Essays on Applied International Trade

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by

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To my family
Essays on Applied International Trade

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ABSTRACT

Two of the most characteristic phenomena of the last three decades in the world economy has been the rapid growth of international trade on one hand and on the other an increase on firms' multinational activity. In particular the value of world merchandise trade has increased from 578 billions in 1973 to 5.4 trillions in 1999 measured in current U.S. dollars (World Trade Organisation, Annual Report). This translates to an annual average growth rate of 6% for the world trade, while world output grew at an average of 3.7% per year over the same period. This clearly underlines the increasing significance of international trade in the world economy.

Two of the countries that have contributed significantly in this dramatic increase of international trade is the US and the UK. US exports and imports of merchandise products account for the 12% of world imports and exports and 19% of US GDP for the year 2004 (US Economic Accounts, Bureau of Economic Analysis). While UK’s trade in merchandise products accounts for the 4.5% of world trade and above 30% of UK GDP for 2004. Hence, international trade is an important part of both the US and UK economies. It is interrelated to many production and consumption decisions in either economy and has been a frequent topic of public and academic discussion.

In this thesis, I examine three empirical research questions that are concerned with the expansion of international trade and the increasing activity of multinational firms. First I attempt to determine empirically the effect of the rising volume of international trade on the relative wages of skilled and unskilled workers in the US economy for the period 1967-1991. Secondly, I try to assess the causal effect on total factor productivity (TFP) growth of a change in the status of British firms from domestic producers to either exporters or subsidiaries of multinational firms over the period 1990 to 1996. Finally, I decompose the growth rate of the volume of US net exports into five components. These are a terms of trade component, an endowment component, a production technology component, a preferences component and an income component. Then I obtain estimates of each component's contribution and I am able to provide possible explanations for the particular path the volume of US net exports followed the period 1966-1991.
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PREFACE

Two of the most pervasive phenomena of the last three decades in the world economy has been the rapid growth of international trade on one hand and on the other an increase on firms' multinational activity. In particular the value of world merchandise trade has increased from 578 billions in 1973 to 12.1 trillions in 2006 measured in current U.S. dollars (World Trade Organisation, Annual Report). This translates to an annual average growth rate of 9% for the world trade, while world output grew at an average of 7% per year over the same period\(^1\). This clearly underlines the increasing significance of international trade in the world economy.

Two of the countries that have contributed significantly in this dramatic increase of international trade is the US and the UK. US exports and imports of merchandise products account for the 12% of world imports and exports and 19% of US GDP for the year 2004 (US Economic Accounts, Bureau of Economic Analysis). While UK's trade in merchandise products accounts for the 4.5% of world trade and above 30% of UK GDP for 2004. Hence, international trade is an important part of both the US and UK economy. It is interrelated to many production and consumption decisions in either economy and has been a frequent topic of public and academic discussion.

This thesis is written such that each chapter can be read independently and for this reason there might be some overlapping of certain parts of different sections. I examine three main empirical research questions that are concerned with the expansion of international trade and the increasing activity of multinational firms. In particular, first I attempt to determine empirically the effect of the rising volume of international trade on the relative wages of skilled and unskilled workers in the US economy for the period 1967-1991. Secondly, I try to assess the causal effect on total factor productivity \((TFP)\) growth of a change in the status of British firms from domestic producers to either exporters or subsidiaries of multinational firms over the period 1990 to 1996. Finally, I decompose the growth rate of the volume of US net exports into five components. These are a terms of trade component, an endowment component, a production technology component, a preferences component and an income component. Then I obtain estimates of each component’s contribution and I am able to provide possible explanations for the particular path the volume of US net exports followed the period 1966-1991.

\(^1\)World Bank, World Development Indicators (WDI) April 2007.
Chapter I, introduces a dual definition of the Factor Content of Trade (FCT) based on the concept of the Equivalent Autarky Equilibrium, (Deardorff and Staiger, 1988) that allows for the presence of jointness in output quantities. Using the Iterative Three Stages Least Square (I3SLS) method, I estimate a symmetric normalized quadratic revenue function for the US manufacturing sector for the period 1965 to 1991. I assume that there are three aggregate goods, an exportable, an importable and a non-tradable and three aggregate inputs, capital, skilled labour and unskilled labour in the US economy. A FCT vector is calculated and then with the use of a quadratic approximation lemma, I relate changes in the factor rewards to changes of FCT, endowments and technological change for the US economy. 

I find that the FCT of capital is positive while the FCT of skilled and unskilled labour are negative, which implies that capital was relatively more abundant than either type of labour. In other words, this suggests that if the US economy was at its hypothetical autarkic equilibrium, less capital would have been employed relative to skilled and unskilled labour. Therefore, the US manufacturing sector has exported goods that are more capital intensive relative to labour for the period 1965 to 1991. This is in contrast with Leontief’s paradox that found negative FCT of capital for the US, but for a different time period. In addition, following Leamer (1980), I show that skilled labour is revealed by trade to be relatively more abundant than unskilled labour, since the share of imported skilled labour is less than the share of imported unskilled labour. Thus, there is a clear ranking of relative factor abundance revealed by trade. Capital is revealed by trade to be the most abundant factor, followed by skilled labour and finally unskilled labour is the scarce factor of the US economy.

Furthermore, I obtain results indicating that the effect of FCT on factor rewards, for the period considered, is positive and about the same for both types of labour, while it is negative for the reward to capital. The effect of technological change is positive for both capital and skilled labour while it is negative for unskilled labour. This adverse effect of technological change on the reward to unskilled labour seems to be the main reason for the observed increase in relative inequality between the wages of skilled and unskilled labour in the US economy over the period 1967-1991.

In Chapter II, I try to assess the causal effect of a change in the status of a British firm on its total factor productivity (TFP) growth. The focus is on UK firms from the manufacturing sector and the causal effect obtained is for the short-run, just one year after the change in a firm’s status occurred. I extend the recent work of Girma et al. (2004) and Wagner (2002) that looked on the causal effect of exporting that used a single treatment framework, by allowing
for an extra treatment. This is the possibility that a firm is acquired by a Multinational Enterprise (MNE). In particular, I estimate the differences on TFP growth for British firms that: i) were producing only for the domestic market and began to export, ii) were domestic producers and became subsidiaries of a multinational company and iii) became exporters compared with being acquired by a MNE. There is an identification problem due to the likely endogeneity between the decision regarding the status of a firm and its TFP. In order to overcome this problem I use the Confounding Variables Approach, Rubin (1974). Then the causal effect of changing status on TFP growth is estimated for all three possible cases, using propensity score matching with replacement.

The results show that UK firms that have become exporters experience higher TFP growth, between 7.79% and 8.79%, with respect to domestic producers. Productivity gains were also experienced for British firms acquired by multinationals relative to domestic producers ranging from 11.55% to just above 13%. Finally, UK exporters have a lower annual TFP growth compared to UK subsidiaries of multinationals by around eight to ten percentage points.

Chapter III, decomposes the determinants of the growth rate of the volume of US net exports. This decomposition is based on the work of Dixit and Woodland (1982) on the determinants of changes of net exports. It incorporates the effect of changes in commodity prices, technological change in production, change in preferences and income variation. Additionally, it allows for the presence of jointness in output quantities in order to decompose the determinants of a change in the volume of net exports for an open economy with non-balanced trade. A general equilibrium analysis is implemented where a revenue (GDP) function and an expenditure function are estimated for the US economy for the period 1963 to 1991. There are three aggregate goods, an exportable, an importable and a non-tradable and three aggregate inputs, capital, skilled labour and unskilled labour in the US economy, as in Chapter I. Then a decomposition of the growth rate of the net exports is implemented. It involves a terms of trade component, an endowment component, a technological change component both in production and consumption and an income component.

I find that the positive growth, approximately 48% on average, on the net exports of the exportable good for at least the first thirteen years is explained by better terms of trade combined with a significant progressive technological change in the production side of the economy, despite the highest income effect observed for all three goods. For the rest of the period, the growth rate of net exports for the exportable was negative, -28%. This is mainly the result of a relative worsening of its terms of trade.
The negative growth rate of the net exports of the importable good are attributed to a significant income effect, a slower improvement in its terms of trade and a regressive technological change. The finding of an adverse technical change on the production of the importable good, gives support to the argument that the import-competing sector in the US has lost its market share in the US economy the last years due to biased technological change.

In contrast to the modest positive growth of the net exports for the exportable and the negative one for the importable, net exports for the non-tradable good grew at a remarkable 106% on average over the period 1966-1978. This is the result of a high and positive terms of trade effect accompanied by very large gains originating from the growth in endowments, regardless of negative effects arising from technological change, changes in preferences and income. This implies that the shares of the three aggregate goods on net exports has changed over the last twenty six years. The non-tradable good has increased its importance on US net exports since it grew dramatically over this period.

Summarising, this thesis focuses on empirical questions regarding US international trade movements and also on the causal effect a change in status has in $\text{TFP}$ growth for UK firms. First, I find that for the US economy the $FCT$ for capital is positive, while the $FCT$ of both types of labour is negative. This suggests that there was no Leontief Paradox over the period of analysis. In addition, the explanation for the worsening of the relative wages in US between skilled and unskilled workers seems to be technological change that hurts unskilled labour.

Then, there is evidence that UK firms acquired by multinational companies outperform in terms of $\text{TFP}$ growth both UK exporters and UK domestic producers, while exporters experience higher $\text{TFP}$ growth relative to domestic producers. Finally, I find that the positive growth rate of US net exports for the exportable good is explained by an improvement in the terms of trade and also progressive technological change. While, the negative growth for the importable good is attributed mostly to a small improvement in the terms of trade that went together with an adverse technological shock and a significant income effect. At the same time, the non-tradable good experienced a very high and positive growth over the same period that was the result of a substantial improvement in its terms of trade and also large gains from the change in the economy's endowments.
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CHAPTER I

A DUAL DEFINITION FOR THE FACTOR CONTENT OF TRADE AND ITS IMPACT ON FACTOR REWARDS IN US MANUFACTURING.

1.1 Introduction

The possible relationship between international trade and wage inequality in developed countries has been an important and regularly debated topic for both academics and politicians in the last decade. Unskilled workers in many developed countries and especially in the US have seen a significant decline in their relative wages\(^1\), while at the same time international trade has grown considerably. Some have argued that the increase of international trade is a likely explanation of the decline in relative wages. Trade economists have approached this question using the Heckscher-Ohlin model, from two different but equivalent angles. The first is based on the traditional Stolper-Samuelson theorem, where changes in product prices cause changes in factor rewards (Leamer, 1997 and 1994; Harrigan and Balaban, 1999); and the second is based on the Factor Content of Trade (FCT) theorem of Vanek (1968) and the work of Deardorff and Staiger (1988), where changes in the volume of net exports are transformed (via an input-output matrix) into changes in relative factor rewards (Borjas et al., 1992; Katz and Murphy, 1992; Wood, 1995; and Baldwin and Cain, 2000).

The FCT approach has been heavily criticized on the grounds that it lacks a solid theoretical foundation and especially that FCT is not related to factor prices. For instance, Panagariya (2000), Leamer and Levinsohn (1995) and Leamer (2000) argue that FCT calculates quantities of indirectly exported and imported factors via international trade but according to the Stolper-Samuelson theorem, it is product prices and not

\(^1\)Figure 1.4 depicts the normalised factor rewards for capital, skilled and unskilled labour, base year 1970. From Figure 1.4 it is clear that wage inequality between skilled and unskilled labour has increased after 1981 in the US. While both types of labour had gains in terms of factor rewards relative to capital.
factor quantities, which are related with factor prices. Yet, by introducing the concept of the Equivalent Autarkic Equilibrium (EAE), Deardorff and Staiger (1988) provide the theoretical foundation and show under which assumptions the FCT and relative wages are related (see also Deardorff, 2000; and Krugman, 2000).

In this chapter, I use the concept of EAE to introduce a new dual definition of the FCT to calculate the Factor Content of Net Exports. My definition of FCT is simply the difference between the endowments at the trade and equivalent autarky equilibria respectively. Then, by using the quadratic approximation lemma (Diewert 1976, 2002) I am able to relate the growth rate of factor rewards of trade equilibria to the growth rate of FCT, the growth rate of endowments and technological change.

In contrast to all previous FCT studies which rely on the use of input-output matrices to calculate the FCT (see Borjas et al., 1992; Katz and Murphy, 1992; Wood, 1995; Baldwin and Cain, 2000), I calculate the FCT by directly estimating the endowments required to achieve the EAE. This is accomplished by estimating a revenue function similar to Harrigan and Balaban (1999) and therefore without relying on the severe restrictions on technology required by the input-output matrices2. I assume the revenue function to be of the Symmetric Normalized Quadratic functional form, discussed in Kohli (1991, 1993) which is more attractive because it has the important property of flexibility when convexity and concavity are imposed. In accordance with most studies of both approaches with the exception of Wood (1995) and Leamer (1997), I also find that technological change is the most important determinant for the decline in relative factor rewards for unskilled workers in the US from 1967 to 1991.

The distinction between the two different types of labour is consistent with some of the early explanations in the literature about the Leontief Paradox (Kenen, 1965; Baldwin, 1971 and Winston, 1979) and seems to be valid for the period 1967-1991, since I find that there is no Leontief Paradox in the US. The FCT for capital is positive, the FCT for skilled labour is negative but quite close to zero, while the FCT of unskilled labour is negative and relative large in magnitude.

The rest of the chapter is organized into four sections. Section 1.2 develops the theoretical model and provides a dual definition of the factor content of trade. Section

2The construction of input-output matrices is based on the assumption of Leontief type technology.
1.3 contains a discussion of the empirical specification and estimation of FCT. Section 1.4 provides a decomposition of the changes of factor rewards using the quadratic approximation lemma. The last section of the chapter contains the conclusion.

1.2 The Model

In this section I develop a general equilibrium model for a trading economy using duality. The production side of the economy is described by a revenue function while the consumption side by an expenditure function. The use of duality, and more specifically the implementation of a revenue function, is preferred because it complies with the standard assumptions made in international trade theory that product prices and endowments are given while factor prices and outputs are the endogenous variables to be determined.

Let \( F(y, v, t) = 0 \) be a transformation function for an economy with a linearly homogeneous technology, which produces \( y = (y_1, \ldots, y_n) \) goods with the use of \( v = (v_1, \ldots, v_m) \) inputs \( (n < m) \) in a perfect competitive environment where \( t \) is a time index that captures technological change. Then, at given international prices \( p = (p_1, \ldots, p_n) \) and domestic inputs \( v \), there exists a competitive production equilibrium. In such equilibrium we can think of the economy as one that maximizes the value of total output subject to the technological and endowment constraints. In other words there is a revenue or Gross Domestic Product (GDP) function such that:

\[
R(p, v, t) = \max_y \{py : F(y, v, t) = 0\} \quad (1.1)
\]

The revenue function has the usual properties, i.e., it is increasing, linearly homogeneous and concave in \( v \) and non-decreasing, linearly homogeneous and convex in \( p \). In addition if \( R(p, v, t) \) is differentiable then from Hotteling's Lemma (Diewert 1974) the equilibrium output and factor rewards \( (w) \) are:

\[
y(p, v, t) = R_p(p, v, t) \quad (1.2)
\]
\[ w(p,v,t) = R_v(p,v,t) \]  

(1.3)

where \( R_p \) and \( R_v \) are the vectors of first partial derivatives of the revenue function with respect to product prices and endowments, respectively.

On the consumption side the economy's preferences defined over the \( n \) goods are represented by an expenditure function, which is continuous and twice differentiable on prices:

\[ E(p,u) = \min_{x} \{ px : u(x) \geq u \} \]  

(1.4)

where \( u \) is the level of utility and \( x = (x_1,...,x_n) \) is the consumption bundle. The expenditure function is non-decreasing, linear homogeneous and concave in prices and increasing in \( u \). From Shepherd's Lemma (Diewert 1974) the consumption vector of the economy is:

\[ x(p,u) = E_p(p,u) \]  

(1.5)

where \( E_p \) is the vector of the first partial derivative of the expenditure function with respect to product prices.

The trade equilibrium is defined as:

\[ R(p,v,t) = E(p,u) \]  

(1.6a)

\[ T = R_p(p,v,t) - E_p(p,u) \]  

(1.6b)

that is the total value of production should be equal to the total expenditure for the economy, which implies trade balance and the difference between production and consumption gives the economy's vector of net exports, \( T^3 \).

Consider now a hypothetical equilibrium, the equivalent autarky equilibrium introduced by Deardorff and Staiger (1988), where production equals consumption, at the same product prices and at the same utility level as in the trading equilibrium. This equilibrium can be achieved by changing the initial endowment of the economy such that the economy is producing what it desires to consume, having no incentive to trade with other countries. Hence, the vector of net exports is going to be a vector of zeros.

\( ^3 \)Figure 1.5 contains the plot of the net exports for all three aggregate goods as defined in the Appendix 1.A and equation (1.A4).
and trade is by definition balanced:

\[ R(p, v^e, t) = E(p, u) \]  
\[ R_p(p, v^e, t) = E_p(p, u) \]

where \( v^e \) is the equivalent autarky equilibrium endowments vector and \( p, u \) are the price vector and utility level respectively as in the trade equilibrium.

In Figure 1.1, following Krugman (2000), I depict the trading and equivalent autarky equilibria. In the Trade Equilibrium, the economy is producing where the production possibilities frontier \( DE \) is tangent to the relative product prices line \( AB \), at \( P \), while the economy is consuming at \( C \) where the relative product prices line is tangent to the indifference curve \( U^0 \). The economy is exporting \( Y_1 - X_1 \) units of good 1 and imports \( X_2 - Y_2 \) units of good 2. The equivalent autarky equilibrium is depicted at \( C \). There, the economy is endowed with the necessary inputs that allow the production of its consumption bundle at the trade relative product prices \( AB \). At the \( EAE \), the production possibilities frontier is \( FG \), and both consumption and production takes place at \( C \) and therefore the trade volume is zero. Note that at the trading equilibrium \( P \) and at the Equivalent Autarky Equilibrium \( C \) preferences are the same and because product prices are also unchanged the vector of consumption is unaltered. Under the assumption of balanced trade, GDP and the economy’s total expenditure would be identical in both equilibria.

Since consumption is the same in both equilibria then from equations (1.6b) and (1.7b) I have:

\[ R_p(p, v^e, t) = R_p(p, v, t) - T \]

and therefore I can explicitly solve from equation (1.8) for the \( EAE \) endowments vector \( v^e \) by knowing the net exports and the revenue function of the economy. Assuming that the implicit function theorem holds, \(|R_{pv}(p, v^e, t)| \neq 0\), where \( R_{pv} \) is the matrix of the second partial derivatives of the revenue function with respect to prices and endowments, I can solve for the \( EAE \) endowment vector \( v^e(p, v, t; T) \) which is going to depend on the trade equilibrium prices, initial endowment, technology and the net

\footnote{The determinant of matrix \( R_{pv} \) is different from zero, where \( R_{pv} \) is the matrix of the second partial derivatives of the revenue function with respect to product prices and endowments.}
export vector. Then, the factor content of trade is defined as the difference between the actual endowments in a trading equilibrium and the endowments at the equivalent autarky equilibrium:

\[ f = v - v^e(p, v, t; T) \]  

(1.9)

In the literature, the usual definition of FCT is just the product of an input requirement matrix, \( \Gamma \), times the trade vector \( T \) (see for example Deardorff and Staiger, 1988). Harrigan (2003) has shown that if there is non-jointness in output quantities, the input requirement matrix \( \Gamma \) is equal to \( R_p^{-1} \) and therefore the factor content of trade will be equal to \( R_p^{-1}T \). It is not difficult to show that my definition of FCT is identical to \( R_p^{-1}T \) under the non-jointness assumption. Under this assumption a revenue function can be written as \( R(p, v, t) = r(p, t)v \), then the vector of outputs is \( R_p = r_p v \), where \( r_p \) is the vector of partial derivatives of \( r(p, t) \) with respect to product prices and \( R_{pv} = r_p \) which is independent of the endowment vector. From equation (1.8) I have that \( T = R_p(p, v, t) - R_p(p, v^e, t) = r_p v - r_p v^e = r_p (v - v^e) = R_p f \), and therefore \( f = R_p^{-1}T \).

