(0.103)	(0.229)

6.3.4 Partial Price Elasticities of Supply

In this group, there are four sets of partial price elasticities to be analysed (see Table 6.2). The own partial price elasticities provide, *inter alia*, information on the slopes of the supply curves for consumption goods, investment goods and exports and the demand curve for imports. The cross-partial price elasticities indicate whether outputs are gross substitutes or not and, in this sense, they provide much the same information as is contained in corresponding elasticities of transformation.

The first set of partial price elasticities involves consumption goods. Of the four elasticities three are statistically insignificant at the 5% level (ε_{CC}, ε_{CI}, ε_{CX}). Thus only ε_{CM} is statistically significant. Since ε_{CM} is negative, it follows that consumption goods are intensive in imports; as for ε_{CC}, ε_{CX} and ε_{CI}, the conclusion arising from the lack of significance indicates that changes in the price of exports and investment goods will have no consistently discernable effect on the supply of consumption goods, certeris paribus, while the supply curve of consumption goods is probably, though not significantly, upward-sloping.

The second set pertains to investment goods. ε_{II} is positive implying that the supply schedule of investment goods is upward-sloping. ε_{IC}, ε_{IX} and ε_{IM} are statistically insignificant from zero. This may be because changes in the prices of consumption goods, exports and imports have a hardly noticeable effect on the supply of investment goods or because the model does not permit a precise evaluation of these effects.

The third set of partial price elasticities refers to exports. The own-price elasticity (ε_{XX}) is positive but not statistically different from zero. This implies that the export supply function is not well determined or perhaps perfectly inelastic since a change in the price of exports will not have a significant effect on the supply of exports; if the latter holds, then only changes in the export demand function will affect the price of exports. The cross-price elasticities ε_{XI} and ε_{XC} are positive and statistically insignificant as well. In contrast, ε_{XM} is negative and statistically different from zero. Thus these estimates indicate that an increase in the price of investment goods or the price of consumption goods will not have a significant impact on the supply of exports, or, if they do, it is indeterminate within the model. On the other hand, an increase in the price of imports will have a significant and negative effect on the supply of exports which is consistent with the earlier findings (Table 6.1), that exports and imports are complements.

The final set of elasticities in this group is with respect to imports. The own-price elasticity of the demand for imports is -1.04 which, given a standard error of ± 0.10, is consistent with Kohli's [1978] findings for Canada which range from -0.902 to -0.993. Clearly the estimate of -1.04 (± 0.10) is significantly different from zero. The negative sign and the statistical significance of this estimate imply that the demand for imports is significantly downward-sloping. The majority of the studies for the United Kingdom, using single equation specifications (cf. chapter 2) report an upward-sloping demand curve. These studies, however, have used a single-equation specification. The results of this thesis thus indicate a contradiction between the single-equation approach and the simultanous equation approach to U.K. import demand that has been used in this thesis. Yet the natural expectation is that import demand 'should' be significantly downward-sloping, whereupon serious doubt is cast on the results of the single-equation studies. In addition, the estimate of the own-price elasticity indicates that the import demand schedule is elastic, since a proportional change in the price of imports would lead to a more than proportional change in the quantity of imports demanded, ceteris paribus. Of the three partial cross-price elasticities, two are statistically significant at the 5% level ($\varepsilon_{MC}, \varepsilon_{MX}$) and one is not ($\varepsilon_{MI}$). These results indicate that an increase in the price of consumption goods or the price of exports will have a significant and positive effect on the demand for imports. An increase in the price of investment goods, on the other hand, has either no significant impact on the demand for imports or cannot be estimated very precisely within the confines of the model used.

Given the results on the various elasticities, observe that consumption goods and exports are import intensive and consumption goods and investment goods are substitutes. This implies that an increase in the price of imports will be accompanied by a fall in the supply of consumption goods and exports. Or, alternatively, that an increase in the price of either output, resulting in a larger supply of that good, will be accompanied by a higher demand for imports. An increase in the price of investment goods, in contrast, which will lead to a larger supply of investment goods but a smaller output of consumption goods, will result in a lower demand for imports and a smaller supply of exports.

6.3.5 *Partial Cross Quantity Elasticities*

This group of elasticities is concerned with the effect of a change in factor endowment on the supply of outputs and the demand for imports. There are four sets of elasticities and each set involves one variable quantity and four fixed inputs (see Table 6.2).

The first set pertains to consumption goods and the four inputs. All four elasticities ($\varepsilon_{CL}, \varepsilon_{CK}, \varepsilon_{RD}, \varepsilon_{CH}$) are statistically significant at the 5% level. These results indicate that an increase in human capital, R&D, human capital or labour will have a significant impact on the supply of consumption goods. The effects of labour, human capital, R&D and capital on the supply of consumption goods are consistent with our earlier results (Table 6.1), that consumption goods are labour intensive, human capital intensive, R&D intensive and capital intensive. The values obtained for ε_{CL} and ε_{CK} are similar to those reported by Kohli [1978].

The second set of elasticities involves investment goods. ε_{IL} and ε_{IK} are significantly different from zero while ε_{IH} and ε_{IRD} are not. These results indicate that an increase in human capital or R&D will have no significant impact on the supply of investment goods. An increase in labour or capital, on the other hand, will have a significant and positive effect on investment goods. The effects of labour and capital on investment goods are consistent with the earlier results (Table 6.1) that investment goods are capital and labour intensive.

The penultimate set of elasticities involves exports and the four fixed inputs. Of the four elasticities three are statistically significant at the 5% level ($\varepsilon_{XRD}, \varepsilon_{XH}, \varepsilon_{XK}$) and one is not ($\varepsilon_{XL}$). The following interpretation is in order: an increase in human capital, R&D or capital will have a significant and positive effect on exports. In contrast, an increase in labour will have no significant impact on the supply of exports. The effects of human capital, R&D, and capital on exports are consistent with our earlier findings (TAble 6.1) that exports are human capital intensive, R&D intensive and capital intensive.

The final set of elasticities in this group pertains to imports and the four fixed factors. $\varepsilon_{MH}, \varepsilon_{MRD}$ and ε_{ML} are significantly different from zero and ε_{MK} is not. This means that an increase in capital will have no impact on the demand for imports or that this input is not precisely estimable in the model. It also implies that increases in the input of capital will have a positive effect on the trade balance, since such increases will have a significantly favourable effect on exports but no effect on imports. An increase in labour, human capital or R&D, on the other hand, will have a significant and positive effect on the demand for imports. With respect to the trade balance, and increase in labour, R&D or human capital will evidently have an adverse net effect.