Consider now the more general case, and note that from the linear homogeneity of the revenue function in \( v \) I have:

\[ R_{pv} v = R_p(p, v, t) \]  

(1.10)

at the trade equilibrium. Substituting equation (1.10) in equation (1.6b) I have:

\[ R_{pv} v = T + E_p(p, u) \]  

(1.11)

Assuming that \( |R_{pv}| \neq 0 \) and that the \( R_{pv} \) is locally independent of \( v \), I can solve equation (1.11) for the vector of endowments which supports the trade equilibrium, i.e.:

\[ v = R_p^{-1}T + R_p^{-1}E_p(p, u) \]  

(1.12)

\[ ^{5} \text{The assumption of non-jointness in output quantities implies that there is Factor Price Equalisation. Hence, factor rewards are a function of product prices and changes in endowments do not cause any change on factor rewards. This is a central assumption in the Heckscher-Ohlin model, but seems not be valid in reality.} \]
Similarly, using the linear homogeneity property of the revenue function with respect to endowments vector at the \( EAE \) and equation (1.76) I have:

\[
R_{pv} v^\epsilon = R_p(p, v^\epsilon, t) = E_p(p, u)
\]

and the \( EAE \) endowment vector will be given by:

\[
v^\epsilon = R_{pv}^{-1} E_p(p, u)
\]  

(1.13)

Substituting equations (1.12) and (1.13) in equation (1.9) I have:

\[
\begin{align*}
f &= R_p^{-1} T + R_{pv}^{-1} E_p(p, u) - R_{pv}^{-1} E_p(p, u) \\
&= R_p^{-1} T
\end{align*}
\]  

(1.14)

Equation (1.14) shows that my definition of \( FCT \) given by equation (1.9) is equivalent to the usual definition appearing in the literature under the above assumptions. My definition is however a generalization to wider technologies even in cases where jointness in output quantity is present.

The factor content of trade, \( f \), can be easily computed from equation (1.9) if we know the equivalent autarky equilibrium endowments \( v^\epsilon \). This in turn can be estimated if we have knowledge of the revenue function and net trade vector of the economy. In the next section I specify a revenue function in order to estimate the factor content of trade for capital, skilled labour and unskilled labour in the US for the period 1965 to 1991.
1.3 Econometric Specification and Estimation

The revenue function is assumed to have the symmetric normalized quadratic functional form as discussed in Kohli (1991, 1993):

\[
R(p, v, t) = \frac{1}{2} \left( \sum_{j=1}^{M} \psi_j v_j \right) \left( \sum_{i=1}^{N} \sum_{h=1}^{N} a_{ih} p_i p_h \right) \left( \sum_{i=1}^{N} \theta_i p_i \right)^{-1} \\
+ \sum_{i=1}^{N} \sum_{j=1}^{M} (c_{ij} p_i v_j) + \frac{1}{2} \left( \sum_{i=1}^{N} \theta_i p_i \right) \left( \sum_{j=1}^{M} \sum_{k=1}^{M} b_{jk} v_j v_k \right) \left( \sum_{j=1}^{M} \psi_j v_j \right)^{-1} \\
+ \left( \sum_{j=1}^{M} \psi_j v_j \right) \left( \sum_{i=1}^{N} d_i p_i \right) t + \left( \sum_{i=1}^{N} \theta_i p_i \right) \left( \sum_{j=1}^{M} e_j v_j \right) t \\
+ \left( \sum_{i=1}^{N} \theta_i p_i \right) \left( \sum_{j=1}^{M} \psi_j v_j \right) \left( \frac{1}{2} h_{tt} t^2 + h_t t \right) 
\]  

(1.15)

where \( p_i \) and \( v_j \) are the product prices and input endowment vectors respectively and \( t \) is an index of exogenous technological change. There are \( N(N-1) + M(M-1) + (N \times M) + 2 \) unknown parameters \( a_{ih}, b_{jk}, c_{ij}, d_i, e_j, h_t \) and \( h_{tt} \), where \( i, h = 1, \ldots, N \) and \( j, k = 1, \ldots, M \). There are also \( N + M \) predetermined parameters \( \theta_i \) and \( \psi_j \). In particular, \( \theta_i \) and \( \psi_j \) are set equal to the share value of each product and input respectively at the base year. Symmetry conditions are imposed \( a_{ih} = a_{hi} \); \( b_{jk} = b_{kj} \) and the assumptions of linear homogeneity in \( p \) and \( v \) require some additional restrictions:

\[
\sum_{i=1}^{N} \theta_i = \sum_{j=1}^{M} \psi_j = 1, \quad \text{and} \quad \sum_{h=1}^{N} a_{ih} = \sum_{k=1}^{M} b_{jk} = \sum_{i=1}^{N} d_i = \sum_{j=1}^{M} e_j = 0 \quad (1.16)
\]

The symmetric normalized quadratic revenue function is attractive because it has a flexible functional form that retains its flexibility under the imposition of convexity and concavity in prices and endowments respectively. The necessary and sufficient condition for global concavity in inputs is that the matrix \( B = [b_{jk}] \)\(^6\) is negative semi-definite and for global convexity in product prices that the matrix \( A = [a_{ih}] \) is positive semi-definite. If these are not satisfied then they are imposed following Dievert and

\(^6\)The sign and magnitude of parameters \( b_{jk} \) determine whether the revenue function is concave or not. In the special case that all of them are zero, then the revenue function is concave and technology is non-joint in output quantities.
Wales (1987) without removing the flexibility properties of the revenue function.

Based on equation (1.15) the reward of the $j$th factor becomes:

$$w_j = \frac{1}{2} \psi_j \left( \sum_{i=1}^{N} \sum_{h=1}^{N} \alpha_{ih} \psi_{ip} \right) \left( \sum_{i=1}^{N} \theta_{ip} \right)^{-1} + \left( \sum_{i=1}^{N} \theta_{ip} \right) \left( \sum_{j=1}^{M} b_{jk} \psi_{vj} \right) \left( \sum_{j=1}^{M} \psi_{vj} \right)^{-1}$$

$$- \frac{1}{2} \psi_j \left( \sum_{i=1}^{N} \theta_{ip} \right) \left( \sum_{j=1}^{M} \sum_{k=1}^{M} b_{jk} \psi_{vj} \right) \left( \sum_{j=1}^{M} \psi_{vj} \right)^{-2} + \sum_{i=1}^{N} c_{ij} \psi_{ip} + \psi_j \left( \sum_{i=1}^{N} d_{ip} \right) t$$

$$+ e_j \left( \sum_{i=1}^{N} \theta_{ip} \right) t + \psi_j \left( \sum_{i=1}^{N} \theta_{ip} \right) h_i t + \frac{1}{2} \psi_j \left( \sum_{i=1}^{N} \theta_{ip} \right) h_{it} t^2$$

(1.17)

Similarly the output supply of good $i$th becomes:

$$y_i = \frac{1}{2} \theta_i \left( \sum_{j=1}^{M} \sum_{k=1}^{M} b_{jk} \psi_{vj} \right) \left( \sum_{j=1}^{M} \psi_{vj} \right)^{-1} + \left( \sum_{j=1}^{M} \psi_{vj} \right) \left( \sum_{h=1}^{N} \alpha_{ih} \psi_{ip} \right) \left( \sum_{i=1}^{N} \theta_{ip} \right)^{-1}$$

$$- \frac{1}{2} \theta_i \left( \sum_{j=1}^{M} \psi_{vj} \right) \left( \sum_{j=1}^{M} \sum_{h=1}^{N} \alpha_{ih} \psi_{ip} \right) \left( \sum_{i=1}^{N} \theta_{ip} \right)^{-2} + \sum_{j=1}^{M} c_{ij} \psi_{vj} + \psi_i \left( \sum_{j=1}^{M} \psi_{vj} \right) t$$

$$+ \theta_i \left( \sum_{j=1}^{M} e_{ij} \psi_{vj} \right) t + \psi_i \left( \sum_{j=1}^{M} \psi_{vj} \right) h_i t + \frac{1}{2} \theta_i \left( \sum_{j=1}^{M} \psi_{vj} \right) h_{it} t^2$$

(1.18)

The estimating model is the equation sets (1.17) and (1.18) together with the parameter restrictions equation (1.16). The errors related to equations (1.17) and (1.18) are assumed to be identically, and independently distributed with zero expected value and a positive definite covariance matrix. These equations are jointly estimated by the iterative three stages least square estimator applied to data for the US manufacturing sector over the period from 1965 to 1991. The three stages least square estimator is equivalent to the application of two stages least square estimation on a system of equations. It is a generalisation of two stages least square that takes into consideration the correlation of the errors across equations. It proceeds as follows:

1. Perform ordinary least squares estimation in each equation having as regressors all exogenous regressors and as the dependent variable the endogenous regressors. Obtain the fitted values for the endogenous regressors.

2. Perform ordinary least squares estimation on the original model by replacing the endogenous regressors with their fitted values from step 1 and obtain the residuals.
3. Perform a generalised least squares estimator to the system of the equations in order to obtain efficient estimates despite the presence of non-spherical errors.

There are six equations, three relating to outputs and three relating to factor rewards. The goods are exportables, importables and non-tradeable and the three factors of production are capital, skilled and unskilled labour. In Appendix 1.A, I provide a detailed construction and sources of the data.

Table 1.2 shows the estimated parameters and the $R^2$ for the system of the six equations. The revenue function is linearly homogeneous in prices and inputs, but initially convexity in prices and concavity in inputs were not satisfied. Following the method proposed by Diewert and Wales (1987) I impose convexity for product prices and concavity for input quantities. From Table 1.2, we see that the hypothesis of no convexity and concavity is rejected at a 5% level of significance (Wald test statistic(4)=32.7). The joint null hypothesis of non-jointness in output quantities is rejected at a 5% level of significance (Wald test statistic(2)=29.1), which is in accordance with the more general technology used above. In addition, the hypothesis of non technological change is rejected (Wald test statistic(2)=98).

The price elasticities of output supply ($\varepsilon_{ih}$) are presented in Table 1.3. All own price elasticities are well below unity, suggesting that the output supplies are inelastic. An increase in the price of exportables reduces the quantity of both importable and non-tradable goods. While an increase of the price of importables increases the output of non-tradable goods. The quantity elasticities of inverse input demand ($\varepsilon_{w_j,v_k}$) are reported in Table 1.4. Capital is the most elastic input compared to skilled and unskilled labour. Capital is a gross-substitute for skilled and unskilled labour while skilled and unskilled labour are gross-complements.

In Tables 1.5 and 1.6, I present the quantity and technological change elasticities of inverse input demand ($\varepsilon_{w_j,v_k}, \varepsilon_{w_j,p_i}$) and the price elasticities of inverse input demand ($\varepsilon_{w_j,p_i}$) in the Equivalent Autarky Equilibrium. We see that the quantity elasticities of inverse input demand have the same signs as in the Trade Equilibrium, but are smaller in magnitude suggesting that factor demands are less elastic in the hypothetical EAE. Regarding the technological change elasticities of inverse input demand, capital's and
skilled labour's rewards gain from technological change, but unskilled labour is hurt. From the price elasticities of inverse input demand we see that an increase in the price of the exportable raises the factor reward to the capital and unskilled labour and reduce the factor reward to the skilled labour. While a rise in the price of the importable and non-tradables lead to higher rewards for capital and skilled labour and a lower reward for unskilled labour.

The estimated parameters of the revenue function are used in order to calculate the \( FCT \) for each input. In particular, solving equation (1.8) for \( v^e \) and then using equation (1.9), allow us to obtain the factor content of trade, \( f_j \), for each input for the period 1965 to 1991. The \( FCT \) for all three factors are plotted in Figure 1.2. We observe that \( FCT \) of capital, \( f_K \), was positive and generally increasing throughout the sample period. The \( FCT \) of both skilled, \( f_S \), and unskilled, \( f_U \), labour was negative and declining till 1986 and then increased till 1991, with the \( FCT \) of skilled labour having a relatively smaller magnitude. Hence, the US economy was exporting the services of capital and importing the services of both types of labour for all the years between 1965 to 1991. The net exports of capital services in 1965 were 16.34 billion USD\(^7\), reached a maximum of 62 billion USD in 1986 and fell to 54.30 billion USD in 1991. The net imports of skilled labour services rose from 9.89 billion USD in the first year of the period to 44.04 billion in 1986 and then were reduced to 32.50 billion USD in 1991. Similarly, the net imports of unskilled labour increased from 20.45 billion in 1965 to 96.88 billion in 1986 and then decreased to 68.48 billion USD in the last year of the sample.

It is evident that for the period 1965-1991 there is no Leontief Paradox in the US economy. My result is consistent with the analysis of Learner (1980), since the \( FCT \) that I calculate is by definition the factor content of net trade. Learner showed that in a multi-factor, multi-product H-O-V environment, a country with positive FC of net exports for both capital and labour is revealed by trade to be relatively capital abundant, if and only if the ratio of the FC of net exports for capital to the FC of net exports for labour is greater than the ratio of capital to labour in the production. He criticised Leontief's (1954) original work that led to the famous paradox, because

---

\(^7\)All net trade services of factors are measured in prices of the year 1970 and is assumed that the economy is in a balanced trade equilibrium (see more in the Appendix 1.A).
according to Leamer; Leontief followed an incorrect method in order to compute trade revealed factor abundance. Leontief compared the ratio of FC of exports for capital to the FC of exports for labour with the ratio of FC of imports for capital to the FC of imports for labour in order to obtain trade revealed factor abundance. Leamer showed that Leontief’s comparison is the correct one for obtaining trade revealed factor abundance ordering only when the FC of net exports of capital and the FC of net exports of labour are opposite in sign. Leamer pointed that in the case of Leontief’s data both the FC of net exports for capital and FC of net exports for labour were positive and hence Leontief’s comparison was incorrect. He then showed that with Leontief’s data, US is revealed by trade to be relatively capital abundant if the correct comparison is performed and consequently there was no paradox.

In my case, capital is revealed by trade to be relatively more abundant to either types of labour, because the FC of net exports for capital is positive and the FC of net exports for either type of labour is negative. But trade revealed factor abundance is not very clear in the case of skilled and unskilled labour. The reason is that both the FCT for skilled and unskilled labour are negative. Following Leamer (1980), we see from Table 1.7, that the ratio of the FCT for skilled labour relative to the FCT for unskilled is lower than the ratio of skilled to unskilled endowments and hence trade reveals that skilled labour is relatively abundant to unskilled labour in the US economy between 1965 and 1991. This is a result that coincides with the findings of Bowen et al. (1987) that the proxy of skilled labour that they used is relatively abundant in the US.

For all of the years in the sample period more unskilled and skilled labour would have been employed in a hypothetical EAE relative to capital, but more unskilled labour would have been employed relative to skilled labour. Therefore in the US manufacturing sector there is a clear ordering of factor abundance revealed by trade. Capital is the most abundant factor relative to both types of labour, while skilled labour is relatively more abundant when compared with unskilled labour between 1965 to 1991.
1.4 Factor Rewards Decomposition

1.4.1 A Special Case: Non-joint Technology, No Endowments Change and No Technological Change

So far I have discussed the definition of the Equivalent Autarky Equilibrium, the calculation of the \( FCT \) using duality in the case of jointness in output quantities and the estimation of the revenue function for US. In this section my goal is to establish a general relationship between changes in factor prices on one side and changes of endowments, \( FCT \) and technology in the other. But first I show the relationship between wage changes and changes in the \( FCT \) when technology is non-joint, endowments remain the same and there is no technological change. In order to proceed, I totally differentiate equation (1.3) with respect to time. That is:

\[
\frac{dw}{dt} = R_{vp} \frac{dp}{dt} + R_{vv} \frac{dv}{dt} + R_{vt}
\]

where \( \left( \frac{dx}{dt} \right) \) indicates the time derivative of \( x \) and \( \Psi_{xy}^{i} = \frac{\partial \Psi}{\partial x} \frac{\partial \Psi}{\partial y} \) indicates the partial derivative of \( \Psi \) with respect to \( x \) and \( y \) at equilibrium \( i \). Equation (1.19) says that changes of factor rewards \( \left( \frac{dw}{dt} \right) \) in the Trade Equilibrium depend on the change of product prices \( \left( \frac{dp}{dt} \right) \), the change of endowments \( \left( \frac{dv}{dt} \right) \) and the matrices of first partial derivatives of factor reward with respect to prices \( \left( R_{vp} = \frac{\partial w}{\partial p} \right) \), endowments \( \left( R_{vv} = \frac{\partial w}{\partial v} \right) \) and technological change \( \left( R_{vt} = \frac{\partial w}{\partial t} \right) \) respectively. In the case that there is no-joint production \( \left( R_{vv} = 0 \right) \), as in Deardorff and Staiger (1988), factor rewards of the two equilibria, Trade and EAE, are the same. To see this, first recall the definition of the trade and equivalent autarky equilibria, equations (1.6) and (1.7). Factor rewards in these equilibria are given by \( w = R_{v}(p,v,t) \) for the trading equilibrium and \( w^{e} = R_{v}(p,v^{e},t) \) for EAE, and since endowment vectors are different, factor rewards would be different as well. Assuming non-jointness in output quantities the revenue function can be written as \( R(v,p,t) = r(p,t)v \) and \( R_{v} = r(p,t) \) which is independent of the endowment vector. Therefore factor rewards would be identical, \( w = w^{e} \). Under this assumption, (1.19) can be written as:
\[
\frac{dw}{dt} = R_{vp} \frac{dp}{dt} + R_{vt}
\]  

(1.20)

d this expression is similar to the Stolper Samuelson Theorem in the case of the same number of factors and products and technological change. Leamer (1994 and 1997) states that this is the relationship that someone should look at if he wants to deduce the effects of international trade and technical change on factor rewards. Within the Heckscher-Ohlin framework, the first part of the right hand side is the effect of international trade, while the second part is the effect of technological change on factor rewards. But such a relationship assumes that product prices are exogenously determined and that there is no link between technological change and product price variation. Leamer (1997) states the importance of this kind of interdependence between product prices and technical change and separates the changes of product prices into two components. The first is arising from international markets, he calls it globalisation, and the second from technological change.

Although Leamer's (1997) decomposition of product price variation seems reasonable, it is inconsistent with one of the core assumptions of the Heckscher-Ohlin model, that product prices are exogenous in a Trade Equilibrium. But Deardorff and Staiger's (1988) introduction of the EAE allows us to establish a relationship between product prices, technological change and endowments, while I continue to assume that product prices are exogenous in the trading equilibrium. In EAE product prices are not exogenous and depend on endowments and technological change, since it is an autarkic equilibrium. Hence, \( p = f(v^e, t) \) and if I differentiate totally with respect to time I get:

\[
\frac{dp}{dt} = \frac{\partial p}{\partial v^e} \frac{dv^e}{dt} + \frac{\partial p}{\partial t}
\]  

(1.21)

Also from the definition of the \( FCT \) equation (1.9) I know that \( v^e = v - f \), totally differentiating with respect to time I get:

\[
\frac{dv^e}{dt} = \frac{dv}{dt} - \frac{df}{dt}
\]  

(1.22)

the change of inputs in the EAE \( \left( \frac{dv^e}{dt} \right) \) is positively related to the change of inputs in the Trade Equilibrium \( \left( \frac{dv}{dt} \right) \) and inversely related to the change of the \( FCT \) \( \left( \frac{df}{dt} \right) \).
If I further assume that endowments do not change (\( \frac{dw}{dt} = 0 \)) and that there is no technological change, product prices changes and \( FCT \) changes are equivalent and carry the same set of information regarding changes in factor rewards. Substituting equation (1.21) into an expression like equation (1.20) evaluated in the EAE and using equation (1.22) under the above assumptions and some rearrangements I get:

\[
\frac{dw}{dt} = -R^e_{vp} \frac{\partial p}{\partial v^e} \frac{df}{dt}
\]

(1.23)

where \( R^e_{vp} = \frac{\partial w^e}{\partial p} \) is the matrix of first partial derivatives of factor rewards with respect to prices in EAE. Equation (1.23) states that the change of factor rewards in the Trade Equilibrium is directly linked to changes of the \( FCT \) in the special case that there is neither jointness in output quantities nor changes on endowments nor in technology. Hence, I am able to establish a relationship between changes in factor rewards and changes in \( FCT \), similar to the one of Deardorff and Stager (1988) under the same set of assumptions, while I use a different (dual) definition of \( FCT \).

1.4.2 The General Case

In the case that there are either endowment or technological changes or both, product prices changes and \( FCT \) changes are not equivalent in terms of their effect on factor reward changes. Then factor reward variation will depend on endowment variation, \( FCT \) variation and technological change.

As it was mentioned above, in the absence of a non-joint technology the factor rewards in the two equilibria will not be equal. I have information on the factor rewards at the Trade Equilibrium and I need to calculate the factor rewards in the EAE in order to obtain the difference between the two of them. With the use of the \( EAE \) I am able to calculate the factor rewards that would have been obtained assuming the economy was endowed with the appropriate allocation of inputs to produce its consumption bundle at the observed product prices. The difference in factor rewards between a trade equilibrium and \( EAE \) for the time period \( s \) can be approximated by using the
quadratic approximation lemma (Diewert, 1976, 2002) that is:

\[
\begin{align*}
\text{w}^* - \text{w}^e &= \text{R}^*_{vv} (v^* - v^e) = \text{R}^*_{sv} f^s, \quad s = 0, 1,
\end{align*}
\]

where matrix \(\text{R}^*_{vv} = \frac{1}{2} (\text{R}^e_{vv} + \text{R}^e_{vu})\) has a typical entry \(\text{r}^*_{v,vk}\) that is the mean effect of a change in the \(k\)th endowment on the reward of the \(j\)th factor evaluated at the trade and equivalent autarky equilibrium at period \(s^8\). After differentiating with respect to time both sides of equation (1.24) I get:

\[
\frac{dw}{dt} = \frac{R^e_{vv}}{R^v} \frac{df}{dt} + \frac{dw^e}{dt}
\]

an expression that relates the change of factor rewards \((\frac{dw}{dt})\) to the change of the FCT \((\frac{df}{dt})\) and the change of the factor rewards at the EAE \((\frac{dw^e}{dt})\).

Similarly, I know that the factor reward at the EAE is \(w^e = R_v (p, v^e, t)\) and that the equilibrium product price \(p\) is a function of EAE endowments \((v^e)\) and technology \((t)\), \(p(v^e, t)\), hence the factor rewards at EAE can be written as \(w^e = R_v(p(v^e, t), v^e, t)\). Differentiating again the previous expression with respect to time and rearranging I get:

\[
\frac{dwe}{dt} = \left( R^e_{vv} \frac{dp}{dv^e} + R^e_{sv} \right) \frac{dv^e}{dt} + R^e_{vp} \frac{dp}{dt} + R^e_{vt}\]

a relationship between the change of factor rewards at the EAE \((\frac{dwe}{dt})\), the change of inputs at the EAE \((\frac{dp}{dt})\) and the effect of technological change on factor rewards in the EAE. \(R^e_{vv} = \frac{dwe}{dv^e}\) is the matrix of partial derivatives of factor rewards with respect to endowments in EAE and \(R^e_{vt} = \frac{dwe}{dt}\) is the vector of partial derivatives of factor rewards with respect to technological change.

Substituting equations (1.26) and (1.22) in equation (1.25) I get that:

\[
\frac{dw}{dt} = \left( R^e_{vp} \frac{dp}{dv^e} + R^e_{ye} \right) \frac{dv^e}{dt} + \left[ (R^e_{vv} - R^e_{vy}) - R^e_{vp} \frac{dp}{dv^e} \right] \frac{df}{dt} + R^e_{vp} \frac{dp}{dt} + R^e_{vt}
\]

Equation (1.27) relates changes in the observed factor rewards at trade equilibrium to changes in actual endowments, changes in FCT and technology. It is a generalization of the results of Deardorff and Staiger (1988) and also of Learner (1997). If I assume no

\footnote{Notice that when there is non-jointness in output quantities, \(R_{vv} = 0\), and therefore \(w^* = w^e\).}
technological change and that the endowments remain constant, the change in factor rewards would have been just a function of the change of the FCT. In addition, if there is non-jointness in output quantities or \( R_{pu} \) is locally independent of \( v \), factor rewards and consequently their changes between the trade and the equivalent autarky equilibrium are the same. Then the effect of FCT on the changes of factor rewards collapses to equation (1.23).

An unfortunate fact of this decomposition is that it still depends on the demand side of the economy. From equation (1.7b), the matrix of first partial derivatives of product prices with respect to EAE endowments is \( \frac{\partial p}{\partial v'} = -(R_{pp} - E_{pp})^{-1} R_{pv} \) and the vector of first partial derivatives of product prices with respect to time is \( \frac{\partial p}{\partial t} = -(R_{pp} - E_{pp})^{-1} R_{pt} \). To compute equation (1.27) I need information on the second derivatives of the expenditure function with respect to prices. Instead, I estimate directly \( \frac{\partial p}{\partial v'} \) and \( \frac{\partial p}{\partial t} \) by using Seemingly Unrelated Regression Estimation (SURE). Assuming a linear relationship between the growth rate of prices, the growth rate of EAE endowments and technological change, the following specification is used for the estimation of \( \frac{\partial p}{\partial v'} \) and \( \frac{\partial p}{\partial t} \): 

\[
\hat{p}_i = a_i + \sum \beta_{ij} \hat{v}_j \tag{1.27}
\]

where \( \frac{\partial p}{\partial v'} = \beta_{ij} \) and \( \frac{\partial p}{\partial t} = a_i; i = E, I, N \) and \( j = K, S, U \).

In Table 1.9, I present the results of the above decomposition (1.27) in growth rates (see Appendix 1.B) for the period 1967-1991. For both types of labour the FCT Effect \( \left( R_{v'v} f' - R_{v'v} f^s - \frac{1}{2} \left( R_{v'v} \frac{\partial p}{\partial v'} + R_{v'v} \frac{\partial p}{\partial v'} + R_{v'v} \frac{\partial p}{\partial v'} + R_{v'v} \frac{\partial p}{\partial v'} \right) (f' - f^s) \right) \), third column in Table 1.9, has a positive impact on the growth of their factor rewards. The FCT Effect raised by 2.75% the growth of skilled labour’s reward and by 4.47% the growth of unskilled labour’s reward, respectively for the period 1967-1981. For the same period, the FCT effect on the growth of the reward of capital was negative, -4.84%. For the rest of the time period, the FCT effect is positive for all three factors of production. The highest magnitude is observed for the reward to capital, 2.79%, while the lowest is for unskilled labour’s reward, 1.62%.

Bearing in mind that capital is the only factor that had experienced positive and high magnitudes of FCT, it appears confusing that the FCT effect had a negative impact on the growth of capital’s reward. There are two explanations for this surprising result.

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9Results are presented in Table 1.8.
and are discussed below.

The first is that the FCT Effect consists of an expression that is linear on the FCT growth of each factor of production. It also depends on the several inverse input demand elasticities with respect to price, quantity and time and also on product price elasticities with respect to endowments. The sign of most of these elasticities is not a priori determined, because of the more general technology used for the estimation (absence of non-jointness in output quantities). As a consequence, there is not a clear theoretic prediction as in the simple 2x2 Heckscher-Ohlin model. Here, the sign of the effect depends on the sign and also magnitude of all the elasticities mentioned above. And since the sign of these elasticities is an open empirical question all possible outcomes could occur.

The second explanation rests on the fact that I can further decompose the FCT effect in equation (1.27) into two components as shown in Table 1.10. The one that arises from the more general technology is called From Jointness and is equal to $R_{tv}^f f_t^f - R_{uu}^f f_t^f - \frac{1}{2} (R_{tv}^{el} + R_{vu}^{es}) (f_t^f - f_t^e)$. The second originates from the relationship between product prices and endowments in EAE, $-\frac{1}{2} \left( R_{ee}^{el} \frac{\partial P_e}{\partial v_i} + R_{c}^{es} \frac{\partial P_c}{\partial v_i} \right) (f_t^f - f_t^e)$ and is termed From Product Prices. The latter is the effect that is usually attributed to international trade in the literature and is given by equation (1.23). From Table 1.10 is obvious that the From Product Prices is positive for all three factors and also that there is a clear ranking of the magnitudes for all periods with the reward to capital having the highest gains, 1.28%, the reward to skilled labour the second highest, 0.47%, and unskilled labour the least gains, 0.19% for the whole period. At the same time, the From Jointness was negative on average for the reward to capital, -3.07% and positive for the reward of both skilled, 2.07%, and unskilled labour, 3.14%, respectively. Hence, it is evident that the reward of capital had the biggest gains from international trade if a no-joint technology is assumed, followed by skilled labour and finally the factor with the lowest gains was unskilled labour. From the estimation it is clear that the quantity elasticity of inverse input demand for capital was negative and large in magnitude relative to the price and technology elasticity of inverse input demands and also the product price elasticities in EAE and as a consequence the From Jointness Effect dominated the From Product Prices Effect leading to a negative FCT Effect for the case of capital.
Next, in the fourth column of Table 1.9 we see that the Endowments Effect
\[ \left( \frac{1}{2} \left( R_{vp} \frac{\partial p^t}{\partial s} + R_{vp} \frac{\partial p^t}{\partial s} + R_{vt} + R_{vt} \right) (v^t - v^t) \right) \]
was negative for the growth rate of capital's and skilled labour's reward, -13.35% and -1.27% respectively for the whole period and positive for the growth rate of unskilled labour's reward, 2.10% over the same period. The signs and the magnitudes of such effects are the expected ones. Capital was the factor that experienced the highest growth in its endowments, followed by skilled labour\(^{10}\) and naturally this growth had affected adversely the reward for each factor. On the opposite side, unskilled labour endowments have declined over the period of investigation\(^{11}\) and such decline in the supply of unskilled labour has caused, ceteris paribus, an increase on the reward of unskilled labour.

The last column of Table 1.9 presents the total Technology Effect
\[ \left( \frac{1}{2} \left( R_{vp} \frac{\partial p^t}{\partial s} + R_{vp} \frac{\partial p^t}{\partial s} + R_{vt} + R_{vt} \right) \right) \]. This effect is positive on average for the growth rate of factor rewards for all three inputs over the period 1967-1991. The technological effect on the growth of capital's reward was the highest in magnitude, an average of 17.52% for the whole period, followed by skilled labour's growth, 5.68%. For the same period the total Technology Effect on the growth of unskilled labour's reward was slightly above zero, 0.50%. It altered signs from positive, 1.51%, in the first sub-period to negative for the second, -1.03%, while it was positive for all sub-periods for the other two factors. So it is clear from Table 1.9 that all factors gained from technological change, with capital experiencing the largest gain and unskilled labour the smallest one in terms of the growth of their reward.

But this Technology Effect can be further decomposed into Endogenous Technological Change Effect \( \left( \frac{1}{2} \left( R_{vp} \frac{\partial p^t}{\partial s} + R_{vp} \frac{\partial p^t}{\partial s} \right) \right) \) and Exogenous Technological Change Effect \( \left( \frac{1}{2} \left( R_{vt} + R_{vt} \right) \right) \) as it is shown in Table 1.11. The Endogenous Technological Change Effect arises from the fact that product prices in the EAE are endogenous and are affected by technological change. While the Exogenous Technological Change is similar to a shift of the production possibilities frontier. From Table 1.11, we see that the Endogenous Technological Change Effect was positive for the rewards of all the three factors and time periods, with the reward to capital enjoying again the highest gains,

\(^{10}\)From Figure 1.3 it is evident that the endowments for capital increased more on average per year compared to the endowments of skilled labour. In particular, capital endowments grew annually by 4.6 percent on average, while skilled labour by 2.2 percent.

\(^{11}\)Figure 1.3 shows the evident decrease of unskilled labour’s endowments for the period 1965-1991.
13.02%, and unskilled labour to gain the least, 2.25% from 1967 to 1991. On the other hand the *Exogenous Technological Change Effect* effect was positive for the growth of the reward to capital, 4.5%, and skilled labour, 0.17%, but negative for the growth of unskilled labour's reward, -1.75%. Hence, I find that *Exogenous Technological Change* has hurt unskilled labour and has benefited capital and skilled labour. This indicates that the small positive effect of overall technological change on the growth of unskilled labour's reward is the net effect of a persistent negative exogenous technical change and a positive endogenous technical change of a slight bigger magnitude.

Finally, from Table 1.9 we see that the difference between the rewards of capital and the two types of labour has narrowed, since the average growth over the whole period for capital, 2.38%, was much smaller than the average growth for skilled labour, 6.95% and unskilled labour, 5.93% respectively. But at the same time, the inequality between workers has increased at a rate of slightly above 1% on average per year. This seems to be attributed to technological change that has favoured considerably much more skilled labour relative to unskilled labour. The total FCT effect is higher for the unskilled labour and so is the *Endowment Effect*, in fact this effect is negative for skilled labour. Consequently, the increasing wage inequality between skilled and unskilled workers seems to be due to the *Technology Effect*. In particular the *Technology Effect* was 6.53% for skilled labour's reward and only 1.51% for the reward of unskilled labour over the period 1967-1981. While for the last period the difference of *Technology Effect* became even bigger between the reward of the two types of labour. It was 4.39% for skilled labour and -1.03% for unskilled. Hence, the widening on relative wages between skilled and skilled workers seems to be the result of technological change that is biased towards skilled labour.

### 1.5 Conclusion

In this chapter, I provide a dual definition for the factor content of trade based on the equivalent autarky equilibrium introduced by Deardorff and Staiger (1988). This new definition of FCT allows for a more general technology that permits the existence of
jointness in output quantities. By estimating a symmetric normalized quadratic revenue function I calculate the FCT of capital, skilled and unskilled labour for the US manufacturing sector for the period 1965 to 1991. Moreover by applying the quadratic approximation lemma to the difference of factor rewards between the trading equilibrium and EAE, I am able to link the observed growth of factor rewards to the growth of FCT, endowments and technological change for 1967-1991.

I find that the FCT of capital is positive while the FCT of skilled and unskilled labour are negative. Hence, for the period of investigation and under the technological specification of my model, it appears that there is no Leontief Paradox. This suggests that if the economy was at EAE less capital would have been employed relative to skilled and unskilled labour. The positive sign of capital's FCT and the negative sign of the FCT of both types of labour implies that US manufacturing sector was a net exporter of goods that are more capital intensive between 1965 to 1991 and that capital was revealed by trade to be relatively more abundant to the two types of labour. In addition, following Learner (1980) I show that skilled labour is revealed by trade to be relatively more abundant to unskilled labour, since the ratio of factor content of skilled labour to the factor content of unskilled labour is smaller than the ratio of skilled to unskilled labour used in the production.

Overall factor rewards between the two types of labour and capital have narrowed but within labour wage inequality has increased. I find that the FCT Effect on factor rewards, for the period considered, is positive for the two types of labour and negative for capital. This is probably the result of the more general technology used in the analysis as the decomposition of the FCT Effect indicates in Table 1.9. From the estimation I found that the sign and magnitude of all the elasticities involved on the calculation of the FCT Effect for capital were such that the From Jointness Effect was negative and dominated the positive From Product Prices Effect. If a non-joint technology was assumed then capital's reward would have experienced the highest FCT Effect, implying that the reward to capital has gained the most because of international trade. The Endowments Effect is negative for the growth of capital's and skilled labour's reward and positive for unskilled labour. Suggesting that the increasing endowments of capital and skilled labour have suppressed their rewards, ceteris paribus, while the opposite
happened for unskilled labour. Technological change has benefited mainly the reward to capital, but also skilled labour's reward to a smaller magnitude. On the contrary, the reward to unskilled labour had almost no gains arising from technological innovation. Finally, the increasing inequality between skilled and unskilled labour's reward seems to be the cause of technological change, both exogenous and endogenous, that was biased in favour of skilled labour's reward.
Appendix 1.A

There are three inputs in my model, capital, $v_K$, skilled labour, $v_S$, and unskilled labour, $v_U$. Data for the value and price of capital and aggregate labour, at a 2-digit SIC87 analysis are obtained from Dale's Jorgenson database for the period 1963-1991\textsuperscript{12}. I construct the value added for capital and aggregate labour and also the price of capital and labour. In particular, the price of inputs is a weighted average of their prices in each 2-digit industry. The weights are the share of each input in every 2-digit industry. I get the quantity of capital and aggregate labour by dividing their value added by their price, respectively.

The division of aggregate labour into skilled and unskilled labour is implemented by using data from the NBER collection of Mare-Winship Data, 1963 1991. It contains data on education levels, weekly wages, status and weeks worked for full time workers in 2-digit SIC industries. I divide workers into skilled and unskilled following Katz and Murphy (1992), a worker is treated as skilled if he or she spent at least twelve years in education. The sample contains only full time workers, aged 16-45, that have completed their educational grade and are working in the private sector. First, I calculate the total number of weeks worked per year and also the annual wages and salaries for skilled and unskilled workers\textsuperscript{13}. Then I divide the annual value of wages and salaries by the corresponding total weeks worked in order to calculate the full time weekly wage for each group respectively. After that I calculate the share of weeks worked for skilled and unskilled workers relative to the total hours worked of all workers. Similarly, I find the shares of wages for each occupational group in the sample. Finally, these shares are multiplied by the total quantity and total wages of aggregate labour, respectively, obtained from Jorgenson's data set in order to get the quantity and wages for skilled and unskilled workers in US.

In Figures 1.3 and 1.4 are plotted the endowments\textsuperscript{14} and rewards\textsuperscript{15} of the three factors of the economy for the period 1965-1991, respectively. From Figure 1.3 it is clear that the quantity of skilled labour was the highest in the economy among all factors

\textsuperscript{12}http://post.economics.harvard.edu/faculty/jorgenson/data/35klem.html

\textsuperscript{13}Following Katz, L. and Murphy, K. (1992) we include only full time workers that have worked more than 39 weeks in that year. Also, top code wage and salaries were multiplied by 1.45.

\textsuperscript{14}Measured in factor rewards of year 1970.

\textsuperscript{15}Measured as the relative factor reward to year 1970.
of production and that it continued to increase for the whole period. The quantity
of unskilled labour was the second highest in 1965, but it declined steadily over the
sample period and as a result in 1970 unskilled labour became the less used factor in
the economy. As for the quantity of capital in the economy, it followed a similar path
to the skilled labour's quantity but it was much smaller in magnitude. Hence, it is
evident from Figure 1.3 that the quantity of skilled labour and capital increased in the
US economy for the period 1965-1991, while unskilled labour experienced a significant
decline in its quantity over the same time period.