6.3.6 Partial Own and Cross Price Elasticities of Demand for Fixed Factors

There are four sets of partial price elasticities of demand to be analysed in this group (see Table 6.3). The partial own-price elasticities define the slopes of the demand curves for the factors of production. The cross-price elasticities provide information on the relationship among the factors. Such information is also contained in the elasticities of complementarity analysed earlier.

The first set refers to labour. It is notable in this group that all four elasticities $(\varepsilon_{LL}, \varepsilon_{LH}, \varepsilon_{LK}, \varepsilon_{LRD})$ are statistically significant at the 5% level. The estimate of ε_{LL} indicates that the demand curve for labour is significantly downward-sloping. This is consistent with economic theory. The estimates of ε_{LRD} and ε_{LH} indicate that labour is complementary to human capital and R&D while ε_{LK} indicates that labour and capital are substitutes. The values obtained for ε_{LL} and ε_{LK} are similar to those reported in Kohli [1978], Berndt and Wood [1975] and Simos [1980] for other economies.

The second set in this group involves human capital. Again, all four elasticities are significantly different from zero. The estimate of ε_{HH} implies that the demand schedule for human capital is significantly downward-sloping. ε_{HRD} and ε_{HL} indicate that an increase in the quantity of R&D or labour will have a significant, negative effect on the price of human capital. In contrast, an increase in capital will have a significant, positive effect.

The third set of elasticities in this group is with respect to R&D. Once again, the four elasticities $(\varepsilon_{RDRD}, \varepsilon_{RDH}, \varepsilon_{RDK}, \varepsilon_{RDL})$ are statistically significant at the 5% level. ε_{RDRD} indicates that the slope of R&D demand is significantly downward-sloping. ε_{RDK} indicates that an increase in capital will have a significantly positive effect on the price of R&D. In contrast, ε_{RDL} and ε_{RDH} indicate that an increase in labour or human capital will have a significantly negative impact on the price of R&D.

The fourth set in this group involves capital. All four elasticities are significantly different from zero. ε_{KK} indicates that the demand schedule of capital is significantly downward-sloping. ε_{KL}, ε_{KH}, ε_{KRD} indicate that an increase in labour, human capital or R&D will have a significant and positive effect on the price of capital. The estimates of ε_{KK} and ε_{KL} are similar to those reported in Kohli [1978], Simos [1980] and Berndt and Wood [1982] for other economies.

6.3.7 Parial Cross Price Elasticities between Outputs and Inputs

This group of elasticities identifies the distribution effects of changes in the prices of the variable quantities on the prices of the fixed factors (see Table 6.3).

The first set involves the distribution effect on the price of labour. Of the four elasticities, three are statistically different from zero at the 5% level ($\varepsilon_{LC}, \varepsilon_{LI}, \varepsilon_{LM}$) and one is not ($\varepsilon_{LX}$). An increase in the price of consumption goods or investment goods will have a significantly positive effect on the price of labour, while an increase in the price of imports will have a significantly negative effect. In contrast, an increase in the price of exports will have no significant impact on the price of labour. Kohli [1978] and Simos [1980] have reported similar results for the Canadian and U.S. economies.

The second set of elasticities in this group refers to the distribution effect on the price of human capital. Three of the four elasticities ($\varepsilon_{HX}, \varepsilon_{HM}, \varepsilon_{HC}$) are statistically significant at the 5% level and one is not (ε_{HI}). These estimates indicate that an increase in the prices of consumption goods or exports will have a significantly positive effect on the price of human capital. In contrast, an increase in the price of imports will have a significant and negative effect while an increase in the price of investment goods will have no significant effect on the price of human capital.

Turning to the distributional effects on the price of R&D, three elasticities ($\varepsilon_{RDC}, \varepsilon_{RDM}, \varepsilon_{RDX}$) are statistically significant at the 5% level and one is not (ε_{RDI}). These results indicate that an increase in the prices of imports will have a significant and negative effect, while an increase in the prices of exports or consumption goods will have a signifcantly positive effect, on the price of R&D. In contrast, an increase in the prices of investment goods will have no significant impact on the price of R&D.

The final set of elasticities pertains to the distribution effects on the price of capital. Three of the four elasticities ($\varepsilon_{KC}, \varepsilon_{KX}, \varepsilon_{KI}$) are significantly different from zero. ε_{KM} is not. Thus an increase in the prices of consumption goods, investment goods or exports will have a significantly positive effect on the price of capital; in contrast, an increase in the prices of imports will have an insignificant but negative effect on the price of capital, that is, either the price of imports has no effect or it has an indeterminate effect on the price of capital.

6.4 Postscript

In the discussion of this chapter, the emphasis has been on partial equilibrium analysis, in part because such analysis is readily comprehensible, while offering some confirmation that the model is a reasonable means of empirical analysis, and because the computational burden is small and easy to execute. However, the analysis in no sense captures the general equilibrium nature of the economic behaviour under discussion. Such a general equilibrium analysis could be undertaken *via* policy simulations of the estimated model, seeking answers to specific questions that are of strstegic importance to the U.K. economy. For example, it has been shown that R&D expenditures, or better, the lack of them, has played an important role in determining the composition of U.K. trade, yet the best that can be said in terms of partial equilibrium analysis is that this analysis does not conflict with a general equilibrium proposition. From the point of view of this thesis, it needs to be argued why the analysis is confined to partial equilibrium analysis, to the exclusion of general equilibrium simulations.

It needs, first of all, to be emphasised that the exercise of policy simulations is not, in any sense, a trivial piece of work. Secondly, such policy simulations need to settle the position of non-significant effects in the model - are these to be excluded and then the model re-estimated, or is the model to be maintained as it is? Thirdly, there is the fundamental issue of whether the model that has been estimated in this thesis is of itself suitable for general equilibrium simulation. After all, the basic model is founded on a Taylor's series approximation to a more general model and, in the light of the Lucas Critique, there is surely no reason to suppose that a linear approximation will be able accurately to accomodate the variation in coefficients that a given policy would entail in the long run.

For all these reasons, no policy simulations have been undertaken, except for the within sample forecasts depicted in Diagrams 5.1-5.8 of Chapter 5. Nevertheless, the results of the thesis are presented as a significant step foward - both theoretically and factually - over what has been available hitherto.

Chapter 7

Summary and Conclusion

This thesis contains an investigation of the foreign trade sector of United Kingdom for the period of 1960-1986. The majority of the studies in this field have confined their scope of inquiry to a single-equation framework in which imports (exports) are a function of real income and relative prices. The present study deviates from this traditional approach. Using a multi-input, multi-output variable profit function, import and export functions are derived within a more general theoretical framework, thus yielding a much larger variety of information about imports and exports; specifically, how these relate to other aggregates of the economy and especially how they relate to human capital and R&D. In order to assess the quantitative importance of R&D and human capital on U.K. trade, completely new series for these variables have had to be constructed.