From Figure 1.4, we observe that the reward to capital was the highest for the period
1965-1974, with the exception of 1970, while the rewards to the two types of labour
were very similar over the same time period. Then from 1975 to 1978 the rewards for
all three factors were almost identical. The same pattern continued for the reward to
skilled and unskilled labour until 1981, while at the same time the reward to capital
declin ed significantly relative to the rewards of the two other factors of production.
After 1981 and till the end of the sample, it is evident that the reward to skilled labour
had the highest increase, followed by unskilled labour and the factor with the lowest
rise in its reward was capital. Hence, it is clear from Figure 1.4 that there was a notable
increase in wage inequality between skilled and unskilled workers in the last eleven years
of the sample, while both types of labour experienced gain in terms of factor rewards
relative to capital.

In my model there are three aggregate products, exportable, $y_E$, importable, $y_I$, and
non tradable, $y_N$. Initially the products are divided into tradeable and non-tradeables.
A 2-digit industry is termed tradable if the ratio of its exports plus imports divided
by its output is above 10\%, otherwise it is termed as non-tradable\(^\text{16}\). Then tradable
industries are grouped into exportables and importables depending on whether their
net exports are positive or negative, respectively. The categorisation of the 2 digit
industries into the three aggregate goods, as explained above, was made for the first
year of the sample, 1965\(^\text{17}\). In addition, the final dataset was constructed in such a

\(^{16}\)Trade data at a 2-digit SIC87 level were obtained online from the Centre for International Data
at the University of California Davis.

\(^{17}\)I chose 1965 as the year to which the aggregation of 2 digit products was made, because it is
easier to interpret the results having as reference point the beginning of the sample. In addition, in
this year the variation of the volume of net exports within each aggregate good was the smallest.
way that once a 2 digit good was incorporated into one of the three aggregate goods, it remained in this particular aggregate good even if the criteria that were used for year 1965 had changed sign or magnitude over time. The reason is that we intended to create aggregate categories with a stable composition over time, in order to avoid potential correlation between the prices of aggregate goods that might have led to econometric problems.

For the calculation of value added of the three aggregate products I again use Jorgenson's data set. While data for output deflators are obtained from the Bureau of Economic Analysis at a 2-digit SIC level. Since these are available from 1977 onwards, the values of output deflators for years before 1977 are obtained by interpolation assuming a constant growth rate equal to the growth rate between 1977 and 1978. The aggregation of the three goods is achieved in three stages. First, I calculate the value added for each aggregate good, then an aggregate price is constructed for each of them. This aggregate price is a weighted average of the prices of all 2-digit industries that belong to an aggregate good, with weights the share of each 2-digit industry. The aggregate quantity of output is calculated by dividing the value of each aggregate good by its aggregate price. Similarly, the volume of net exports is calculated by dividing the value of net exports for each aggregate good by its corresponding aggregate price.

The assumption of balanced trade is not satisfied by the data. For that reason, the actual trade volumes for each good are adjusted according to the share of output relative to total revenue in the economy in order to guarantee balanced trade. I define the volume of net exports T as:

\[ T = y - c, \]  

(1.A1)

where \( y \) and \( c \) are the vector of production and consumption respectively. I assume trade balance, which implies that economy's volume of net exports priced at the exogenous given international prices \( p \) is zero:

\[ pT = p(y - c) = 0 \]  

(1.A2)

From the data I get that (1.A2) is not satisfied, instead I get a trade deficit or surplus.

\(^{18}\)Table 1.1 shows the SIC categories that are included in each aggregate good.
\((IMBAL)\) varying from year to year:

\[ pT = p_y - p_c = IMBAL \]  \hspace{1cm} (1.A3)

In order to impose trade balance, I subtract from the volume of net exports for every good \(i\) a fraction of \(IMBAL\) equal to each good's share of total value of output in the economy:

\[ ADJT_i = T_i - \left( \frac{y_i}{\sum_{i=1}^{N} y_i P_i} \right) IMBAL \]  \hspace{1cm} (1.A4)

and from equations (1.A1) and (1.A4) I calculate the new consumption vector \(x\):

\[ x_i = y_i - ADJT_i = y_i - T_i + \left( \frac{y_i}{\sum_{i=1}^{N} y_i P_i} \right) IMBAL \]  \hspace{1cm} (1.A5)

Figure 1.5 depicts the plots of the adjusted volume of net exports, as it is given by equation (1.A4), for the three goods in the economy. The adjusted volume of net exports for the exportable good was mainly increasing from 7 billion USD in 1965 to 17.5 billion USD in 1981. This pattern was followed by a five year period of decline, 10 billion of USD in 1986 and then they began to increase again until 1991. While the adjusted volume of net exports for the non-tradable remained relatively stable for the first sixteen years from 150 million USD in 1965 to 67 million in 1980. Then from 1981 till 1986 had a rapid increase and reached a maximum of 9 billion USD, followed by a decline during the last six years of the sample. On the contrary, the adjusted volume of the net exports for the importable good experienced a steady decline from -7 billion USD (7 billion of USD net imports) in 1965 to -19 billion (19 billion USD net imports) in 1984 and then remained relatively stable for the last eight years of the sample. Hence, we see that net exports of the exportable were mainly increasing and were the highest in magnitude relative to the two other aggregate goods. Similarly, the net exports of the nontradable were rising over time, but were smaller in magnitude relative to the exportable. Finally, the net exports of the importable experienced a steady decline and had the smallest magnitude for the period 1965-1991.
Appendix 1.B

Let \( \ddot{x} = \frac{dx}{dt}X^{-1} \) indicates the vector of the growth rates of variables \( x = (x_1, \ldots, x_n) \), \( X \) is the diagonal matrix that has variables \( x \) on the diagonal and zero elsewhere, \( \varepsilon^i_{xy} = \frac{\partial x^i}{\partial y} \) indicates the matrix of elasticities of \( x \) with respect to \( y \) in equilibrium \( i \) and \( R^i_{yz} = \frac{\partial^2 R}{\partial z \partial z} = \frac{\partial w}{\partial z} \) is the matrix of second partial derivatives of the revenue function with respect to \( v \) and \( z \) in equilibrium \( i \). Equation (1.19) can be written in a growth format as:

\[
\frac{dw}{dt} = R_{vp} \frac{dp}{dt} + R_{ev} \frac{dv}{dt} + R_{vt} \\
W^{-1} \frac{dw}{dt} = W^{-1} \frac{\partial w}{\partial P} P \left( p^{-1} \frac{dp}{dt} \right) + W^{-1} \frac{\partial w}{\partial V} V \left( V^{-1} \frac{dv}{dt} \right) + W^{-1} \frac{\partial w}{\partial t} \\
\hat{w} = \varepsilon_{wp} \hat{p} + \varepsilon_{wv} \hat{v} + \varepsilon_{wt} \\
\text{(1.1B)}
\]

the growth rate of factor rewards in Trade Equilibrium (\( \hat{w} \)) depends linearly on the product of the growth rate of product prices (\( \hat{p} \)) and the elasticity of factor reward with respect to product prices (\( \varepsilon_{wp} \)), the product of the growth rate of Trade Equilibrium endowments (\( \hat{v} \)) and the elasticity of factor reward with respect to endowments (\( \varepsilon_{wv} \)) and the elasticity of factor reward with respect to technological change (\( \varepsilon_{wt} \)). Equation (1.1B) is equivalent to the growth format of the Stolper-Samuelson relationship with endowment and technological change. In the case that non-jointness in output quantities is assumed (\( R_{vv} = 0 \)), then the elasticity of factor reward with respect to endowments is also equal to zero (\( \varepsilon_{wv} = 0 \)) and equation (1.1B) reduces to:

\[
\hat{w} = \varepsilon_{wp} \hat{p} + \varepsilon_{wt} \\
\text{(1.1B2)}
\]

which is the equivalent of equation (1.20) expressed in growth rates. Equation (1.1B2) states that the growth rate of factor rewards in TE depends on the growth of product prices, factor reward elasticity of product prices and factor reward elasticity with respect to technology.

Similarly, from the relationship \( w^e = R^e_v (p, v^e, t) \) and the fact that in EAE product prices (\( p \)) depend on on EAE endowments (\( v^e \)) and technology (\( t \)) I get that \( w^e = \)
Differentiating this with respect to time and then rearranging I get:

\[
\frac{dw^e}{dt} = R^e_{vp} \left( \frac{\partial p}{\partial v^e} \frac{dv^e}{dt} + \frac{\partial p}{\partial t} \right) + R^e_{vt} \frac{dv^e}{dt} + R^e_{vt}
\]

\[
[W^e]^{-1} \frac{dw^e}{dt} = [W^e]^{-1} \frac{\partial w^e}{\partial p} P \left( P^{-1} \frac{\partial p}{\partial v^e} V^e \left( [V^e]^{-1} \frac{dv^e}{dt} \right) + P^{-1} \frac{\partial p}{\partial t} \right) + [W^e]^{-1} \frac{\partial w^e}{\partial v^e} V^e \left( [V^e]^{-1} \frac{dv^e}{dt} \right) + [W^e]^{-1} \frac{\partial w^e}{\partial t}
\]

\[
\hat{w} = \left( \varepsilon_{we}^e \varepsilon_{pv}^w + \varepsilon_{we}^t \right) \hat{v}^e + \varepsilon_{we}^p \varepsilon_{pt}^e + \varepsilon_{we}^t (1.83)
\]

which corresponds to equation (1.26) and says that the growth of factor rewards in EAE depends on the product of the growth of EAE endowments times \( \left( \varepsilon_{we}^e \varepsilon_{pv}^w + \varepsilon_{we}^t \right) \) and the sum of elasticities \( \varepsilon_{we}^p \varepsilon_{pt}^e + \varepsilon_{we}^t \). Hence, the growth rate of wages in the EAE depends on the growth rate of endowments and also on exogenous and endogenous technological change.

Rearranging equation (1.22) and solving for \( \hat{v}^e \) I get:

\[
\hat{v}^e = [V^e]^{-1} V \hat{v} - [V^e]^{-1} F \hat{f}
\]

(1.84)

which is an identity and originates from the definition of the FCT in equation (1.19).

Then expressing equation (1.25) in a growth format I have:

\[
\frac{dw}{dt} = \frac{1}{2} (R^e_{vo} + R^e_{vt}) \frac{df}{dt} + \frac{dw^e}{dt}
\]

\[
W^{-1} \frac{dw}{dt} = \frac{1}{2} \left( [W^e]^{-1} \left( \frac{\partial w}{\partial v} \right)^* V V^{-1} + W^e (W^e)^{-1} \left( \frac{\partial w}{\partial v} \right)^* V^e (V^e)^{-1} \right) F F^{-1} \frac{df}{dt} + W^{-1} W^e [W^e]^{-1} \frac{dw^e}{dt}
\]

\[
\hat{w} = \frac{1}{2} \left( [W^e]^{-1} \varepsilon_{we}^e V^{-1} + W^e \varepsilon_{we}^e (V^e)^{-1} \right) F \hat{f} + W^{-1} W^e \hat{w}^e
\]

(1.85)

which states that the difference in the growth rates of wages between the trade equilibrium and the EAE is equal to a weighted average of the growth rate of the FCT.
Substituting equations (1.54) and (1.53) into equation (1.55) and rearranging I get:

$$\tilde{w} = W^{-1}W^e (\varepsilon_{wp}^e \varepsilon_{pu}^e + \varepsilon_{wu}^e) [V^e]^{-1} V^e + \left[\frac{1}{2}W^{-1} (W\varepsilon_{wu}^e V^{-1} + W^e \varepsilon_{wu}^e [V^e]^{-1}) F - W^{-1}W^e (\varepsilon_{wp}^e \varepsilon_{pu}^e + \varepsilon_{wu}^e) [V^e]^{-1} F \right] \hat{f} + W^{-1}W^e \varepsilon_{wp}^e \varepsilon_{pt}^e + W^{-1}W^e \varepsilon_{wt}^e$$

(1.B6)

this is equivalent to equation (1.27) expressed in growth format. It involves the growth rate of TE endowments, the growth rate of FCT and the effect of technological change. Assume now the case that the technology is no-joint in output quantities ($R_{vv}^e = \varepsilon_{wu}^e = 0$) and that there is neither growth in TE endowments ($\tilde{\nu} = 0$) nor technological change ($\varepsilon_{pt}^e = \varepsilon_{wt}^e = 0$). Then, factor rewards in both equilibria are going to be the same ($w = \tilde{w}^e$) and consequently their growth rates are going to be the same ($\tilde{w} = \tilde{w}^e$) and equal to the following expression:

$$\tilde{w} = \tilde{w}^e = -\varepsilon_{wp}^e \varepsilon_{pu}^e [V^e]^{-1} F \hat{f}$$

(1.B7)

This is the FCT Effect From Prices. Under all the above assumptions, the growth rate of factor rewards in TE depends on the growth rate and level of FCT, the level of EAE endowments, the elasticity of factor rewards with respect to product prices and the elasticity of product prices with respect to EAE endowments. The FCT Effect From Jointness is equal to the whole expression on the second line in equation (1.56), the total FCT Effect, minus the FCT Effect From Prices, equation (1.B7):

$$\frac{1}{2}W^{-1} (W\varepsilon_{wu}^e V^{-1} + W^e \varepsilon_{wu}^e [V^e]^{-1}) F - W^{-1}W^e \varepsilon_{wu}^e [V^e]^{-1} F \hat{f}$$

(1.B8)

this is the effect of the FCT on the growth of factor rewards that arises due to the more general technology that allows production to be non-joint in output quantities. While the expression on the third line in equation (1.B6), $W^{-1}W^e \varepsilon_{wp}^e \varepsilon_{pt}^e + W^{-1}W^e \varepsilon_{wt}^e$, is the total Technology Effect. The first part of that expression, $W^{-1}W^e \varepsilon_{wp}^e \varepsilon_{pt}^e$, represents the Endogenous Technological Change Effect and the second part, $W^{-1}W^e \varepsilon_{wt}^e$, is the Exogenous Technological Change Effect.
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<td>Non-jointness</td>
<td>Wald(2)=29.1</td>
<td>5.991</td>
</tr>
<tr>
<td>No technological change</td>
<td>Wald(2)=98</td>
<td>5.991</td>
</tr>
</tbody>
</table>

\[19\] These are the estimates of the parameters that appear in equation (1.15) of the revenue function. The $a_{ih}$ parameters determine the convexity of the revenue function and also the linear homogeneity with respect to product prices. Similarly, the $b_{jk}$ parameters determine the concavity of the revenue function and also the linear homogeneity with respect to endowments. The $c_{ij}$ parameters affect the sign and magnitude of the cross elasticities between outputs and endowments. Finally, the parameters $h_{t}$ and $h_{u}$ capture the linear and quadratic effects of technological change proxied by time.
Table 1.3: Price Elasticities of Output Supply ($\varepsilon_{ih}$)
(Mean values, Std. Error in parenthesis)

<table>
<thead>
<tr>
<th>Quantity</th>
<th>$\varepsilon_{iE}$</th>
<th>$\varepsilon_{iH}$</th>
<th>$\varepsilon_{iN}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Exportable</td>
<td>0.316</td>
<td>-0.217</td>
<td>-0.010</td>
</tr>
<tr>
<td></td>
<td>(1.103)</td>
<td>(0.543)</td>
<td>(0.598)</td>
</tr>
<tr>
<td>Importable</td>
<td>-0.515</td>
<td>0.353</td>
<td>0.162</td>
</tr>
<tr>
<td></td>
<td>(1.291)</td>
<td>(0.669)</td>
<td>(0.780)</td>
</tr>
<tr>
<td>Non-tradable</td>
<td>-0.241</td>
<td>0.165</td>
<td>0.076</td>
</tr>
<tr>
<td></td>
<td>(1.449)</td>
<td>(0.796)</td>
<td>(0.659)</td>
</tr>
</tbody>
</table>

Table 1.4: Quantity Elasticities of Inverse Input Demand ($\varepsilon_{w_jv_k}$)
(Mean values, Std. Error in parenthesis)

<table>
<thead>
<tr>
<th>Factor Reward</th>
<th>Capital</th>
<th>Skilled labour</th>
<th>Unskilled labour</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\varepsilon_{w_jv_K}$</td>
<td>$\varepsilon_{w_jv_S}$</td>
<td>$\varepsilon_{w_jv_U}$</td>
<td></td>
</tr>
<tr>
<td>Capital</td>
<td>-1.180</td>
<td>0.705</td>
<td>0.475</td>
</tr>
<tr>
<td></td>
<td>(0.482)</td>
<td>(0.277)</td>
<td>(0.254)</td>
</tr>
<tr>
<td>Skilled labour</td>
<td>0.331</td>
<td>-0.197</td>
<td>-0.133</td>
</tr>
<tr>
<td></td>
<td>(0.130)</td>
<td>(0.088)</td>
<td>(0.058)</td>
</tr>
<tr>
<td>Unskilled labour</td>
<td>0.766</td>
<td>-0.457</td>
<td>-0.309</td>
</tr>
<tr>
<td></td>
<td>(0.411)</td>
<td>(0.201)</td>
<td>(0.224)</td>
</tr>
</tbody>
</table>
Table 1.5: Quantity & Techn. Change Elasticities
Of Inverse Inputs Demands in The EAE ($\varepsilon_{w_{ik}}^e$ & $\varepsilon_{w_{it}}^e$)
(Mean values, Std. Error in parenthesis)

<table>
<thead>
<tr>
<th>Factor Reward</th>
<th>Capital</th>
<th>Skilled labour</th>
<th>Unskilled labour</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$\varepsilon_{w_{ik}^{e}}$</td>
<td>$\varepsilon_{w_{ik}^{S}}$</td>
<td>$\varepsilon_{w_{ik}^{U}}$</td>
</tr>
<tr>
<td>Capital</td>
<td>-0.397</td>
<td>0.062</td>
<td>0.334</td>
</tr>
<tr>
<td></td>
<td>(0.051)</td>
<td>(0.043)</td>
<td>(0.045)</td>
</tr>
<tr>
<td>Skilled labour</td>
<td>0.039</td>
<td>-0.009</td>
<td>-0.031</td>
</tr>
<tr>
<td></td>
<td>(0.029)</td>
<td>(0.010)</td>
<td>(0.020)</td>
</tr>
<tr>
<td>Unskilled labour</td>
<td>0.831</td>
<td>-0.150</td>
<td>-0.681</td>
</tr>
<tr>
<td></td>
<td>(0.407)</td>
<td>(0.139)</td>
<td>(0.295)</td>
</tr>
</tbody>
</table>

Table 1.6: Price Elasticities of Inverse
Input Demand in The EAE ($\varepsilon_{w_{j}}^{e}$)
(Mean values, Std. Error in parenthesis)