Generally, then, the thesis contributes to the literature in four respects.

1. An augmented form of a known trade model has been applied for the first time to the U.K. economy.
2. The augmentations to the known model enable a quantitative assessment of various factors, again for the first time. These factors, some have argued, account for special features of the observed performance of the U.K. economy, in particular the contributions of education, skills and R&D. Hence there is made available in the thesis a completely novel assessment of these and other

factors, based upon theory and fact.

3. The augmentations also require the development of appropriate economic statistics. This development has been successfully undertaken and completed.

4. In general, the model has made available new quantitative facts concerning the performance of and prospects for the U.K. economy.

In view of the quantitative results emerging from estimation of the model, the following conclusions are indicated.

(i) Consumption goods and investment goods are substitutes in production.

(ii) Consumption goods and exports are intensive in imports while investment goods are not. Thus a policy of trade liberalisation will benefit both the consumption goods sector and the export sector.

(iii) Capital is found to be a substitute for labour and R&D, a perfectly reasonable conclusion. Human capital is a complement for labour and R&D. A complementarity relationship between capital and R&D is also confirmed.

(iv) Investment goods are relatively labour-intensive while consumption goods, exports and imports are relatively intensive in R&D.

(v) Both the neo-factor endowment theory and the neo-technology theory of trade receive confirmation as a viable theory explaining U.K. export patterns.

(vi) The suggestion that U.K. suffers from a low technology syndrome is confirmed.

(vii) The import demand schedule is significantly downward-sloping while the supply curve for consumption goods, investment goods and exports are upward-sloping.

(viii) An increase in the endowment of labour will result in an increase in the supply of consumption goods and investment goods; but it will have no effect on the supply of exports. In contrast, the endowment of labour will have a significant and positive effect on import demand. Its effects on the trade balance will be unfavourable.

(ix) An increase in the endowment of human capital stock will have a positive effect on the production of consumption goods, exports but a negative effect on investment goods. It also has a positive effect on the demand for imports with an unfavourable net effect on the balance of trade.

(x) An increasee in the endowment of R&D stock will have a positive effect on the production of consumption goods and exports and on the demand for imports, but a negative effect on investment goods. It will also result in a deterioration of the trade balance.

(xi) An increase in the endowment of capital stock will have a positive effect on consumption goods, investment goods and exports. It will have no effect on the demand for imports with a positive net effect on the balance of trade.

(xii) The demand schedules for labour, human capital, R&D and capital are all significantly downward-sloping.

(xiii) An increase in the price of consumption goods will be more favourable to R&D and labour than human capital and capital while an increase in the price of investment goods will be more favourable to labour and capital than human capital and R&D. An increase in the price of exports will be more favourable to human capital and R&D than labour and capital while an decrease in the price of imports will benefit R&D and human capital.

A natural direction for future research seems to be towards the use of disaggregated variables. For example, consumption can be disaggregated into durables, non-durables and services; investment into residential, non-residential construction, plant and equipment; imports and exports can be disaggregated into food, beverages, tobacco, crude materials and fuels, manufactured goods, etc. Thus we will be able to obtain the interrelationships between various components of the major economic aggregates.

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APPENDIX

The Yearly Values of the Elasticities

year	θ_{CC}	θ_{II}	θ_{XX}	θ_{MM}
1960	0.187	1.361	0.123	3.799
1961	0.184	1.194	0.120	3.802
1962	0.191	1.697	0.111	3.799
1963	0.182	0.960	0.140	3.804
1964	0.182	0.929	0.152	3.801
1965	0.183	0.966	0.159	3.812
1966	0.180	0.881	0.153	3.816
1967	0.179	0.956	0.158	3.828
1968	0.179	0.984	0.159	3.830
1969	0.176	0.883	0.174	3.846
1970	0.180	1.041	0.173	3.830
1971	0.177	0.993	0.160	3.840
1972	0.175	0.839	0.158	3.840
1973	0.177	0.745	0.180	3.837
1974	0.179	0.842	0.156	3.816
1975	0.180	0.852	0.129	3.790
1976	0.181	0.939	0.104	3.783
1977	0.181	1.079	0.090	3.782
1978	0.183	0.929	0.123	3.780
1979	0.182	1.059	0.120	3.783
1980	0.182	1.215	0.129	3.798
1981	0.179	1.075	0.115	3.825
1982	0.187	1.645	0.158	3.851
1983	0.185	1.815	0.102	3.827
1984	0.185	1.697	0.086	3.812
1985	0.186	1.648	0.130	3.833
1986	0.187	1.619	0.172	3.857

year	θ_{CI}	θ_{CX}	θ_{CM}	θ_{IX}
1960	-0.183	0.303	0.735	0.279
1961	-0.160	0.230	0.733	0.299
1962	-0.233	0.314	0.738	0.248
1963	-0.119	0.288	0.731	0.320
1964	-0.111	0.284	0.732	0.320
1965	-0.119	0.282	0.731	0.313
1966	-0.108	0.279	0.728	0.326
1967	-0.125	0.276	0.726	0.315
1968	-0.132	0.275	0.726	0.310
1969	-0.117	0.265	0.722	0.318
1970	-0.142	0.272	0.726	0.298
1971	-0.139	0.272	0.723	0.309
1972	-0.110	0.270	0.722	0.330
1973	-0.084	0.264	0.723	0.336
1974	-0.101	0.277	0.728	0.330
1975	-0.101	0.289	0.732	0.339
1976	-0.118	0.299	0.733	0.337
1977	-0.147	0.306	0.733	0.325
1978	-0.110	0.296	0.735	0.331
1979	-0.138	0.296	0.735	0.315
1980	-0.171	0.292	0.732	0.293
1981	-0.152	0.292	0.726	0.315
1982	-0.235	0.290	0.728	0.233
1983	-0.267	0.309	0.731	0.240
1984	-0.248	0.315	0.732	0.258
1985	-0.236	0.300	0.730	0.245
1986	-0.230	0.285	0.727	0.231