<table>
<thead>
<tr>
<th>Price</th>
<th>Exportable</th>
<th>Importable</th>
<th>Non-tradable</th>
</tr>
</thead>
<tbody>
<tr>
<td>Factor Reward</td>
<td>$\varepsilon_{w_{j}P}^e$</td>
<td>$\varepsilon_{w_{j}I}^e$</td>
<td>$\varepsilon_{w_{j}N}^e$</td>
</tr>
<tr>
<td>Capital</td>
<td>0.841</td>
<td>0.042</td>
<td>0.116</td>
</tr>
<tr>
<td></td>
<td>(0.030)</td>
<td>(0.018)</td>
<td>(0.012)</td>
</tr>
<tr>
<td>Skilled labour</td>
<td>-0.056</td>
<td>0.569</td>
<td>0.487</td>
</tr>
<tr>
<td></td>
<td>(0.058)</td>
<td>(0.040)</td>
<td>(0.023)</td>
</tr>
<tr>
<td>Unskilled labour</td>
<td>1.997</td>
<td>-0.329</td>
<td>-0.668</td>
</tr>
<tr>
<td></td>
<td>(0.698)</td>
<td>(0.279)</td>
<td>(0.420)</td>
</tr>
<tr>
<td>Year</td>
<td>$f_s$</td>
<td>$f_u$</td>
<td>$v_s$</td>
</tr>
<tr>
<td>------</td>
<td>-------</td>
<td>-------</td>
<td>-------</td>
</tr>
<tr>
<td>1965</td>
<td>-9,894</td>
<td>-20,454</td>
<td>87,416</td>
</tr>
<tr>
<td>1966</td>
<td>-11,087</td>
<td>-24,001</td>
<td>95,779</td>
</tr>
<tr>
<td>1967</td>
<td>-10,465</td>
<td>-21,777</td>
<td>105,545</td>
</tr>
<tr>
<td>1968</td>
<td>-11,799</td>
<td>-27,548</td>
<td>107,833</td>
</tr>
<tr>
<td>1969</td>
<td>-10,811</td>
<td>-25,357</td>
<td>112,674</td>
</tr>
<tr>
<td>1970</td>
<td>-10,335</td>
<td>-24,665</td>
<td>117,119</td>
</tr>
<tr>
<td>1971</td>
<td>-11,783</td>
<td>-31,995</td>
<td>111,391</td>
</tr>
<tr>
<td>1972</td>
<td>-12,695</td>
<td>-35,470</td>
<td>108,780</td>
</tr>
<tr>
<td>1973</td>
<td>-16,021</td>
<td>-35,343</td>
<td>116,096</td>
</tr>
<tr>
<td>1974</td>
<td>-26,023</td>
<td>-49,092</td>
<td>127,452</td>
</tr>
<tr>
<td>1975</td>
<td>-20,951</td>
<td>-35,356</td>
<td>128,089</td>
</tr>
<tr>
<td>1976</td>
<td>-17,031</td>
<td>-38,029</td>
<td>116,340</td>
</tr>
<tr>
<td>1977</td>
<td>-25,190</td>
<td>-50,266</td>
<td>124,090</td>
</tr>
<tr>
<td>1978</td>
<td>-28,816</td>
<td>-54,606</td>
<td>130,304</td>
</tr>
<tr>
<td>1979</td>
<td>-24,694</td>
<td>-44,582</td>
<td>141,359</td>
</tr>
<tr>
<td>1980</td>
<td>-20,999</td>
<td>-38,364</td>
<td>149,267</td>
</tr>
<tr>
<td>1981</td>
<td>-26,920</td>
<td>-49,270</td>
<td>144,607</td>
</tr>
<tr>
<td>1982</td>
<td>-23,461</td>
<td>-48,191</td>
<td>147,143</td>
</tr>
<tr>
<td>1983</td>
<td>-20,162</td>
<td>-55,187</td>
<td>139,791</td>
</tr>
<tr>
<td>1984</td>
<td>-35,637</td>
<td>-83,273</td>
<td>143,587</td>
</tr>
<tr>
<td>1985</td>
<td>-37,077</td>
<td>-83,727</td>
<td>154,355</td>
</tr>
<tr>
<td>1986</td>
<td>-44,050</td>
<td>-96,889</td>
<td>157,080</td>
</tr>
<tr>
<td>1987</td>
<td>-40,198</td>
<td>-93,058</td>
<td>155,780</td>
</tr>
<tr>
<td>1988</td>
<td>-36,831</td>
<td>-85,636</td>
<td>157,651</td>
</tr>
<tr>
<td>1989</td>
<td>-36,929</td>
<td>-78,954</td>
<td>164,882</td>
</tr>
<tr>
<td>1990</td>
<td>-40,781</td>
<td>-79,476</td>
<td>167,120</td>
</tr>
<tr>
<td>1991</td>
<td>-32,498</td>
<td>-68,480</td>
<td>167,067</td>
</tr>
</tbody>
</table>
Table 1.8: Parameter Estimates from Growth Equations

<table>
<thead>
<tr>
<th>Parameter $E$</th>
<th>Estimate</th>
<th>t-stat</th>
<th>Parameter $I$</th>
<th>Estimate</th>
<th>t-stat</th>
</tr>
</thead>
<tbody>
<tr>
<td>$a_E$</td>
<td>0.069</td>
<td>6.607</td>
<td>$\beta_{IS}$</td>
<td>0.446</td>
<td>-2.260</td>
</tr>
<tr>
<td>$\beta_{EK}$</td>
<td>-0.208</td>
<td>-1.743</td>
<td>$\beta_{IU}$</td>
<td>-0.308</td>
<td>-1.473</td>
</tr>
<tr>
<td>$\beta_{ES}$</td>
<td>0.288</td>
<td>2.108</td>
<td>$a_N$</td>
<td>0.071</td>
<td>6.670</td>
</tr>
<tr>
<td>$\beta_{EU}$</td>
<td>-0.274</td>
<td>-1.889</td>
<td>$\beta_{NK}$</td>
<td>-0.191</td>
<td>-1.562</td>
</tr>
<tr>
<td>$a_I$</td>
<td>0.076</td>
<td>5.011</td>
<td>$\beta_{NS}$</td>
<td>0.269</td>
<td>1.919</td>
</tr>
<tr>
<td>$\beta_{IK}$</td>
<td>-0.227</td>
<td>-1.312</td>
<td>$\beta_{NU}$</td>
<td>-0.238</td>
<td>-1.601</td>
</tr>
</tbody>
</table>

Syst. $R^2$: 0.99

Table 1.9: Factor Rewards Decomposition (Annual growth rates)

<table>
<thead>
<tr>
<th>Period</th>
<th>Fitted Growth</th>
<th>FCT Effect</th>
<th>Endowment Effect</th>
<th>Technology Effect</th>
</tr>
</thead>
<tbody>
<tr>
<td>Capital</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1967-1981</td>
<td>3.63</td>
<td>-4.84</td>
<td>-10.01</td>
<td>18.48</td>
</tr>
<tr>
<td>1982-1991</td>
<td>0.53</td>
<td>2.79</td>
<td>-18.34</td>
<td>16.08</td>
</tr>
<tr>
<td>1967-1991</td>
<td>2.38</td>
<td>-1.79</td>
<td>-13.35</td>
<td>17.52</td>
</tr>
<tr>
<td>Skilled labour</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1967-1981</td>
<td>9.17</td>
<td>2.75</td>
<td>-0.11</td>
<td>6.53</td>
</tr>
<tr>
<td>1982-1991</td>
<td>3.62</td>
<td>2.23</td>
<td>-3.00</td>
<td>4.39</td>
</tr>
<tr>
<td>1967-1991</td>
<td>6.95</td>
<td>2.54</td>
<td>-1.27</td>
<td>5.68</td>
</tr>
<tr>
<td>Unskilled labour</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1967-1981</td>
<td>8.44</td>
<td>4.47</td>
<td>2.46</td>
<td>1.51</td>
</tr>
<tr>
<td>1982-1991</td>
<td>2.16</td>
<td>1.62</td>
<td>1.57</td>
<td>-1.03</td>
</tr>
<tr>
<td>1967-1991</td>
<td>5.93</td>
<td>3.33</td>
<td>2.10</td>
<td>0.50</td>
</tr>
</tbody>
</table>

The FCT Effect, Endowment Effect and Technology Effect are given by the expressions on the second, first and third line respectively in equation (1.B6).
Table 1.10: \textit{FCT Effect Further Decomposition}
(Annual growth rates)

<table>
<thead>
<tr>
<th>Period</th>
<th>\textit{FCT} Effect</th>
<th>From Jointness</th>
<th>From Product Prices</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Capital</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1967-1981</td>
<td>-4.84</td>
<td>-5.79</td>
<td>0.95</td>
</tr>
<tr>
<td>1982-1991</td>
<td>2.79</td>
<td>1.01</td>
<td>1.78</td>
</tr>
<tr>
<td>1967-1991</td>
<td>-1.79</td>
<td>-3.07</td>
<td>1.28</td>
</tr>
<tr>
<td><strong>Skilled labour</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1967-1981</td>
<td>2.75</td>
<td>2.33</td>
<td>0.42</td>
</tr>
<tr>
<td>1982-1991</td>
<td>2.23</td>
<td>1.67</td>
<td>0.56</td>
</tr>
<tr>
<td>1967-1991</td>
<td>2.54</td>
<td>2.07</td>
<td>0.47</td>
</tr>
<tr>
<td><strong>Unskilled labour</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1967-1981</td>
<td>4.47</td>
<td>4.28</td>
<td>0.19</td>
</tr>
<tr>
<td>1982-1991</td>
<td>1.62</td>
<td>1.44</td>
<td>0.18</td>
</tr>
<tr>
<td>1967-1991</td>
<td>3.33</td>
<td>3.14</td>
<td>0.19</td>
</tr>
</tbody>
</table>

The \textit{FCT Effect From Product Prices} and the \textit{FCT Effect From Jointness} are given by equation (1.67) and (1.68), respectively.
Table 1.11: Technology Effect Further Decomposition

(Annual growth rates)

<table>
<thead>
<tr>
<th>Period</th>
<th>Technology Effect</th>
<th>Endogenous</th>
<th>Exogenous</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Capital</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1967-1981</td>
<td>18.48</td>
<td>14.30</td>
<td>4.18</td>
</tr>
<tr>
<td>1982-1991</td>
<td>16.08</td>
<td>11.10</td>
<td>4.98</td>
</tr>
<tr>
<td>1967-1991</td>
<td>17.52</td>
<td>13.02</td>
<td>4.50</td>
</tr>
<tr>
<td></td>
<td>Skilled labour</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1967-1981</td>
<td>6.53</td>
<td>6.40</td>
<td>0.13</td>
</tr>
<tr>
<td>1982-1991</td>
<td>4.39</td>
<td>4.18</td>
<td>0.21</td>
</tr>
<tr>
<td>1967-1991</td>
<td>5.68</td>
<td>5.51</td>
<td>0.17</td>
</tr>
<tr>
<td></td>
<td>Unskilled labour</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1967-1981</td>
<td>1.51</td>
<td>3.42</td>
<td>-1.91</td>
</tr>
<tr>
<td>1982-1991</td>
<td>-1.03</td>
<td>0.47</td>
<td>-1.50</td>
</tr>
<tr>
<td>1967-1991</td>
<td>0.50</td>
<td>2.25</td>
<td>-1.75</td>
</tr>
</tbody>
</table>

The Endogenous and the Exogenous Technological Effect are equal to $W^{-1}W^e\varepsilon_{wp}^e$ and $W^{-1}W^e\varepsilon_{wat}^e$, respectively.
Figure 1.1: Trade and Equivalent Equilibria

Figure 1.2: Factor Content of Capital ($f_K$), Factor Content of Skilled Labour ($f_s$) and Factor Content of Unskilled Labour ($f_u$) in billion of USD 1970 factor rewards.
Figure 1.3: Endowments of capital ($v_k$), skilled labour ($v_s$) and unskilled labour ($v_u$) in billion of USD 1970 factor rewards.

Figure 1.4: Normalised factor rewards for capital ($w_k$), skilled labour ($w_s$) and unskilled labour ($w_u$), base year 1970.
Figure 1.5: Adjusted Volume of Net Exports of the exportable ($T_E$), importable ($T_I$) and the non-tradable ($T_N$) in billion of USD 1970 product prices.
References


Centre for International Data at UC Davis.


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CHAPTER II

THE CAUSAL EFFECT OF EXPORTING AND MULTINATIONAL ACQUISITIONS ON TOTAL FACTOR PRODUCTIVITY IN THE UK.

2.1 Introduction

During the last two decades the UK has become one of the most globally integrated economies in the world. There are many aspects of this phenomenon in the UK economy, but two can be considered as the most important. The first is the rapid expansion of UK's international trade with other countries\(^{20}\). The second is the growing activities and importance of Multinational Enterprises (MNEs) within the UK and in particular the increase of Foreign Direct Investment (FDI)\(^{21}\). The effects of increased trade and FDI have raised numerous discussions among the public and the academic community with regard to the benefits and losses for national economies. In this chapter the discussion will focus on the UK economy and the question whether the decision of a British firm to become an exporter or the acquisition of a British firm by a multinational company affects its productivity.

There is already a vast literature that tries to assess the exporting decision versus productivity question, see for example Clerides et al. (1998), Bernard and Jensen (1999) and Girma et al. (2004). The main question that is addressed in this body of literature is whether the decision of a firm to export leads to better performance. In particular there are two main hypotheses under investigation: i) the learning by exporting (LBE) hypothesis and ii) the self selection hypothesis. The first suggests

\(^{20}\)2.64% annual increase for total trade in constant prices for the period 1960-2003 (OECD, Historical International Trade by Commodities, 1961-1990, 1991-2003.)

\(^{21}\)$28 billion of inward FDI inflow on average per year over the period 1981-2004 (OECD, International Direct Investment Statistics Yearbook, 2006).
that when a firm enters the export market it becomes more productive due to higher competition and by accumulating knowledge from a potentially more advanced market. The second hypothesis claims that future exporters experience an increase in their productivity some time before exporting takes place, since they have to be able to cover sunk costs in order to enter the foreign market.

From an econometric perspective, it is clear that there is a problem of causality. Do exporters become more productive or is it that more productive firms enter foreign markets? Many different approaches have been implemented in order to tackle the causality problem and different results were obtained. For example, Clerides et al. (1998) used full information maximum likelihood and generalised method of moments estimators on a panel of Colombian, Mexican and Moroccan firms and found that there is no learning by exporting\(^{22}\) and that exporters self select. Similar results were obtained by Bernard and Jensen (1999) on a much larger unbalanced panel of US plants, but without looking for causal effects. On the other hand, Girma et al. (2004) implemented a difference in difference approach in an unbalanced panel of matched UK firms and found that both self selection and learning by exporting exist.

Similar to the literature on the decision to export and productivity, research on the theory of FDI is voluminous and dates back at least three decades\(^{23}\). One of the first attempts was by Dunning (1977, 1981)\(^{24}\), who stated that a multinational firm should be superior to local firms in order to enter the domestic market due to costs of entry. Dunning specified this superiority in terms of three advantages a multinational should possess in order to be able to undertake FDI. These are: i) an ownership advantage, ii) a location advantage and iii) an internalisation advantage. The ownership advantage refers to exclusive product or production practices like patents or R&D. The location advantage is related to trade restrictions, such as tariffs and quotas, transportation cost and lower labour cost at the host country. The internalisation advantage refers to the fact that firm specific practices and technologies are better transferred within the

\(^{22}\)with the exception of Moroccan firms.

\(^{23}\)for early studies see Kindleberger (1969) and Hymer (1976).

\(^{24}\)see Markusen 1995 for a summary.
same company rather than by licensing. Hence, the ability of the MNE to transfer its advanced technology to its subsidiary could lead to better performance in terms of total factor productivity for the newly acquired firm.

Recently, a new stream of the literature has tried to integrate the two existing theoretical frameworks discussed above by formulating a model where a firm can choose the mode of entry in a foreign market, either by exporting or undertaking FDI and the importance of firm productivity differences. Helpman et al. (2004) construct a model in which firms can serve a market abroad by exporting or horizontal FDI, similar to the proximity-concentration literature (see Krugman, 1983, Horstmann and Markusen, 1992, Brainard, 1993, and Markusen and Venables, 2000), that allows for firm heterogeneity in productivity. Firms choose to undertake FDI, if trade costs are higher than the cost of acquiring or building and maintaining a plant abroad. Helpman et al. show that there is a clear partition of firms with respect to their productivity and the mode of serving a foreign market. The most productive firms will engage into FDI, while the next most productive firms will export and the least productive firms will just sell in the domestic market. This result seems to be consistent with empirical evidence in the case of UK (Girma et al., 2005) and for the case of Japan (Head and Ries, 2003).

In this chapter, following on the recent theoretical literature on exports versus FDI and productivity and the empirical research on the causal effect of exporting on productivity, I try to assess the causal effect of the exporting decision or acquisition by MNEs on the Total Factor Productivity (TFP) growth of British firms for the period 1990-1996. For that reason, I extend the single treatment approach followed by Girma et al. (2004) and Wagner (2002), allowing for an additional treatment. This additional treatment is the possible outcome that a local firm is acquired by a multinational. More specifically, using a multiple treatment approach based on the literature on evaluation methods, Blundell and Costa Dias (2000), Frolich (2004), Lechner (2001) and (2002) and Heckman and Navarro-Lozano (2004), I will try to assess the following causal effects

on TFP for British firms for the period 1990-1996: i) becoming an exporter relative to remaining a domestic producer, ii) being acquired by an MNE relative to remaining domestic producer and iii) becoming an exporter relative to being acquired by an MNE.

I find that British exporters are more productive than British firms selling only domestically. Exporters appear to be more productive relative to domestic producers by 7.79% to 8.79% one year after they became exporters. This finding is similar with the results obtained in other studies, see for example Girma et al. (2004) for the UK, Alvarez and Lopez (2005) for Chile and Wagner (2002) for Germany. I also find that British firms acquired by MNEs experience higher TFP growth one year after acquisition than domestic sellers. They gain between eleven to thirteen percentage points more TFP when compared with domestic producers. This result is similar in terms of sign and magnitude as the one obtained in Conyon et al. (2002) with the solely difference that they look at labour productivity for British firms. Girma and Gorg (2007) also found a positive causal effect, but very small in magnitude in their work for two sectors in British manufacturing. While Harris and Robinson (2002) found that British subsidiaries experience lower TFP growth relative to domestic producers a year after acquisition. Finally, there is evidence that British exporters are less productive when compared to British firms acquired by MNEs. New British exporters have a smaller productivity growth of 8.6 to 9.95 percent one year after they begin to export. This result seems to be in agreement with the argument of Dunning (1977) that MNEs have a superior technology and are able to transfer it to their subsidiaries.

The rest of this chapter is organised as follows. In Section 2.2 I briefly discuss a simple theoretical framework as a way to motivate the empirical question. Sections 2.3 and 2.4 describe econometric issues that arise because of the simultaneity problem and the three causal effects that can be estimated. The control for confounding approach that is used and the necessary conditions in order to identify the counterfactual are discussed in Section 2.5. While Section 2.6 describes the advantages of pair-matching on the propensity score estimator that is implemented to get the causal effect for the
following three cases; a) exporting vs domestic production, b) exporting vs becoming a subsidiary of a MNE and c) being acquired by a MNE vs domestic producers. In addition, it discusses the extensions of the propensity score matching estimator that permit for bias correction when not exact matching is present and when heteroscedastic variances are allowed for different treatments. Section 2.7 offers a detailed description of the original data and the steps followed to construct the final sample. In Section 2.8, I present and discuss the results for the Multinomial Logit and the Average Treatment Effect for the Treated estimates obtained when the condition of Common Support is imposed and for the whole sample, respectively. Furthermore, the validity of the Irrelevant Independence Alternatives assumption and the Common Support condition are tested and discussed. Finally, Section 2.9 offers a detailed conclusion of the results and discuss their implications.

2.2 Theoretical Background

One of the first papers that addressed the question of the determinants on the decision to export and also the self-selection hypothesis is by Roberts and Tybout (1997). The work of Roberts and Tybout (1997) is based on the "the sunk-cost hysteresis hypothesis" developed by Baldwin (1989), Dixit (1989) and Krugman (1989). Roberts and Tybout developed a dynamic binary choice model in an attempt to explain persistent export status. In their model sunk costs differ between new entrants and firms that re-enter the export market and there is a cost of exit. The current decision of a firm to export depends on the history of the export status, the initial sunk cost and any cost of past exit and re-entry. A firm will decide to export if its current and expected discounted gains from exporting are greater than the original cost of entry plus any costs of exit and re-entry. They assume that the latent variable current and expected profits from exporting minus costs can be approximated by a reduced form equation of exogenous
firm characteristics, time dummies, last year's export status, the history of export status and noise.

They use plant level data in manufacturing with at least 10 employees from the Colombian manufacturing census from 1981 to 1989 and estimate the model by implementing Keane's (1994) Method of Simulated Moments to panel data. They found that sunk costs do affect the decision to export but this impact is decreasing over time and after two years of absence from exporting there is no difference in the sunk costs of new entrants and firms that re-enter. Plants that are large, older and owned by corporations have a higher probability to export. Unobserved heterogeneity leads to higher probability to export and industry shocks have an ambiguous effect.

In another paper Clerides et al (1998) try to shed light on the direction of causality between exporting and productivity and also to test whether learning by exporting is present. They developed a theoretical model similar to the one by Roberts and Tybout with the difference that they model learning by exporting. In their theoretical model, they assume monopolistic competition and that firms potentially could face two different downward sloping demand equations. They further assume that marginal cost is fixed and consequently current gross profits can be presented as a function of demand conditions and marginal cost in the domestic and foreign market. Then they discuss the case, where apart from a per period fixed cost there is also a sunk cost of entry into the exporting market, which results to a dynamic model where firms are forward looking. In particular, their model assumes that the cost function at the time \( t \) is a function of the set of exogenous variables that could potentially alter the cost level, like wages, the one year lagged value of cost and the one year lagged value of exporting status.

They use data on inputs, outputs, export levels and costs at plant level for Colombia, Mexico and Morocco for different time period ranging from 1981 to 1991. Simulations of the marginal costs trajectories, after controlling for industry and plant-specific char-

\textsuperscript{26}They assume that expected future gains from exporting include any positive externalities from learning by exporting.
acteristics, showed that there is no evidence of learning by exporting with the only exception in few Colombian plants. Their results indicate that plants with lower marginal cost have higher probability to export. Previous export status appears to be important and especially the last year's status increases the likelihood of exporting but this affect dies out as time passes. On the contrary past export status does not significantly affect marginal cost and hence there is no evidence for learning by exporting.

In the two papers mentioned above a firm can sell in a foreign market only by exports, there is no any other way to service the foreign market. Brainard (1993) in her proximity-concentration model allows firms to choose between two different ways of servicing a foreign market: a) by exporting or b) by building a plant in the foreign market. Her model assumes two countries and two sectors, where firms produce a homogeneous good and a differentiated one. The homogeneous good sector is characterised by constant returns to scale, while firms in the differentiated good sector operate in a Chamberlinian monopolistic environment with increasing returns to scale. As a result, firms have an incentive to concentrate production in the differentiated good sector, because in such a scenario unit cost will be reduced. It is also assumed that firms have to pay a fixed cost in order to produce, which reflects the cost of building a plant. At the same time exporting incurs a per unit cost related to trade impediments, which in addition is also increasing in distance. Firms choose between producing abroad and exporting by comparing the extra variable cost of exporting to the extra fixed cost of setting up a plant abroad. Brainard (1993) finds that there are three possible equilibria where: 1) all firms have plants in both countries and they do not export, 2) all firms have a plant in the home country only and export to the foreign market and 3) some firms have plants in both markets and the rest of the firm produce only at home at export abroad. The first equilibrium occurs, when trade impediments are high and the fixed cost of setting up a plant abroad is relatively low, while the second equilibrium occurs, when the above reasoning is reversed. The third equilibrium occurs, when trade barriers and transportation cost do not differ a lot.
A theoretical framework similar to a type of proximity-concentration trade-off model is needed in order to describe the setup of my research question. In particular, I assume that firms operate within a dynamic monopolistic competition environment, are initially producing and selling only into the domestic market and then have the possibility to choose between three different alternative states. They can decide to: i) remain domestic producers, ii) become exporters or iii) become subsidiaries of MNEs. The difference between this setup to other theoretical models, like Helpman et al. (2004), lays in the fact that I look at the case where a firm is the recipient of FDI rather than being the investor. As in similar models there are benefits and costs associated to the three decisions of the firm. A profit maximising firm will choose one of the three alternatives, only if its current and future discounted revenues from such a choice are higher than the cost.

First, consider the decision of a firm to export compared to a situation where it sells only at home. The cost of such a decision consists mainly of trade restrictions (tariffs), transportation cost and sunk costs of exporting (product alteration). The benefit is the additional revenues that arise from increased sales or the presence of economies of scale. Hence, a firm will decide to export if the expected discounted gains from exporting are greater than the cost of entry into the foreign market, as in the model of Roberts and Tybout (1997).

Second, a firm faces the choice to accept the offer of a MNE to become its subsidiary relative to remaining a domestic producer. The gains associated with such a decision are mainly financial and more specifically the amount offered by the MNE for the acquisition. While the cost is the loss of ownership and is related to the market value of firm plus the present value of any future revenues. In addition, assume that the domestic firm faces uncertainty in the market that it operates, which affects its future profits. Hence, the local firm will choose to become a subsidiary of a multinational if the
monetary reward is higher than its present market value and future profits (adjusted for uncertainty)\textsuperscript{27}. Similarly, the decision of the domestic firm between exporting and being a subsidiary of a MNE depends on the net gains from exporting compared to the net gains of becoming affiliated to a multinational. If the former is higher than the latter then the firm decides to export and vice versa.

In an environment like this, an increase in the fixed cost of exporting will lead to a situation in which there are less exporters and more of domestic producers and firms acquired by MNEs. While a fall in uncertainty will result in less companies to be acquired by MNEs and more companies exporting and selling domestically. This is a rather simple theoretical background, it is definitely not a model and its main purpose is to motivate the empirical question and discussion.

\textbf{2.3 Econometric Issues}

This chapter tries to assess the effect of a change in the status of British firms on their total factor productivity growth. In particular, the focus lays on the estimation of the causal differences on the TFP growth for a British firm that is producing only for the domestic market and is becoming either an exporter or is acquired by a multinational company. As it was discussed earlier, the direction of causality between the decision of a firm to change status and its observed productivity is not clear. More specifically there is a simultaneity problem. Exporters might increase their productivity because they learn from the new market (learning by exporting), but equally exporters might need to experience an increase to their productivity before exporting to the foreign market in order to cover the fixed cost of entry. Similar arguments apply for the case of the acquisition of domestic firms by MNEs. A British firm that becomes the subsidiary

\textsuperscript{27}The multinational that desires to acquire the local firm is willing to pay more than the present market value plus discounted future profits, because it might be cheaper to serve the domestic market this way rather than exporting.
of a MNE could gain in terms of productivity through the superior technology and management of the multinational. While, MNEs might target highly productive British firms for acquisition (cherry picking).

The estimation technique that is followed in this chapter, multiple treatment matching, is trying to address this simultaneity problem embedded in the research question. A simple comparison of the productivities between firms that chose different alternatives, for example an exporter versus a domestic producer, will suffer from estimation bias. The reason is that firms that chose a particular status might have certain characteristics that would have allowed them to experience an increase in TFP, even without a change in their status. The simultaneity problem would cease to exist if there was available information about the potential TFP of those that chose a particular status had they chosen another. For example, the TFP growth that an exporting firm would have experienced had it decided to remain a domestic producer. This is a counterfactual and it is not possible to be observed. But with the use of matching techniques and some assumptions it is possible to identify these causal effects.

There are studies of Girma et al. (2003), Girma et al. (2004) and Wagner (2002) that estimate the differences in TFP growth for exporters and non-exporters in UK and Germany, respectively. Both studies control for the possible endogeneity problem of selection for exporters using matching techniques. Here, I am extending this approach, allowing for an extra "treatment", the possibility that a firm is acquired by a multinational firm. Hence, I follow a multiple treatment approach based on the recent literature on evaluation methods, see Blundell and Costa Dias (2000) for example.
2.4 The Problem of Identification and the Three Causal Effects

2.4.1 Counterfactual and the Stable Unit Treatment Assumption

In the current setup a treatment is defined as the status that a firm has been through from time $t$ to time $t + 1$. Hence, there are three possible treatments. Either becoming an exporter or being acquired by a MNE or remaining a domestic producer. Let $i = 1, \ldots, n$ indicate a firm, let $j = DP, EX, AM$ denotes a treatment, where $DP$ indicates a domestic producer, $EX$ an exporter and $AM$ indicates a subsidiary of a multinational. I assume that a firm is a domestic producer, if it produces and sells its product only in the domestic market. An exporter is defined as a firm that produces and sells domestically, but some of its output is also exported. Both domestic producers and exporters are owned by British firms that are not engaged in multinational activities. While a subsidiary of a MNE produces and sells for the domestic market, but it is owned by a multinational firm.

The treatments should be mutually exhaustive and exclusive. Each firm can have just one of the three statuses at one point in time. This restricts the sample, because we should drop all firms that are subsidiaries of multinationals and exporters at the same time. In addition, only firms that were domestic producers before treatment are considered.\footnote{The reason is that I am interested of estimating the causal effect on TFP growth of either becoming an exporter or a subsidiary of a MNE relative to remaining a domestic producer. In order to do so I exclude from the analysis firms that have been either exporters or subsidiaries in the past.}

Let $Y_{it}^j$ indicate a vector of potential outcomes on a set of performance measures, TFP, for each firm $i$ and treatment $j$ at time $t$. There are three such potential outcomes; $Y_{it}^{DP}, Y_{it}^{EX}$ and $Y_{it}^{AM}$. The first, $Y_{it}^{DP}$, is the outcome that will be observed had the $ith$ firm remained a domestic producer at time $t$, the second, $Y_{it}^{EX}$, is the outcome that will
be observed if firm $i$ had become an exporter at $t$ and finally the last one, $Y_{it}^{AM}$, is the outcome that will be observed if firm $i$ had been acquired by a multinational company.

Before participating in any treatment, all these potential outcomes are latent and are only observed had the firm gone through the treatment. After participation, at time $t+1$, only one of this three potential outcomes is observed, because the firm either remained a domestic producer, or became an exporter or was acquired by a multinational. The rest of the potential outcomes are counterfactual and are not observed. Using statistical techniques that require some assumptions will enable us to identify these counterfactuals and then estimate the causal effects of different treatments.

The first such assumption that needs to be satisfied is the Stable Unit Treatment Value assumption, Rubin (1980), which states that the potential outcomes of a firm should not be influenced by the treatment followed by other firms. Let $\phi_{it}$ be a ternary indicator of the treatment that firm $i$ followed at time $t$.

$$\phi_{it} = \begin{cases} 
0, & \text{if domestic producer (DP)} \\
1, & \text{if exporter (EX)} \\
2, & \text{if acquired by MNE (AM)} 
\end{cases} \quad (2.1)$$

$\phi_{it}$ equal to zero indicates that firm $i$ is a domestic producer at time $t$, when $\phi_{it}$ is equal to one the firm is an exporter and a value of two for $\phi_{it}$ indicates that the firm is a subsidiary of a MNE. Let $\Phi$ be an $n \times 1$ vector that contains each firm’s indicator $\phi_{it}$. $Y$ denotes the observed outcome vector for all firms and $Y(\Phi)$ the potential outcome that will prevail if all firms had followed their treatment according to their indicator $\phi_{it}$. Let $Y_i(\Phi)$ be the potential outcome of the $ith$ firm. Assume that there are two possible treatment allocations for every firm $\Phi$ and $\Phi'$ respectively. Then, the Stable Unit Treatment Value assumption states that

$$Y_i(\Phi) = Y_i\left(\Phi'\right) \quad \text{if} \quad \phi_i = \phi_i' \quad (2.2)$$

which means that the observed outcome for the $ith$ firm depends only on its treatment.
and not on the treatment followed by other firms. This is a strong assumption since it rules out any interaction between firms, like spillovers and other externalities. In the presence of such interactions, it is possible that the outcome variable might also be affected. For example, if there are spillovers between firms then the TFP of domestic firms might change due to a change in the TFP of exporters or firms that were acquired by multinationals. But the magnitude of these kind of effects will be small as long as the participants in the corresponding treatments are small relative to the population of the firms. In the case that there are spillovers between firms, the most likely is that such spillovers will run from exporters or MNEs to domestic firms. Hence, in that case the results obtained in this chapter are probably downwards biased, since I do not account for the fact that part of the productivity of less productive firms (usually domestic producers) is due to the spillovers from the more advanced, highly productive firms (usually exporters and MNEs). There are studies in the labour market programmes evaluation literature, Blanchard and Diamond (1989) and Blanchard and Diamond (1990) for example, that try to estimate the effects in the case that the Stable Unit Treatment Value assumption is not fully satisfied. But such a task is not easy and generates other difficulties for the estimation of the causal effects29.

2.4.2 The Three Causal Effects and a Naive Estimator

There are three possible effects that can be estimated:

a) the Average Treatment Effect (ATE)

\[ E [Y^k - Y^l] \]  

(2.3)

defined as the difference between the outcome expected after following treatment \( k \) and the outcome expected after following treatment \( l \) for a random firm from the entire

\[ ^{29} \text{For more details see Frolich (2004).} \]
population,

b) the Average Treatment on the Treated (ATET)

\[ E [Y^k - Y^i \mid \Phi = k] \]  \hspace{1cm} (2.4)

is similar to the ATE but with the difference that now the firm is selected from the subpopulation of the participants in treatment \( k \), and

c) the Average Treatment Effect on the Non-Treated (ATENT)

\[ E [Y^k - Y^i \mid \Phi = l] \]  \hspace{1cm} (2.5)

which is the difference in the expected outcome between the participants in treatment \( k \) and \( l \), for a firm drawn from the subpopulation of those that participated in treatment \( l \).

The estimate of most interest is the Average Treatment Effect on the Treated, because it provides information about the causal effect on the outcome for those firms that have gone through a particular treatment had they decided to follow another one, instead. For example, the Average Treatment Effect on the Treated for exporters relative to domestic producers, \( E [Y^{EX} - Y^{DP} \mid \Phi = EX] \), tell us what the gain or loss on TFP exporters experienced had they chosen to remain domestic producers. On the other hand, the Average Treatment Effect would have provided an estimate of the causal effect of becoming an exporter relative to remaining domestic producer for the whole population of firms. Hence, the ATE would have included in the estimation those firms that remained either domestic producers or were acquired by MNEs. The interest of this chapter lays on the causal effect on TFP growth for those firms that became either exporters or subsidiaries of MNEs and for that reason the ATET is the appropriate causal effect to consider.

In order to highlight the presence of bias on the estimation if simultaneity is not taken in consideration, we consider the case of a naive estimator as it is termed in
Blundell, Dearden and Sianesi (2004). This naive estimator involves the difference in expected outcomes between two firms that have followed treatments $k$ and $l$ respectively:

$$E[Y^k | \Phi = k] - E[Y^l | \Phi = l] = E[Y^k - Y^l | \Phi = k] + \{E[Y^l | \Phi = k] - E[Y^l | \Phi = l]\}$$

where the first term on the right hand side is the the Average Treatment Effect on the Treated (ATET) and the second term is the bias$^{30}$ that arises from such a naive estimator. The reason is that the decisions made by firms to change status are systematic and consequently the sample of firms that take a decision is not random. Failing to take this into consideration and comparing firms that took a specific decision with those that they took a different one will result in biased estimates.

Hence, comparing the observed outcomes of exporters and pure domestic firms is not an unbiased estimator of the causal effect of becoming an exporter, since exporters might self-select themselves into to foreign markets. A firm that is to become an exporter might have already$^{31}$ experienced an improvement in its $TFP$. If this is not taken into consideration and a naive estimator is calculated then an increase in the $TFP$ of the new exporter might be wrongly attributed to the change of firm status.

As it was discussed above the correct estimation requires information about the expected outcomes of a firm had it followed both of the treatments. For example, the causal effect on $TFP$ growth for a firm that has become an exporter would require information about the $TFP$ of this firm had it remained a domestic producer, $E[Y^{DP} | \Phi = EX]$. But after treatment, only one of the potential outcomes is observed and the other is a counterfactual. There are methods that try to identify this counterfactual by imposing some structure and assumptions in the analysis and are discussed in the next section.

$^{30}$Heckman and Robb (1985) and Manski (1991) had termed it selection bias.

$^{31}$Before the change in its status.
2.5 Identification Strategies

One way to solve the identification problem of the counterfactual is usually\(^\text{32}\) to design and implement a randomised experiment. This would mean that firms are assigned randomly into the three different potential treatments. More formally, this would imply that the potential outcomes, \(Y^j\), are statistically independent of the treatment \(\Phi\). Hence, in a randomised experiment the decision to go through a particular treatment is random and does not affect the potential outcome.

A randomised experiment ensures that any differences between firms that followed different treatments are random and not systematic. Hence, in such a setup the observed outcome for those that participated in treatment \(k\) has the same expected value as the potential outcome for those that participated in programme \(l\); \(E[Y^k | \Phi = k] = E[Y^k | \Phi = l] = E[Y^k]\). As a consequence, under randomisation the naive estimator is applicable because there is not any selection bias. But randomisation in the context of the choice of the status of a firm is very difficult if not applicable at all.

For this reason this chapter focuses on other approaches that have been suggested in order to tackle the problem of identification. The control for confounding variables approach, Rubin (1974), is one of them and is used here with some modifications. The control for confounding variables approach tries to reproduce the structure of a randomised experiment by constructing comparable groups with similar features. Assume there are two firms with very similar characteristics, then their potential outcomes should be very close. If these two firms differ only on the treatment that they have been through, then any difference in their observed outcomes should be attributed to the different treatment followed. If it is possible to find a lot of pairs similar to this, then the causal effect of treatment \(k\) relative to treatment \(l\) can be estimated. But for consistent estimation it is necessary that within each pair, firms should have the same or very similar confounding variables \(X\). The confounding variables \(X\) are variables that

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\(^{32}\)Heckman and Smith (1995) discuss the potential bias that may arise in the case of random experiments.
affect the decision to participate in a treatment and also affect the potential outcomes.

The use of the control for confounding variables approach allows the identification of the counterfactual outcome and consequently the estimation of all the three causal effects mentioned. But it requires that the Conditional Independence Assumption (CIA) for multiple treatments, Imbens (2000) and Lechner (2001), to be satisfied:

\[ Y^{DP}, Y^{EX}, Y^{MA} \perp \Phi | X \]  

Equation (2.7) states that conditional on the confounding variables \( X \), the treatment assignment indicator \( \Phi \) is independent of the potential outcomes \( Y^j, j = DP, EX, MA \). This means, that given all the confounding variables \( X \), knowledge of the treatment followed by a firm does not provide any additional information about its potential outcome. It should be noted as Lechner (2002) points out that the Conditional Independence Assumption is not the minimal assumption that allows identification. The minimal assumption is conditional mean independence and according to Lechner (2002) in practice it usually implies CIA.

The second necessary condition for identification in the case of multiple treatments is the common support requirement. Let \( S^j = \{ x : P (\Phi = j | X = x) > 0 \} \) denote the support of \( X \) for the participants in treatment \( j \), where \( P (\Phi = j | X = x) \) is the probability of firm \( i \) with characteristics \( x \) follows treatment \( j \). The support of \( X \) for treatment \( j \), \( S^j \), defines a subsample where all firms with characteristics \( x \) have a positive probability of following treatment \( j \). The common support condition requires that for the identification of ATET, \( E [Y^k - Y^l | \Phi = k] \), it is necessary that \( S^k \subseteq S^l \). This means that any firm with characteristics \( x \) and positive probability of following treatment \( k \) should also belong to the support for the participants in treatment \( l \). In other words, in order to be able to identify the ATET, \( E [Y^k - Y^l | \Phi = k] \), those firms that had treatment \( k \) and those that had treatment \( l \) should share the same (common) support.