year	θ_{IM}	θ_{XM}	ω_{LL}	ω_{HH}
1960	0.588	1.196	-4.531	-3.184
1961	0.598	1.196	-4.529	-3.265
1962	0.567	1.195	-4.645	-3.186
1963	0.614	1.198	-4.632	-3.353
1964	0.617	1.199	-4.699	-3.387
1965	0.612	1.201	-4.724	-3.347
1966	0.618	1.201	-4.665	-3.374
1967	0.610	1.203	-4.691	-3.302
1968	0.608	1.203	-4.745	-3.271
1969	0.612	1.206	-4.725	-3.245
1970	0.603	1.204	-4.907	-3.212
1971	0.605	1.204	-4.933	-3.152
1972	0.617	1.204	-5.000	-3.159
1973	0.625	1.206	-5.060	-3.202
1974	0.621	1.201	-5.243	-3.181
1975	0.625	1.196	-5.466	-3.185
1976	0.620	1.192	-5.578	-3.120
1977	0.610	1.191	-5.627	-3.052
1978	0.621	1.194	-5.732	-3.110
1979	0.612	1.194	-5.767	-3.052
1980	0.598	1.196	-5.742	-2.967
1981	0.602	1.198	-5.680	-2.894
1982	0.559	1.205	-5.707	-2.744
1983	0.554	1.196	-5.873	-2.716
1984	0.564	1.193	-5.940	-2.759
1985	0.563	1.200	-5.887	-2.747
1986	0.559	1.207	-5.828	-2.718

year	ω_{KK}	ω_{RDRD}	ω_{LH}	ω_{LRD}
1960	-1.066	-7.523	-1.701	-1.807
1961	-1.045	-7.566	-1.795	-1.778
1962	-1.063	-7.744	-1.763	-1.693
1963	-1.009	-7.587	-1.964	-1.818
1964	-1.992	-7.591	-2.049	-1.852
1965	-1.005	-7.686	-2.008	-1.789
1966	-1.005	-7.692	-2.012	-1.753
1967	-1.027	-7.773	-1.931	-1.686
1968	-1.030	-7.794	-1.921	-1.688
1969	-1.041	-7.805	-1.878	-1.664
1970	-1.027	-7.788	-1.934	-1.777
1971	-1.044	-7.815	-1.873	-1.753
1972	-1.029	-7.761	-1.919	-1.858
1973	-1.004	-7.660	-2.004	-1.991
1974	-0.988	-7.606	-2.074	-2.136
1975	-0.961	-7.455	-2.200	-2.374
1976	-0.966	-7.400	-2.173	-2.374
1977	-0.982	-7.468	-2.109	-2.476
1978	-0.950	-7.214	-2.240	-2.457
1979	-0.967	-7.374	-2.181	-2.683
1980	-0.999	-7.554	-2.060	-2.604
1981	-1.033	-7.695	-1.940	-2.456
1982	-1.089	-7.837	-1.780	-2.290
1983	-1.086	-7.842	-1.822	-2.128
1984	-1.061	-7.806	-1.903	-2.218
1985	-1.070	-7.812	-1.863	-2.284
1986	-1.088	-7.838	-1.804	-2.245

year	ω_{LK}	ω_{HRD}	ω_{RDK}	ω_{HK}
1960	1.831	-3.217	0.800	1.562
1961	1.824	-3.322	0.791	1.577
1962	1.848	-2.961	0.792	1.562
1963	1.828	-3.469	0.791	1.592
1964	1.833	-3.535	0.793	1.597
1965	1.841	-3.334	0.793	1.589
1966	1.832	-3.381	0.787	1.596
1967	1.843	-3.119	0.790	1.583
1968	1.873	-3.023	0.793	1.576
1969	1.854	-2.958	0.793	1.572
1970	1.878	-2.932	0.794	1.560
1971	1.888	-2.782	0.796	1.550
1972	1.894	-2.891	0.794	1.548
1973	1.895	-3.102	0.794	1.527
1974	1.918	-3.126	0.788	1.544
1975	1.943	-3.280	0.785	1.539
1976	1.963	-3.210	0.786	1.525
1977	1.977	-3.037	0.782	1.514
1978	1.981	-3.331	0.782	1.520
1979	1.994	-3.113	0.787	1.511
1980	2.003	-2.825	0.780	1.500
1981	2.007	-2.571	0.782	1.492
1982	2.034	-2.180	0.786	1.474
1983	2.061	-2.113	0.791	1.468
1984	2.062	-2.235	0.792	1.471
1985	2.057	-2.208	0.793	1.471
1986	2.054	-2.124	0.796	1.469

year	ψ_{CL}	ψ_{CH}	ψ_{CRD}	ψ_{CK}
1960	1.107	0.256	1.561	0.728
1961	1.108	0.224	1.559	0.729
1962	1.109	0.261	1.522	0.731
1963	1.111	0.189	1.559	0.731
1964	1.112	0.177	1.558	0.733
1965	1.113	0.411	1.543	0.732
1966	1.112	0.192	1.546	0.730
1967	1.113	0.177	1.531	0.727
1968	1.114	0.201	1.526	0.727
1969	1.114	0.212	1.526	0.724
1970	1.117	0.216	1.526	0.728
1971	1.119	0.233	1.523	0.724
1972	1.121	0.248	1.538	0.724
1973	1.122	0.242	1.555	0.728
1974	1.125	0.231	1.561	0.731
1975	1.129	0.242	1.579	0.735
1976	1.132	0.242	1.585	0.735
1977	1.133	0.264	1.577	0.733
1978	1.134	0.285	1.601	0.738
1979	1.135	0.271	1.585	0.736
1980	1.135	0.288	1.564	0.732
1981	1.135	0.311	1.547	0.726
1982	1.133	0.326	1.507	0.726
1983	1.137	0.378	1.504	0.725
1984	1.138	0.384	1.515	0.728
1985	1.136	0.372	1.512	0.727
1986	1.135	0.378	1.503	0.726

year	ψ_{IL}	ψ_{IH}	ψ_{IRD}	ψ_{IK}
1960	2.002	-1.640	-1.465	1.623
1961	1.974	-1.660	-1.376	1.601
1962	2.075	-1.774	-1.430	1.653
1963	1.953	-1.652	-1.266	1.568
1964	1.960	-1.677	-1.250	1.561
1965	1.971	-1.648	-1.206	1.568
1966	1.944	-1.637	-1.166	1.558
1967	1.963	-1.591	-1.134	1.571
1968	1.978	-1.569	-1.125	1.575
1969	1.956	-1.492	-1.073	1.567
1970	2.019	-1.531	-1.153	1.581
1971	2.015	-1.446	-1.106	1.580
1972	1.996	-1.380	-1.095	1.559
1973	1.988	-1.376	-1.126	1.542
1974	2.041	-1.403	-1.203	1.550
1975	2.084	-1.413	-1.286	1.545
1976	2.124	-1.388	-1.351	1.555
1977	2.163	-1.383	-1.380	1.574
1978	2.151	-1.373	-1.424	1.551
1979	2.186	-1.374	-1.417	1.568
1980	2.213	-1.356	-1.391	1.592
1981	2.172	-1.232	-1.245	1.586
1982	2.288	-1.297	-1.323	1.655
1983	2.353	-1.423	-1.353	1.669
1984	2.346	-1.327	-1.365	1.652
1985	2.426	-1.300	-1.342	1.651
1986	2.308	-1.264	-1.298	1.653

year	ψ_{XL}	ψ_{XH}	ψ_{XRD}	ψ_{XK}
1960	0.447	1.361	2.111	0.970
1961	0.448	1.373	2.098	0.970
1962	0.439	1.356	2.036	0.970
1963	0.431	1.392	2.105	0.971
1964	0.420	1.401	2.111	0.971
1965	0.415	1.395	2.085	0.970
1966	0.423	1.398	2.079	0.970
1967	0.419	1.387	2.050	0.970
1968	0.413	1.382	2.041	0.970
1969	0.410	1.381	2.044	0.970
1970	0.390	1.375	2.051	0.970
1971	0.391	1.363	2.031	0.970
1972	0.385	1.364	2.056	0.970
1973	0.371	1.375	2.105	0.970
1974	0.358	1.367	2.109	0.971
1975	0.343	1.362	2.131	0.971
1976	0.339	1.347	2.128	0.972
1977	0.340	1.335	2.103	0.972
1978	0.315	1.350	2.178	0.972
1979	0.312	1.341	2.144	0.971
1980	0.312	1.331	2.107	0.971
1981	0.324	1.319	2.057	0.971
1982	0.305	1.307	2.023	0.969
1983	0.308	1.294	1.982	0.970
1984	0.307	1.297	1.994	0.971
1985	0.295	1.303	2.016	0.970
1986	0.286	1.306	2.023	0.969

year	ψ_{ML}	ψ_{MH}	ψ_{MRD}	ψ_{MK}
1960	1.396	1.913	2.246	0.552
1961	1.397	1.946	2.236	0.555
1962	1.405	1.913	2.169	0.553
1963	1.405	1.999	2.231	0.561
1964	1.410	1.985	2.227	0.565
1965	1.414	2.000	2.201	0.560
1966	1.410	1.975	2.202	0.559
1967	1.415	1.962	2.174	0.553
1968	1.420	1.960	2.164	0.552
1969	1.422	1.938	2.168	0.546
1970	1.432	1.919	2.167	0.552
1971	1.437	1.922	2.157	0.547
1972	1.442	1.938	2.187	0.550
1973	1.446	1.919	2.227	0.555
1974	1.456	1.909	2.232	0.562
1975	1.467	1.881	2.259	0.573
1976	1.474	1.856	2.268	0.574
1977	1.478	1.876	2.250	0.571
1978	1.486	1.856	2.308	0.577
1979	1.489	1.833	2.274	0.574
1980	1.491	1.820	2.236	0.565
1981	1.493	1.782	2.206	0.552
1982	1.502	1.764	2.156	0.536
1983	1.509	1.771	2.131	0.542
1984	1.511	1.776	2.146	0.550
1985	1.512	1.776	2.155	0.544
1986	1.513	1.648	2.152	0.535

year	ε_{CC}	ε_{CI}	ε_{CX}	ε_{CM}
1960	0.154	-0.032	0.086	-0.20.
1961	0.150	-0.029	0.085	-0.200
1962	0.158	-0.039	0.089	-0.202
1963	0.148	-0.022	0.080	-0.199
1964	0.148	-0.021	0.079	-0.200
1965	0.148	-0.022	0.078	-0.199
1966	0.145	-0.021	0.077	-0.197
1967	0.144	-0.024	0.076	-0.196
1968	0.144	-0.025	0.076	-0.195
1969	0.141	-0.022	0.073	-0.193
1970	0.145	-0.026	0.075	-0.196
1971	0.142	-0.026	0.075	-0.194
1972	0.140	-0.021	0.075	-0.193
1973	0.142	-0.017	0.072	-0.194
1974	0.144	-0.019	0.077	-0.197
1975	0.145	-0.019	0.081	-0.201
1976	0.146	-0.022	0.085	-0.202
1977	0.146	-0.027	0.088	-0.202
1978	0.148	-0.021	0.083	-0.203
1979	0.148	-0.026	0.084	-0.203
1980	0.148	-0.031	0.082	-0.200
1981	0.144	-0.028	0.083	-0.196
1982	0.153	-0.040	0.080	-0.194
1983	0.152	-0.044	0.088	-0.197
1984	0.152	-0.042	0.091	-0.199
1985	0.153	-0.040	0.084	-0.196
1986	0.154	-0.039	0.078	-0.193

year	ε_{II}	ε_{IC}	ε_{IX}	ε_{IM}
1960	0.239	-0.151	0.079	-0.161
1961	0.216	-0.130	0.084	-0.163
1962	0.284	-0.193	0.070	-0.155
1963	0.181	-0.096	0.089	-0.168
1964	0.176	-0.090	0.089	-0.169
1965	0.182	-0.096	0.086	-0.166
1966	0.168	-0.087	0.090	-0.168
1967	0.180	-0.101	0.097	-0.164
1968	0.184	-0.107	0.086	-0.164
1969	0.169	-0.094	0.087	-0.163
1970	0.193	-0.114	0.082	-0.162
1971	0.186	-0.112	0.085	-0.162
1972	0.162	-0.088	0.091	-0.165
1973	0.146	-0.068	0.092	-0.168
1974	0.162	-0.081	0.091	-0.168
1975	0.164	-0.081	0.095	-0.172
1976	0.177	-0.096	0.096	-0.171
1977	0.199	-0.119	0.093	-0.168
1978	0.176	-0.090	0.093	-0.172
1979	0.196	-0.112	0.089	-0.169
1980	0.219	-0.139	0.082	-0.164
1981	0.198	-0.122	0.089	-0.162
1982	0.277	-0.192	0.064	-0.149
1983	0.299	-0.219	0.068	-0.149
1984	0.284	-0.203	0.074	-0.153
1985	0.278	-0.194	0.069	-0.151
1986	0.274	-0.189	0.063	-0.148