For the identification of ATE, \( E [Y^k - Y^l] \), the common support condition requires
a stronger assumption. That is $S^k = S^l = S$, where $S$ is the union of all treatment supports, $S \cup S^j$. This implies that the support for the population and the two sub-populations should be the same, so that the probability for any observed firm with characteristics $x$ is positive and very similar to the probability that any firm with characteristics $x$ is following any of the treatments, either $k$ or $l$.

Under the Conditional Independence Assumption and the common support requirement the following is true

$$E[Y^k | X, \Phi = k] = E[Y^k | X, \Phi = l] = E[Y^k | X]$$  \hspace{1cm} (2.8)

which states that conditional on $X$ the observed outcome $Y^k$ for the firms that have followed treatment $k$ has the same expected value as the potential outcome $Y^k$ for those that followed treatment $l$. Consequently, all the three effects can now be identified. In particular, by following the law of iterated expectations the Average Treatment Effect can be expressed in the following way:

$$E[Y^k - Y^l] = E[Y^k] - E[Y^l] \hspace{1cm} (2.9)$$

$$= E_X [E[Y^k | X] - E[Y^l | X]]$$

$$= \int \{ E[Y^k | X, \Phi = k] - E[Y^l | X, \Phi = l] \} f_x dx$$

where $f_x$ is the population probability density function of $X$ and both $E[Y^k | X, \Phi = k]$ and $E[Y^l | X, \Phi = l]$ are identified and can be estimated from the data. Hence, the Average Treatment Effect is the difference of the expected outcomes given $X$ of both treatment groups weighted by the population probability density function of $X$. 

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The Average Treatment Effect on the Treated is written as:

\[
E[Y^k - Y^l | X, \Phi = k] = E[Y^k | X, \Phi = k] - E[Y^l | X, \Phi = k] \tag{2.10}
\]

\[
= E[Y^k | X, \Phi = k] - E_X [E[Y^l | X, \Phi = k | \Phi = k]
\]

\[
= E[Y^k | X, \Phi = k] - \int \left\{ E[Y^l | X, \Phi = l] \right\} f(x|\Phi=k)dx
\]

where \(f(x|\Phi=k)\) is the probability density function of \(X\) among the participants in programme \(k\). The first part of the left hand side, \(E[Y^k | X, \Phi = k]\), is identified and can be estimated directly from the data, while the second part, \(\int \left\{ E[Y^l | X, \Phi = l] \right\} f(x|\Phi=k)dx\), needs to be estimated non-parametrically. The estimation of the second part proceeds by adjusting the expected outcome of participating in treatment \(l\) for the distribution of firm characteristics \(X\) for the participants in treatment \(k\).

Similarly, the Average Treatment Effect on the Non-Treated (ATENT) is:

\[
E[Y^k - Y^l | X, \Phi = l] = E[Y^k | X, \Phi = l] - E[Y^l | X, \Phi = l] \tag{2.11}
\]

\[
= E_X [E[Y^k | X, \Phi = l | \Phi = l] - E[Y^l | X, \Phi = l]
\]

\[
= \int \left\{ E[Y^k | X, \Phi = k] \right\} f(x|\Phi=l)dx - E[Y^l | X, \Phi = l]
\]

where \(f(x|\Phi=l)\) is the probability density function of \(X\) among the participants in programme \(l\). The Average Treatment Effect on the Non-Treated is the difference on the potential outcomes between treatments \(k\) and \(l\) averaged over the probability density function of the participants in the \(lth\) treatment.
2.6 The Curse of Dimensionality and Propensity Score

Matching

The matching estimator for the ATET, $E[Y^k - Y^l \mid X, \Phi = k]$, tries to find for each firm that participated in treatment $k$ at least one firm that participated in treatment $l$ with identical or very similar confounding variables $X$. If many pairs like this can be found then the causal effect on $Y$ of following treatment $k$ relative to $l$ is obtained by averaging the difference between the observed outcomes of the matched pairs. Hence, the matching estimator needs to condition on a usually high dimensional vector of $X$. This creates computational difficulties because the estimation of $\int \{ E[Y^l \mid X, \Phi = l] \} f(x \mid \Phi = k) dx$ is non-parametric and results in the so called curse of dimensionality. Rosenbaum and Rubin (1983) have shown that conditioning instead on a scalar function of $X$, the propensity score, is sufficient for identification in the case of a single treatment. Furthermore, propensity score matching implies that the subsamples of the treated and non-treated groups should have very similar distributions for variables $X$ (Balancing Property) and as a consequence the quality of "matching" is improved. For multiple treatments Lechner (2001) showed that conditional independence on $X$ implies conditional independence on the propensity score $p^{ijkl}(x)$ and consequently the CIA can be re-written as:

$$Y^l \perp \Phi \mid p^{ijkl}(x), \Phi \in \{k, l\}$$

(2.12)

where $p^{ijkl}(x) = \frac{p^j(x)}{p^l(x) + p^j(x)}$ is the probability of being a participant of the $l$th treatment instead of participating on treatment $k$ and $p^j(x) = P(\Phi = j \mid X)$ is the marginal probability of participating in treatment $j$ given characteristics $X$. Equation (2.12) states that conditional on the propensity score $p^{ijkl}(x)$ the choice of treatment is independent of the potential outcome $Y^l$. So both equations (2.9), (2.10) and (2.11) can be

33 The propensity score in the case of a single treatment is defined as the probability of participating in a treatment.
estimated but with the difference that in this case we need to average over the distribution of the propensity score \( p^{llk} (x) \) and not the probability density function of \( X \). For example, in the case of ATET equation (2.10) the second part of the left hand side is going to be

\[
E [Y^l | X, \Phi = k] = E_X [E [Y^l | p^{llk} (x), \Phi = l] | \Phi = k] \tag{2.13}
\]

\[
= \int \{ E [Y^l | p^{llk} (x), \Phi = l] \} f_{(p^{llk} | \Phi = k)} (p^{llk}) dp^{llk}
\]

where \( f_{(p^{llk} | \Phi = k)} \) is the density of the probability to participate in treatment \( l \) instead of participating in treatment \( k \) in the subpopulation of \( k \).

There are several estimators that are suggested and can be summarised in the following generalised matching estimator (GME) for the ATET, as discussed in Frolich (2004):

\[
GME = \frac{1}{n_k} \sum_{i=1}^{n_k} \widehat{\theta}_l \left( p^{llk} (x_i) \right) \tag{2.14}
\]

where \( n_k \) is the number of participants in treatment \( k \) and \( \widehat{\theta}_l (x) \) is an estimate of the expected outcome of participating in treatment \( l \) for those that actually participated in \( k \), conditional on the propensity score of the firms that followed treatment \( l \), \( \theta_l (x) = E [Y^l | p^{llk} (x_i), \Phi = l] \). GME is implemented by adjusting the estimate of the conditional expectation \( \widehat{\theta}_l (x) \) for the distribution of \( p^{llk} (x_i) \) on the subpopulation \( k \) and then averaging \( \widehat{\theta}_l (x) \) for the values of \( p^{llk} (x_i) \).

One of the most frequently used estimator is the pair-matching estimator, Rubin (1974), and is implemented here with some modifications. It advances by finding, "matching", for every observation in the treated (target) group an observation in the non-treated (control) group with the same or very similar propensity score. Hence, the observations from the control group that are used as "matches" are forced to follow the distribution of the propensity score from the target group as equation (2.13) indicates. Pair-matching finds only one "match", the most similar in terms of propensity score, for every observation in the treated sub-sample. It ignores all other observations in the
control group that might have slightly more distant values of propensity score. The only exception occurs, when there are more than one observations in the non-treated sub-sample with propensity scores that are equally distanced from the propensity score of an observation in the treated sub-sample. In this case, the average outcome of these non-treated observations is used for the estimation of the counterfactual.

In the analysis of this chapter I use pair-matching with replacement on the propensity score. This implies that each observation from the control group can be used more than once as a "match". For example, when three "matches" are allowed, the same observation from the non-treated group can be used as a "match" for observations in the treated group for a maximum of three times. This results in a higher variance for the estimates, but improves the quality of matches and has been suggested by Abadie and Imbens (2002) as a way to eliminate any bias that arises from non exact matching.

The problem of bias in the case of not exact matching can also be dealt with the use of bias-corrected matching estimators, see Abadie, Drukker, Herr and Imbens (2004). These estimators adjust the difference on the outcomes between the "matched" observation and the "match" by including the difference on their propensity score. Another issue regarding the matching estimator is that usually the conditional variance of outcome \( j \) for firm \( i \) given its propensity score, \( \text{var} \left( Y_j \mid p^{j|kl}(x_i) \right) \), is assumed to be constant across different propensity scores \( p^{j|kl}(x_i) \) and treatments \( j \). Here I implement estimators that take into consideration both potential problems and correct for the possible bias from a "poor" quality matching and also allow the conditional variance of outcome to be heteroscedastic.

Furthermore, I check whether the Balancing Property of propensity score matching is satisfied by performing a formal test proposed by Smith and Todd (2005). Finally, since the Conditional Independence Assumption does not hold in the sample I follow Lechner (2002) and I carry out matching on a new restricted sample, in which the Conditional Independence Assumption is imposed.
2.7 Data Description

The dataset that is used is primarily extracted from the OneSource database\textsuperscript{34} for the UK from 1990 to 1996. It is an unbalanced longitudinal set that includes all public and private limited companies that employ more than fifty employees. There are 110,000 companies in total and any of them that were in the process of liquidation or dissolved have been excluded from the sample. Due to the fact that only firms with fifty or more employees are included in the database, it is very likely that the sample is biased towards larger firms. But this should not create problems within the context of the analysis that is implemented. Exporters and multinational subsidiaries generally employ more than fifty employees and matching them with domestic producers of the same size in order to form comparable groups seems to be validated.

Additionally, OneSource also contains information on employment, physical capital, output, sales, exports, ownership status and the age of firms. Although the database provides information of foreign ownership for the latest year, this is not sufficient in order to observe the time that a British firm was acquired by a foreign multinational company. For that reason, our sample was matched to a list of British subsidiaries of foreign multinational companies provided by the Office of National Statistics. In addition, OneSource does not offer any information on whether British firms are acquired by British MNEs. In order to identify these subsidiaries of domestic MNEs our sample was once again matched with the European Linkages and International Ownership Structure (ELIOS) database\textsuperscript{35}.

The analysis concentrates on the manufacturing sector only. Furthermore, any firms that had an annual employment or output growth higher than 100\% are dropped from the sample\textsuperscript{36}, on the ground that such observations tend not to be reliable. In order to get the final sample I divide the original one into two years subsamples 1990-1991,

\textsuperscript{34}OneSource CD-ROM, "UK companies, vol. 1", October 2000.
\textsuperscript{35}The ELIOS database was constructed by the University of Urbino, Italy.
\textsuperscript{36}I should greatly acknowledge Dr Surafel Girma for providing me with the sample of the data.
1991-1992, 1992-1993, 1993-1994, 1994-1995 and 1995-1996. Within each subsample, firms that are either exporters or subsidiaries of multinationals in the earlier year are excluded. I do so because I am interested in the causal effect of a firm's status change on its \textit{TFP} growth. If a firm has already gone through "treatment" in the earliest time period that is observed, then it does not provide any useful information for the analysis. For each subsample the same firms are observed in both years. All firms are domestic producers in the earliest year of every subsample and in the next year some of them switch (becoming exporters or subsidiaries of \textit{MNEs}) while others remain domestic producers.

The final sample is constructed by merging all two years subsamples and amounts to 34,752 observations. It includes information on an unbalanced panel of more than 14,113 British firms in the manufacturing sector for the period from 1990 to 1996 as Table 2.1 shows. Firms are divided into three types: pure domestic (non-exporters), exporters and firms acquired by domestic and foreign multinationals. There are between 1,677 and 3,137 firms each year and all of them are observed at least for two consecutive years. The earlier partition of the sample into two years overlapping subsamples is the reason why in the first and last year there are fewer observations than in other years as Table 2.1 shows.

From Table 2.1 it is also evident that the sample is balanced through the years with regard to the volume of new exporters and new subsidiaries of \textit{MNEs}. The highest number of new exporters is observed in the last year 1996, when 120 British firms began to export, while the minimum was in the year before with only 94 new exporters. Similarly, 1994 was the year with the most acquisitions of British firms by \textit{MNEs}, 75 in total and the year before a minimum of 41 new acquisitions took place. In total, over all the years in the sample there were 624 new exporters and 356 new subsidiaries of \textit{MNEs} in the British manufacturing.

It is clear from Table 2.1 that changes in the status of firms are not happening at the same time. Hence, I treat the timing of a change in status as an "experimental
time" $t_e$ in order to proceed with matching. Observations are grouped according to two "experimental" periods. The first is "experimental" time period zero, $t^0_e$, in which all firms are domestic producers and the second is "experimental" time period one, $t^1_e$, where some firms have experienced a change in their status\textsuperscript{37}. Table 2.2 shows that there are 17,376 domestic producers at "experimental" time period zero and in the next "experimental" time period 624 of them became exporters and 356 were acquired by MNEs. It is clear from the above discussion about the construction of the data that all the results refer to short-time causal effects, one year after the change of a firm’s status.

2.8 Results

I perform propensity score matching allowing for replacement, bias adjustment and heteroscedastic variances in order to estimate the Average Treatment Effect on the Treated for three cases. These are the causal effects on $TFP$ growth for British firms of: i) becoming exporters in relation to remaining domestic producers, ii) becoming subsidiaries of MNEs compared with remaining domestic producers and iii) beginning to export relative to being acquired by MNEs. This requires knowledge about each firm’s propensity score for all the three cases. Therefore, I estimate a Multinomial Logit model on the entire sample so as to get estimates of the marginal probability for each firm to be in one of the three statuses conditional on a set of variables $X$. Let $\phi_i$ indicate the status $j$ of the $i$th firm

$$
\phi_i = j \begin{cases} 
0, \text{ if domestic producer} \\
1, \text{ if exporter} \\
2, \text{ if acquired by multinational}
\end{cases}
$$

\textsuperscript{(2.15)}

This is achieved using the two years subsample discussed earlier.
Assuming that the errors are independent and identically distributed across different statuses with a log Weibull (type I extreme value) distribution, \( G(u_{ij}) = \exp(-e^{-u_{ij}}). \) The probability that status \( j \) is observed for firm \( i \) given \( X \) is:

\[
\Pr(\phi_i = j) = \frac{\exp(\beta_j x_{ij})}{\sum_{j=0}^{2} \exp(\beta_j x_{ij})}
\]  

(2.16)

where \( x_{ij} \) includes the logarithm of lagged employment, the logarithm of lagged physical capital and lagged age of the firm. I use one year lagged values for the \( X \) variables in an attempt to capture the sequential nature of a firm’s decision to change status. The log of the odds for the multinomial logit are given in Table 2.3. All parameters, with the exception of the two employment coefficients, are statistically significant at the 1% level. There are 30,675 observations in the estimation, because there are missing values for some of the lagged \( X \) variables.

The assumption about the identical and independent distribution of the errors across statuses implies that the log of the odds for any pair of statuses does not depend on any others. This is referred to as the Independence of Irrelevant Alternatives (IIA) assumption. I test for the Independence of Irrelevant Alternatives assumption using the Small-Hsiao specification and I find that it is satisfied by the data as it is shown in Table 2.4.

The Small-Hsiao Test for the IIA proceeds as follows: First the entire sample is divided into two random subsamples of the same size. Estimates are obtained from the two subsamples. Then one of the two subsamples is chosen (unrestricted model) and all of its observations associated with a particular status are eliminated. This restricted model is estimated again. Finally, a typical Likelihood Ratio (LR) test is calculated, with the LR statistic of the form \(-2[\text{likelihood function}(\text{restricted}) - \text{likelihood function}(\text{unrestricted})]\) following a chi-square distribution with degrees of freedom equal to the number of parameters in the restricted model.

The null hypothesis declares that status \( j \) and status \( h \) are independent of other
statuses. For example, in the first row of Table 2.4 the null hypothesis is that the log of the ratio of the probability that a firm is an exporter relative to the probability that it is a domestic producer is not affected by the other available statuses. Table 2.4 shows that this null hypothesis cannot be rejected at very high levels of significance. The IIA assumption cannot be rejected for the other two cases either at the 5% level as it is evident from Table 2.4. This implies that a firm's choice between the two statuses does not depend on the availability of other statuses. Hence, the distinction between domestic producers, exporters and subsidiaries of MNEs in the analysis also seems to be valid econometrically.

The descriptive statistics of marginal probabilities by the status of the firm are presented in Table 2.5. Their mean values and standard deviations are quite similar across firms with different status. It is clear from Table 2.5 that the Common Support requirement is not satisfied in the case of the ATET of exporting relative to remaining domestic producer. Although the maximum value of the probability $Pr(\phi = 1)$ for an exporter (5.72) is smaller than the corresponding maximum value for a domestic producer (7.49), the minimum value for exporters (0.70) is smaller than that for domestic producers (0.73). This implies that the support for the exporters [0.70, 5.72] is not a subset of the support for the domestic producers [0.73, 7.49] as the Common Support condition demands for the estimation of the ATET. The Common Support Condition is not satisfied either in the case of the ATET of beginning to export relative to becoming a subsidiary of a MNE. Again, the support of exporters [0.70, 5.72] is not a subset of the support for the subsidiaries of MNEs [0.87, 4.93]. Only in the last case the of ATET of being acquired by a MNE relative to remaining a domestic producer the Common Support condition holds, because as it can be seen from Table 2.5 the support for subsidiaries of MNEs [0.35, 4.21] belongs to the support for domestic consumers [0.18, 6.28].

The fact that the Common Support is not satisfied by the data, suggests that the estimate of ATET might not be accurate. The reason is that failure of the Common
Support condition indicates that for some observations in the treated group there are no comparable observations in the control and consequently the counterfactual cannot be identified. A possible solution is to restrict the analysis and perform matching on the subsample of the data, where the Common Support requirement holds. In such a case the ATET, $E [Y^k - Y^l \mid X, \Phi = k]$, is redefined as the causal effect for only those observations that satisfy the Common Support condition.

Following Lechner (2002), I exclude all observations with probabilities lower than the highest value of the minimum probability across statuses. Analogously, I delete all observations with probabilities greater than the lowest value of the maximum probability between different statuses. This results to dropping 4,411 observations, 12.69% of the sample. This is a quite large part of the sample, but about 99% of the observations dropped were for domestic producers that are the most populous group in the data. The remaining 29,372 observations of domestic producers in contrast to the 33,772 in the initial sample still seem to be a good representation of the British firms serving the domestic and international markets. This is also evident from the very similar results produced by propensity score matching on the Common Support and the whole sample as Table 2.6 and Table 2.7 present respectively.

Equation (2.13) has been estimated having as outcome variable the annual total factor productivity growth of British firms in manufacturing. TFP growth has been estimated from a translog production function using Generalised Least Squares. Pair-Matching is performed on the propensity score with replacement, allowing for a maximum of four matches for each observation on the control group. Table 2.6 also includes estimates that correct for bias estimation arising from not exact matching (bias adj) and also estimates that allow for heteroscedastic variances of statuses (robust).

From Table 2.6 it is evident that the ATET for exporters relative to domestic producers in UK is positive and significant at a 1% level of significance for all numbers of matches and variations of estimation. The smallest estimate is just above 7.79%.

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38 I would like to thank Dr Surafel Girma for providing me with the initial data that also contained the growth of TFP for each firm.
when the number of matches is one and the maximum is above 8.79% when the number of matches is two. This result strongly supports the argument that domestic firms that become exporters gain in terms of productivity. In particular, firms that became exporters gained on average between 7.79 and 8.79 percentage points on their annual productivity a year after the change in their status.