year	ε_{XX}	ε_{XC}	ε_{XI}	ε_{XM}
1960	0.035	0.250	0.049	-0.327
1961	0.034	0.245	0.054	-0.327
1962	0.031	0.260	0.041	-0.327
1963	0.039	0.234	0.060	-0.327
1964	0.042	0.231	0.061	-0.328
1965	0.044	0.229	0.059	-0.326
1966	0.042	0.225	0.062	-0.326
1967	0.044	0.223	0.059	-0.324
1968	0.044	0.222	0.058	-0.324
1969	0.048	0.212	0.061	-0.322
1970	0.047	0.220	0.055	-0.324
1971	0.044	0.218	0.058	-0.323
1972	0.044	0.215	0.064	-0.323
1973	0.049	0.211	0.066	-0.324
1974	0.043	0.223	0.064	-0.326
1975	0.036	0.233	0.065	-0.329
1976	0.030	0.242	0.064	-0.329
1977	0.026	0.247	0.060	-0.328
1978	0.035	0.240	0.063	-0.330
1979	0.034	0.241	0.058	-0.329
1980	0.036	0.237	0.053	-0.328
1981	0.033	0.235	0.958	-0.323
1982	0.044	0.238	0.039	-0.321
1983	0.029	0.253	0.039	-0.323
1984	0.025	0.258	0.043	-0.324
1985	0.036	0.246	0.041	-0.323
1986	0.047	0.234	0.039	-0.321

year	ε_{MM}	ε_{MC}	ε_{MI}	ε_{MX}
1960	-1.039	0.585	0.103	0.605
1961	-1.038	0.605	0.108	0.599
1962	-1.039	0.599	0.095	0.611
1963	-1.038	0.611	0.116	0.594
1964	-1.039	0.594	0.117	0.595
1965	-1.036	0.595	0.115	0.594
1966	-1.035	0.594	0.118	0.588
1967	-1.032	0.588	0.115	0.333
1968	-1.031	0.585	0.114	0.332
1969	-1.027	0.584	0.117	0.331
1970	-1.031	0.578	0.112	0.330
1971	-1.029	0.586	0.113	0.332
1972	-1.029	0.580	0.119	0.333
1973	-1.029	0.577	0.123	0.330
1974	-1.035	0.580	0.120	0.332
1975	-1.042	0.587	0.120	0.336
1976	-1.043	0.591	0.117	0.339
1977	-1.044	0.593	0.112	0.342
1978	-1.044	0.594	0.118	0.336
1979	-1.043	0.597	0.113	0.337
1980	-1.040	0.598	0.108	0.336
1981	-1.033	0.594	0.111	0.339
1982	-1.026	0.585	0.094	0.333
1983	-1.032	0.598	0.091	0.341
1984	-1.036	0.598	0.094	0.343
1985	-1.030	0.599	0.095	0.337
1986	-1.024	0.599	0.095	0.331

year	ε_{LL}	ε_{LK}	ε_{LH}	ε_{LRD}
1960	-0.765	1.132	-0.283	-0.084
1961	-0.765	1.137	-0.288	-0.084
1992	-0.767	1.144	-0.293	-0.084
1963	-0.767	1.156	-0.303	-0.086
1964	-0.768	1.167	-0.312	-0.088
1965	-0.768	1.167	-0.311	-0.087
1966	-0.767	1.161	-0.308	-0.086
1967	-0.768	1.158	-0.305	-0.085
1968	-0.769	1.162	-0.308	-0.860
1969	-0.769	1.157	-0.304	-0.085
1970	-0.772	1.179	-0.318	-0.090
1971	-0.772	1.178	-0.316	-0.090
1972	-0.773	1.188	-0.322	-0.093
1973	-0.774	1.201	-0.331	-0.036
1974	-0.776	1.223	-0.345	-0.102
1975	-0.779	1.254	-0.366	-0.109
1976	-0.780	1.264	-0.371	-0.113
1977	-0.781	1.265	-0.371	-0.113
1978	-0.782	1.284	-0.384	-0.118
1979	-0.782	1.283	-0.383	-0.118
1980	-0.782	1.272	-0.375	-0.115
1981	-0.781	1.257	-0.364	-0.112
1982	-0.781	1.246	-0.355	-0.110
1983	-0.783	1.264	-0.367	-0.114
1984	-0.783	1.277	-0.377	-0.117
1985	-0.783	1.269	-0.371	-0.115
1986	-0.782	1.259	-0.363	-0.113

year	ε_{HH}	ε_{HL}	ε_{HK}	ε_{HRD}
1960	-0.529	-0.287	0.966	-0.150
1961	-0.524	-0.303	0.983	-0.156
1962	-0.529	-0.291	0.967	-0.147
1963	-0.518	-0.325	1.007	-0.164
1964	-0.515	-0.335	1.017	-0.168
1965	-0.518	-0.327	1.007	-0.162
1966	-0.516	-0.331	1.011	-0.165
1967	-0.522	-0.316	0.994	-0.157
1968	-0.524	-0.311	0.988	-0.153
1969	-0.526	-0.305	0.981	-0.151
1970	-0.528	-0.304	0.980	-0.148
1971	-0.531	-0.293	0.967	-0.143
1972	-0.531	-0.297	0.971	-0.145
1973	-0.528	-0.307	0.984	-0.150
1974	-0.530	-0.307	0.985	-0.149
1975	-0.529	-0.313	0.993	-0.151
1976	-0.533	-0.304	0.982	-0.146
1977	-0.536	-0.293	0.968	-0.140
1978	-0.534	-0.305	0.985	-0.147
1979	-0.536	-0.296	0.972	-0.141
1980	-0.540	-0.280	0.953	-0.133
1981	-0.547	-0.267	0.953	-0.126
1982	-0.547	-0.243	0.900	-0.113
1983	-0.546	-0.251	0.911	-0.110
1984	-0.547	-0.248	0.907	-0.114
1985	-0.547	-0.242	0.900	-0.113
1986	-0.547	-0.242	0.485	-0.110

year	ε_{RDRD}	ε_{RDL}	ε_{RDH}	ε_{RDK}
1960	-0.351	-0.305	-0.535	1.191
1961	-0.356	-0.300	-0.533	1.190
1962	-0.385	-0.280	-0.492	1.156
1963	-0.359	-0.301	-0.536	1.967
1964	-0.360	-0.303	-0.538	1.200
1965	-0.374	-0.291	-0.516	1.182
1966	-0.375	-0.288	-0.517	1.181
1967	-0.391	-0.276	-0.493	1.159
1968	-0.395	-0.274	-0.484	1.153
1969	-0.398	-0.271	-0.479	1.148
1970	-0.394	-0.279	-0.482	1.155
1971	-0.401	-0.274	-0.469	1.144
1972	-0.388	-0.287	-0.486	1.161
1973	-0.370	-0.305	-0.512	1.186
1974	-0.362	-0.316	-0.521	1.199
1975	-0.353	-0.338	-0.545	1.226
1976	-0.336	-0.346	-0.548	1.231
1977	-0.344	-0.341	-0.534	1.219
1978	-0.318	-0.366	-0.571	1.255
1979	-0.334	-0.353	-0.547	1.234
1980	-0.355	-0.334	-0.514	1.203
1981	-0.376	-0.315	-0.482	1.173
1982	-0.404	-0.291	-0.434	1.130
1983	-0.409	-0.291	-0.426	1.126
1984	-0.398	-0.301	-0.443	1.142
1985	-0.400	-0.299	-0.440	1.138
1986	-0.407	-0.291	-0.428	1.126

year	ε_{KK}	ε_{KL}	ε_{KH}	ε_{KRD}
1960	-0.659	0.309	0.260	0.090
1961	-0.651	0.308	0.253	0.090
1962	-0.658	0.305	0.260	0.093
1963	-0.638	0.303	0.246	0.090
1964	-0.632	0.300	0.243	0.089
1965	-0.637	0.300	0.246	0.091
1966	-0.637	0.301	0.244	0.091
1967	-0.645	0.302	0.250	0.093
1968	-0.646	0.300	0.252	0.093
1969	-0.650	0.302	0.255	0.094
1970	-0.645	0.295	0.256	0.093
1971	-0.651	0.296	0.261	0.094
1972	-0.645	0.293	0.260	0.093
1973	-0.636	0.290	0.256	0.090
1974	-0.631	0.284	0.257	0.089
1975	-0.620	0.277	0.256	0.087
1976	-0.622	0.274	0.261	0.087
1977	-0.628	0.274	0.266	0.088
1978	-0.616	0.270	0.261	0.085
1979	-0.622	0.270	0.266	0.087
1980	-0.635	0.273	0.273	0.089
1981	-0.647	0.276	0.280	0.091
1982	-0.667	0.278	0.294	0.095
1983	-0.666	0.275	0.296	0.096
1984	-0.657	0.272	0.291	0.094
1985	-0.660	0.274	0.293	0.094
1986	-0.667	0.276	0.296	0.096

year	ε_{CL}	ε_{CH}	ε_{CRD}	ε_{CK}
1960	0.187	0.043	0.073	0.450
1961	0.187	0.036	0.073	0.454
1962	0.183	0.043	0.076	0.452
1963	0.184	0.029	0.074	0.462
1964	0.182	0.027	0.074	0.467
1965	0.181	0.030	0.075	0.464
1966	0.183	0.027	0.075	0.463
1967	0.182	0.032	0.077	0.457
1968	0.181	0.034	0.077	0.456
1969	0.181	0.035	0.078	0.452
1970	0.176	0.038	0.077	0.457
1971	0.175	0.042	0.078	0.451
1972	0.173	0.041	0.077	0.455
1973	0.172	0.041	0.075	0.461
1974	0.167	0.038	0.095	0.467
1975	0.161	0.040	0.073	0.474
1976	0.158	0.040	0.072	0.473
1977	0.157	0.045	0.073	0.469
1978	0.155	0.050	0.070	0.478
1979	0.154	0.046	0.072	0.474
1980	0.154	0.051	0.073	0.465
1981	0.156	0.057	0.076	0.455
1982	0.155	0.061	0.078	0.444
1983	0.151	0.075	0.078	0.445
1984	0.150	0.077	0.077	0.451
1985	0.151	0.074	0.077	0.449
1986	0.152	0.075	0.078	0.445

year	ε_{IL}	ε_{IH}	ε_{IRD}	ε_{IK}
1960	0.338	-0.273	-0.068	1.003
1961	0.333	-0.267	-0.065	0.998
1962	0.343	-0.295	-0.071	1.023
1963	0.323	-0.255	-0.060	0.992
1964	0.320	-0.255	-0.059	0.994
1965	0.321	-0.255	-0.059	0.987
1966	0.320	-0.250	-0.057	0.987
1967	0.321	-0.251	-0.057	0.988
1968	0.321	-0.251	-0.057	0.978
1969	0.318	-0.242	-0.054	0.992
1970	0.317	-0.252	-0.058	0.985
1971	0.315	-0.244	-0.057	0.978
1972	0.309	-0.232	-0.055	0.978
1973	0.304	-0.227	-0.054	0.989
1974	0.302	-0.234	-0.057	0.997
1975	0.297	-0.235	-0.059	1.002
1976	0.297	-0.237	-0.061	1.007
1977	0.300	-0.243	-0.064	1.005
1978	0.293	-0.236	-0.063	1.009
1979	0.296	-0.241	-0.064	1.011
1980	0.301	-0.247	-0.065	0.993
1981	0.299	-0.231	-0.061	1.014
1983	0.313	-0.258	-0.068	1.024
1983	03149	-0.267	-0.071	1.023
1984	0.309	-0.263	-0.070	1.018
1985	0.309	-0.259	-0.069	1.012
1986	0.310	-0.255	-0.067	0.425

year	ε_{XL}	ε_{XH}	ε_{XRD}	ε_{XK}
1960	0.075	0.226	0.098	0.600
1961	0.076	0.221	0.099	0.605
1962	0.072	0.226	0.101	0.601
1963	0.071	0.215	0.100	0.614
1964	0.069	0.213	0.100	0.618
1965	0.067	0.216	0.102	0.615
1966	0.070	0.214	0.101	0.615
1967	0.069	0.219	0.103	0.609
1968	0.067	0.221	0.104	0.608
1969	0.067	0.224	0.104	0.605
1970	0.061	0.226	0.104	0.609
1971	0.061	0.230	0.104	0.605
1972	0.059	0.229	0.103	0.609
1973	0.057	0.227	0.102	0.615
1974	0.053	0.228	0.100	0.619
1975	0.049	0.226	0.098	0.627
1976	0.047	0.230	0.097	0.626
1977	0.047	0.235	0.097	0.621
1978	0.043	0.232	0.096	0.630
1979	0.042	0.236	0.097	0.625
1980	0.042	0.242	0.099	0.617
1981	0.045	0.247	0.100	0.608
1982	0.042	0.260	0.104	0.594
1983	0.041	0.261	0.103	0.595
1984	0.040	0.257	0.102	0.601
1985	0.039	0.259	0.103	0.598
1986	0.038	0.263	0.105	0.594

year	ε_{ML}	ε_{MH}	ε_{MRD}	ε_{MK}
1960	0.236	0.318	0.104	0.341
1961	0.236	0.313	0.105	0.346
1962	0.232	0.318	0.108	0.342
1963	0.233	0.307	0.106	0.355
1964	0.230	0.304	0.116	0.360
1965	0.230	0.308	0.107	0.355
1966	0.232	0.306	0.107	0.354
1967	0.232	0.312	0.109	0.347
1968	0.230	0.314	0.110	0.346
1969	0.231	0.317	0.111	0.341
1970	0.225	0.318	0.110	0.347
1971	0.225	0.324	0.111	0.341
1972	0.223	0.323	0.109	0.345
1973	0.221	0.320	0.108	0.352
1974	0.216	0.320	0.106	0.359
1975	0.209	0.317	0.104	0.370
1976	0.206	0.321	0.103	0.370
1977	0.205	0.326	0.104	0.365
1978	0.203	0.322	0.102	0.374
1979	0.202	0.326	0.103	0.369
1980	0.203	0.334	0.105	0.358
1981	0.205	0.341	0.108	0.346
1982	0.206	0.355	0.111	0.328
1983	0.201	0.355	0.111	0.333
1984	0.199	0.351	0.110	0.341
1985	0.201	0.353	0.110	0.335
1986	0.203	0.358	0.112	0.328

year	ε_{LC}	ε_{LI}	ε_{LX}	ε_{LM}
1960	0.910	0.352	0.1261	-0.382
1961	0.905	0.356	0.126	-0.382
1962	0.919	0.347	0.124	-0.384
1963	0.902	0.368	0.120	-0.383
1964	0.904	0.371	0.116	-0.385
1965	0.904	0.371	0.115	-0.384
1966	0.899	0.372	0.117	-0.382
1967	0.987	0.370	0.116	-0.381
1968	0.897	0.371	0.114	-0.382
1969	0.892	0.373	0.112	-0.379
1970	0.902	0.374	0.107	-0.386
1971	0.897	0.377	0.108	-0.385
1972	0.895	0.385	0.106	-0.386
1973	0.899	0.391	0.101	-0.388
1974	0.907	0.393	0.099	-0.395
1975	0.912	0.401	0.096	-0.403
1976	0.915	0.398	0.097	-0.407
1977	0.917	0.407	0.098	-0.408
1978	0.922	0.404	0.089	-0.410
1979	0.922	0.398	0.088	-0.411
1980	0.921	0.400	0.088	-0.408
1981	0.913	0.385	0.092	-0.403
1982	0.930	0.388	0.084	-0.400
1983	0.931	0.393	0.088	-0.407
1984	0.933	0.392	0.088	-0.411
1985	0.933	0.390	0.083	-0.406
1986	0.934	0.391	0.079	-0.402

year	ε_{HC}	ε_{HI}	ε_{HX}	ε_{HM}
1960	0.210	-0.288	0.383	-0.523
1961	0.183	-0.300	0.387	-0.532
1962	0.216	-0.297	0.385	-0.523
1963	0.153	-0.311	0.388	-0.541
1964	0.144	-0.318	0.388	-0.546
1965	0.156	-0.310	0.385	-0.540
1966	0.142	-0.313	0.388	-0.542
1967	0.162	-0.300	0.384	-0.532
1968	0.170	-0.294	0.382	-0.528
1969	0.173	-0.285	0.379	-0.523
1976	0.189	-0.284	0.377	-0.522
1971	0.199	-0.270	0.376	-0.514
1972	0.193	-0.266	0.377	-0.515
1973	0.185	-0.271	0.376	-0.520
1974	0.195	-0.270	0.378	-0.520
1975	0.196	-0.272	0.382	-0.524
1976	0.213	-0.262	0.384	-0.519
1977	0.230	-0.255	0.383	-0.512
1978	0.220	-0.260	0.380	-0.518
1979	0.234	-0.254	0.378	-0.512
1980	0.253	-0.244	0.374	-0.502
1981	0.263	-0.227	0.373	-0.491
1982	0.311	-0.219	0.361	-0.475
1983	0.314	-0.218	0.369	-0.476
1984	0.305	-0.222	0.373	-0.481
1985	0.310	-0.219	0.366	-0.477
1986	0.317	-0.214	0.358	-0.472

year	ε_{RDC}	ε_{RDI}	ε_{RDX}	ε_{RDM}
1960	1.283	-0.257	0.595	-0.614
1961	1.273	-0.248	0.592	-0.611
1962	1.261	-0.239	0.577	-0.594
1963	1.266	-0.238	0.587	-0.608
1964	1.266	-0.237	0.585	-0.609
1965	1.254	-0.227	0.576	-0.598
1966	1.248	-0.223	0.576	-0.597
1967	1.234	-0.214	0.567	-0.586
1968	1.229	-0.211	0.564	-0.583
1969	1.222	-0.205	0.560	-0.579
1970	1.232	-0.214	0.563	-0.583
1971	1.221	-0.207	0.561	-0.578
1972	1.228	-0.211	0.568	-0.586
1973	1.246	-0.221	0.577	-0.597
1974	1.258	-0.232	0.584	-0.605
1975	1.275	-0.247	0.598	-0.621
1976	1.282	-0.255	0.606	-0.626
1977	1.276	-0.254	0.604	-0.621
1978	1.301	-0.270	0.613	-0.638
1979	1.288	-0.262	0.605	-0.627
1980	1.269	-0.250	0.592	-0.612
1981	1.245	-0.229	0.582	-0.596
1982	1.238	-0.223	0.559	-0.574
1983	1.231	-0.223	0.565	-0.575
1984	1.240	-0.228	0.574	-0.583
1985	1.241	-0.226	0.566	-0.579
1986	1.235	-0.219	0.555	-0.571

year	ε_{KC}	ε_{KI}	ε_{KX}	ε_{KM}
1960	0.599	0.285	0.273	-0.151
1961	0.595	0.289	0.274	-0.152
1962	0.605	0.277	0.275	-0.151
1963	0.593	0.295	0.271	-0.153
1964	0.596	0.296	0.269	-0.154
1965	0.595	0.295	0.268	-0.152
1966	0.589	0.298	0.269	-0.152
1967	0.586	0.296	0.268	-0.152
1968	0.585	0.295	0.268	-0.149
1969	0.579	0.299	0.266	-0.149
1970	0.587	0.293	0.266	-0.146
1971	0.581	0.295	0.268	-0.149
1972	0.579	0.300	0.268	-0.146
1973	0.583	0.303	0.265	-0.147
1974	0.589	0.299	0.269	-0.149
1975	0.594	0.297	0.273	-0.153
1976	0.594	0.294	0.277	-0.158
1977	0.593	0.290	0.279	-0.158
1978	0.600	0.294	0.274	-0.158
1979	0.599	0.290	0.274	-0.159
1980	0.594	0.286	0.273	-0.158
1981	0.585	0.292	0.275	-0.155
1982	0.596	0.279	0.268	-0.149
1983	0.594	0.275	0.277	-0.143
1984	0.595	0.276	0.279	-0.146
1985	0.597	0.278	0.272	-0.149
1986	0.596	0.279	0.266	-0.146