The gains for the firms that were acquired by multinationals relative to domestic producers in UK were even higher and again significant at 1% level. Firms acquired by multinationals had on average experienced an increase in their productivity growth ranging from 11.55% to 13.09% relative to domestic producers a year after they became subsidiaries of MNEs. This result verifies empirically the hypothesis that multinational firms have a superior technology compared to domestic producers in UK and are able to transfer this technological advantage to their subsidiaries. This is observed as a higher TFP growth for the subsidiaries of MNEs when compared with firms only producing for the domestic market.

In contrast, the ATET for exporters relative to firms acquired by multinationals is negative but significant at 6% only when one match and heteroscedastic variance are allowed. For the rest of the cases the level of significance is between 7% and 10%. The 6% statistically significant effect has a coefficient of -9.95% indicating that exporters have on average a lower annual TFP growth of almost ten percentage points compared to firms that have been acquired by multinationals. The rest of the estimates present a similar picture showing a lower productivity for exporters varying from just below 8.6% to almost 9.95%, but are significant at a 10% level.

It is clear from the above discussion and Table 2.6 that the number of "matches" allowed in the estimation has an impact only on the magnitude and not the sign of the estimates or the level of significance. But even the changes in the magnitude of the estimates are of a quite small size. The maximum difference was 1.54% for the ATET between subsidiaries and domestic producers when one and two "matches" were used.

\[39\] The only exception is for the ATET between exporters and subsidiaries of MNEs when heteroscedastic variances are allowed. When one "match" is allowed, the effect is statistically significant at a 6% level, but for the rest numbers of "matches" it is significant at a 10% level.
Equally, the bias-correction estimation does not alter significantly the magnitude of the estimates compared to the basic estimation. For most cases, a change in the estimates is observed at the seventh decimal point, while the highest difference occurred at the fourth decimal point. This suggests that there is no problem of non exact matching and that the "quality" of the matching is very high. Moreover, allowing for heteroscedastic variance in the estimation reduces the standard error of the estimates, as expected, but not substantially as it seen from Table 2.6.

To test the Balancing Property of the Propensity Score I perform a test proposed by Smith and Todd (2005) that suggests running a regression of the following form:

$$x_i = \alpha + \sum_{\rho=1}^{4} \beta_{\rho} PSC(X)^{\rho} + \sum_{\rho=1}^{4} \gamma_{\rho} [D \times PSC(X)^{\rho}] + u$$

(2.17)

where \(x_i\) indicates each of the \(X\) variables used to estimate the Multinomial Logit. \(PSC(X) = \frac{Pr(\Phi=j)}{Pr(\Phi=j) + Pr(\Phi=h)}\) denotes the propensity score that status \(j\) occurs relative to status \(h\).

\(D\) is a dummy variable taking the value of one when \(\Phi = j\) and the value of zero when \(\Phi = h\). The null hypothesis that the coefficients \(\gamma_{\rho}\) are jointly statistically insignificant implies that the balancing property of the propensity score holds. The intuition behind the test is that, if the Balancing Property is satisfied then the decision to change status \(D\) conditional on the propensity score does not affect any of the \(x_i\). In other words, the test seeks to check whether there are differences on \(x_i\) for those that have \(D = 0\) against those that have \(D = 1\). The results of the Balancing Property test are presented in Table 2.8. The null hypothesis that the \(\gamma_{\rho}\) coefficients are jointly statistically insignificant at the 5% level is satisfied in 7 out of 9 cases. Hence, there seems to be evidence that the Balancing Property holds for the great majority of the cases.
2.9 Conclusion

This chapter has tried to assess the causal effects of a change in the status of firms in terms of potential total factor productivity gains. There is a vast literature that highlights the possible gains for different measures of performance, like TFP, labour productivity and size, for firms that enter foreign markets through exports. They have also highlighted and analysed theoretically and empirically the problems of causality within this analysis, Roberts and Tybout (1997) and Clerides et al. (1998) among others. There is also a growing literature on the gains of horizontal FDI or acquisition of firms by multinationals, Helpman et al. (2004) and Head and Ries (2003). The purpose of this chapter is to analyse and empirically estimate the causal effects of a change in the status of firms from pure domestic producers to either exporters or firms that have been acquired by multinationals and also the effect of becoming an exporter relative to a subsidiary of a MNE.

There are simultaneity problems that have been highlighted in the literature of evaluation methods that is mainly concerned about the effectiveness of labour market programmes, Blundell, Dearden and Sianesi (2005) for example. Motivated by this literature and also by some new research on applied international trade that employed these techniques in the case of a single treatment, Girma et al. (2004) and Wagner (2002), I have tried to analyse the effects described above within the context of multiple treatments methods and this is the most significant novelty of the chapter. Multiple treatment matching methods are able to identify the counterfactual and consequently estimate causal effects.

The matching technique in the case of multiple treatments has been used having as different treatments three possible statuses for a firm. These are: i) domestic producer, ii) exporter and iii) subsidiary of a multinational company. Pair-matching on the propensity score with replacement was implemented, allowing for a maximum of four "matches" for each observation in the target group for the estimation of each
ATET. The marginal probabilities on being in any of these three possible statuses were estimated by a Multinomial Logit model, where the variables $X$ affecting each of the decisions were lagged employment, lagged physical capital and lagged age of the firm. Descriptive statistics of the resulting estimates for the marginal probabilities by status are presented in Table 2.5, from where it is clear that the probability of being a domestic producer is by far the higher reflecting the big number of pure domestic firms in our sample.

The estimated ATETs presented in Table 2.6 are for the sample that it is restricted to satisfy the Common Support condition. It shows that the short-term $TFP$ gains for exporters relative to domestic producers are between 7.79% and 8.79% depending on the number of matches allowed and are all significant at a 1% level of significance. Identical in sign and again statistically significant at a 1% level, but higher in magnitude are the gains experienced by subsidiaries of multinationals relative to domestic producers, one year after the acquisition. On average firms that were acquired by MNEs had a higher annual productivity growth between 11.55% to 13.09% relative to domestic producers. Finally, the difference in $TFP$ growth, one year after the change in status, between exporters and firms that were acquired by MNEs was negative for all the number of matches. But only one was significant at the 6% level with a value of 9.94%. The rest of the estimates were ranging between 8.58% and 9.49% less productivity for exporters, but only significant at the 10% level.

Concluding, it can be said that new exporters experience higher $TFP$ growth, between 7.79% to 8.79% a year after beginning to export, with respect to domestic producers. Productivity gains were also experienced for firms acquired by multinationals relative to domestic producers ranging from 11.55% to 13.09%, after controlling for the likely problems of simultaneity in our analysis. In both of these cases all the effects estimated were statistically significant at the 1% level. In the last case, which assessed the difference in $TFP$ between exporters and firms that were acquired by MNEs the effect was negative and significant at the 10% level. This suggests that exporters have a lower
annual $TFP$ growth compared to firms acquired by $MNEs$ by around 9.95 percentage points, but this result is less robust, than the first two.
**Table 2.1: Descriptive Statistics Of Sample**

all years

<table>
<thead>
<tr>
<th>year</th>
<th>pure domestic</th>
<th>exporters</th>
<th>MNE acquired</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>1990</td>
<td>2,441</td>
<td>0</td>
<td>0</td>
<td>2,441</td>
</tr>
<tr>
<td>1991</td>
<td>4,976</td>
<td>115</td>
<td>58</td>
<td>5,149</td>
</tr>
<tr>
<td>1992</td>
<td>5,348</td>
<td>102</td>
<td>67</td>
<td>5,517</td>
</tr>
<tr>
<td>1993</td>
<td>5,658</td>
<td>98</td>
<td>41</td>
<td>5,797</td>
</tr>
<tr>
<td>1994</td>
<td>5,985</td>
<td>95</td>
<td>75</td>
<td>6,155</td>
</tr>
<tr>
<td>1995</td>
<td>6,273</td>
<td>94</td>
<td>63</td>
<td>6,430</td>
</tr>
<tr>
<td>1996</td>
<td>3,091</td>
<td>120</td>
<td>52</td>
<td>1,677</td>
</tr>
<tr>
<td>Total</td>
<td>33,772</td>
<td>624</td>
<td>356</td>
<td>34,752</td>
</tr>
</tbody>
</table>

Exporters are all the firms that sell in the domestic and foreign markets and are not owned by MNEs.

*MNE* acquired are the firms that only sell in the domestic market and are owned by MNEs.

**Table 2.2: Descriptive Statistics Of Sample**

Experimental Time

<table>
<thead>
<tr>
<th>Experimental Time</th>
<th>pure domestic</th>
<th>exporters</th>
<th>MNE acquired</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>17,376</td>
<td>0</td>
<td>0</td>
<td>17,376</td>
</tr>
<tr>
<td>1</td>
<td>16,396</td>
<td>624</td>
<td>356</td>
<td>17,376</td>
</tr>
<tr>
<td>Total</td>
<td>33,772</td>
<td>624</td>
<td>356</td>
<td>34,752</td>
</tr>
</tbody>
</table>

77
**Table 2.3: Multinomial Logit**

<table>
<thead>
<tr>
<th>Pr(φ₁=0) Pr(φ₂=2)</th>
<th>coef</th>
<th>std error</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>age</td>
<td>0.007</td>
<td>0.002</td>
<td>0.004</td>
</tr>
<tr>
<td>log employment</td>
<td>0.010</td>
<td>0.063</td>
<td>0.869</td>
</tr>
<tr>
<td>log capital</td>
<td>-0.213</td>
<td>0.049</td>
<td>0.000</td>
</tr>
<tr>
<td>constant</td>
<td>6.706</td>
<td>0.378</td>
<td>0.000</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Pr(φ₁=1) Pr(φ₂=2)</th>
<th>coef</th>
<th>std error</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>age</td>
<td>0.020</td>
<td>0.003</td>
<td>0.000</td>
</tr>
<tr>
<td>log employment</td>
<td>-0.063</td>
<td>0.079</td>
<td>0.429</td>
</tr>
<tr>
<td>log capital</td>
<td>-0.249</td>
<td>0.060</td>
<td>0.000</td>
</tr>
<tr>
<td>constant</td>
<td>3.269</td>
<td>0.466</td>
<td>0.000</td>
</tr>
</tbody>
</table>

Observations 30675
Log likelihood -4922
Pseudo $R^2$ 0.0118

LR test of joint significance

<table>
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<tr>
<th>Outcome</th>
<th>Outcome</th>
<th>$\chi^2$</th>
<th>p-value</th>
<th>Evidence</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0</td>
<td>0.947</td>
<td>0.918</td>
<td>Ho true</td>
</tr>
<tr>
<td>1</td>
<td>2</td>
<td>8.416</td>
<td>0.077</td>
<td>Ho true</td>
</tr>
<tr>
<td>0</td>
<td>2</td>
<td>2.811</td>
<td>0.590</td>
<td>Ho true</td>
</tr>
</tbody>
</table>

Table 2.4: Small-Hsiao Test for the IIA Assumption

Ho: outcome $j$ vs outcome $h$ are independent of others
Table 2.5: Descriptive Statistics Of Marginal Probabilities (%) By Status

<table>
<thead>
<tr>
<th>Marginal Probabilities</th>
<th>domestic producer</th>
<th>exporter</th>
<th>subsidiary of MNE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pr(φ_i = 0)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>mean</td>
<td>96.80</td>
<td>96.70</td>
<td>96.80</td>
</tr>
<tr>
<td>std. dev</td>
<td>0.005</td>
<td>0.006</td>
<td>0.005</td>
</tr>
<tr>
<td>min</td>
<td>92.17</td>
<td>92.89</td>
<td>94.22</td>
</tr>
<tr>
<td>max</td>
<td>97.83</td>
<td>97.57</td>
<td>97.57</td>
</tr>
<tr>
<td>Pr(φ_i = 1)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>mean</td>
<td>2.03</td>
<td>2.22</td>
<td>1.86</td>
</tr>
<tr>
<td>std. dev</td>
<td>0.006</td>
<td>0.007</td>
<td>0.005</td>
</tr>
<tr>
<td>min</td>
<td>0.73</td>
<td>0.70</td>
<td>0.87</td>
</tr>
<tr>
<td>max</td>
<td>7.49</td>
<td>5.72</td>
<td>4.93</td>
</tr>
<tr>
<td>Pr(φ_i = 2)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>mean</td>
<td>1.16</td>
<td>1.06</td>
<td>1.33</td>
</tr>
<tr>
<td>std. dev</td>
<td>0.004</td>
<td>0.004</td>
<td>0.004</td>
</tr>
<tr>
<td>min</td>
<td>0.18</td>
<td>0.30</td>
<td>0.35</td>
</tr>
<tr>
<td>max</td>
<td>6.28</td>
<td>6.40</td>
<td>4.21</td>
</tr>
<tr>
<td>Observations</td>
<td>(29695)</td>
<td>(624)</td>
<td>(356)</td>
</tr>
</tbody>
</table>
Table 2.6: Causal Effects On TFP Growth (%)

common support; standard error x 100 in parenthesis

<table>
<thead>
<tr>
<th>ATET</th>
<th>number of matches</th>
<th>bias robust adj.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>one</td>
<td>two</td>
</tr>
<tr>
<td>exporter vs domestic</td>
<td>7.79590***</td>
<td>8.79102***</td>
</tr>
<tr>
<td></td>
<td>(3.099)</td>
<td>(2.947)</td>
</tr>
<tr>
<td>exporter vs producer</td>
<td>7.79584***</td>
<td>8.79101***</td>
</tr>
<tr>
<td></td>
<td>(3.0.99)</td>
<td>(2.947)</td>
</tr>
<tr>
<td>subsidiary of MNE vs domestic producers</td>
<td>11.55923***</td>
<td>13.09936***</td>
</tr>
<tr>
<td></td>
<td>(3.926)</td>
<td>(3.713)</td>
</tr>
<tr>
<td>exporter vs subsidiary of MNE</td>
<td>-9.95368*</td>
<td>-8.58146*</td>
</tr>
<tr>
<td></td>
<td>(5.840)</td>
<td>(5.283)</td>
</tr>
</tbody>
</table>

* *** , ** and * indicate 1%, 6% and 10% level of significance, respectively
Table 2.7: Causal Effects On TFP Growth (%)
whole sample; standard error x 100 in parenthesis

<table>
<thead>
<tr>
<th>ATET</th>
<th>number of matches</th>
<th>bias robust adj.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>one</td>
<td>two</td>
</tr>
<tr>
<td>exporter vs domestic producer</td>
<td>7.77871***</td>
<td>8.57184***</td>
</tr>
<tr>
<td></td>
<td>(3.066)</td>
<td>(2.907)</td>
</tr>
<tr>
<td>subsidiary of MNE vs domestic producers</td>
<td>7.77850***</td>
<td>8.57184***</td>
</tr>
<tr>
<td></td>
<td>(3.066)</td>
<td>(2.907)</td>
</tr>
<tr>
<td>exporter vs subsidiary of MNE</td>
<td>7.77871***</td>
<td>8.57184***</td>
</tr>
<tr>
<td></td>
<td>(2.685)</td>
<td>(2.793)</td>
</tr>
<tr>
<td>subsidiary of MNE vs domestic producers</td>
<td>11.31803***</td>
<td>12.87603***</td>
</tr>
<tr>
<td></td>
<td>(3.924)</td>
<td>(3.714)</td>
</tr>
<tr>
<td></td>
<td>(5.806)</td>
<td>(5.218)</td>
</tr>
</tbody>
</table>

***, ** and * indicate 1%, 5% and 11% level of significance, respectively
Table 2.8: Balancing Property Test

\( H_0 : \gamma_1 = \gamma_2 = \gamma_3 = \gamma_4 = 0 \)

<table>
<thead>
<tr>
<th>Propensity Score</th>
<th>( y_x )</th>
<th>age</th>
<th>employment</th>
<th>capital</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \frac{Pr(\delta_i=1)}{Pr(\delta_i=1)+Pr(\delta_i=0)} )</td>
<td>reject ( H_0 )</td>
<td>reject ( H_0 )</td>
<td>accept ( H_0 )</td>
<td>(0.026)</td>
</tr>
<tr>
<td>( \frac{Pr(\delta_i=1)}{Pr(\delta_i=1)+Pr(\delta_i=2)} )</td>
<td>accept ( H_0 )</td>
<td>accept ( H_0 )</td>
<td>accept ( H_0 )</td>
<td>(0.363)</td>
</tr>
<tr>
<td>( \frac{Pr(\delta_i=2)}{Pr(\delta_i=2)+Pr(\delta_i=0)} )</td>
<td>accept ( H_0 )</td>
<td>accept ( H_0 )</td>
<td>accept ( H_0 )</td>
<td>(0.494)</td>
</tr>
</tbody>
</table>

p-values in parenthesis
References


Blundell, R., Dearden, L. and Sianesi, B. (2005). 'Evaluating the effect of education on earnings: models, methods and results from the National Child Development...


CHAPTER III


3.1 Introduction

One of the most characteristic phenomena of the last three decades in the world economy has been the rapid growth of international trade. In particular the value of world merchandise exports has increased from 578 billion in 1973 to 12 trillions in 2006 measured in current U.S. dollars (World Trade Organisation, Annual Report). This translates to an annual average growth rate of 8.6% for the world exports, while world output grew at an average of 7% per year over the same period. This clearly underlines the increasing significance of international trade in the world economy. One of the countries that has contributed significantly in this dramatic increase of international trade is the US. US exports and imports of merchandise products account for the 11.8% of world imports and exports and 21% of US GDP for the year 2006 (US Economic Accounts, Bureau of Economic Analysis). Hence, international trade is an important part of the US economy, it is interrelated to many production and consumption decisions and has been a frequent topic of investigation for many researchers.

There exists a vast theoretical literature, see for example Krugman and Baldwin (1987) and Feenstra (1998), that offers four main explanations for the enormous changes in the volume of international trade the last thirty years. The first core explanation is the gradual abolition of restrictive trade policies, mainly tariffs and quotas, that have been introduced by most of the countries through bilateral trade agreements within the World Trade Organisation (WTO). The second is the advancement of technology that has resulted in lower transportation costs. Due to more efficient and less costly means of transportation, it has become profitable to exchange products in international trade.
markets that before these changes were not. Thirdly, it is argued that the growth in real income, in the developed countries at least, is another reason of explaining the higher value and volume of international trade. While the last one (Feenstra, 1998) suggests that the rise of outsourcing has led to increased trade volumes between host and home countries.

Most of the empirical work in the existing literature, initiated with the work of Tinbergen (1962), has tried to assess empirically the factors that explain the growth of international trade using the gravity model, see Deardorff (1998) for a survey. In a recent paper using an augmented gravity model, Baier and Bergstrand (2001), found that income growth accounts for 66% of trade growth for sixteen OECD countries for the period 1958-1988. While tariff reductions can explain 26% and transport reductions 8% of trade growth respectively. On the other hand different approaches have been followed in an attempt to answer the same question like the work of Rose (1991) and Besedes (2005). Rose (1991) argues that there are three more potential reasons, the convergence of capital labour ratios of countries, the fall in the relative price of tradeables to non-tradeables and the growth of international reserves, that could explain the growth of world trade in an analysis of sixteen OECD countries for the period 1951-1985. He finds that for small open economies, rises in real output, rises in international reserves and declines in tariffs can explain the growth of their trade, while for large open economies none of the explanatory variables in his analysis has any statistical significance. Besedes (2005) uses a Ricardian model with a continuum of goods for five OECD countries for the period 1884-1992 in order to decompose the growth rate of import shares into two components. The first refers to changes in restrictive trade policies and the second to changes in the supply side of the economy. He finds that the former cannot explain solely the growth of international trade and that changes in the supply side of the economy, mainly technological change, should also be considered.

Another strand of the empirical literature, Laursen and Meltzer (1950), Persson and Svensson (1985) and Mendoza (1995), focuses on nominal factors, mainly exchange rate changes as possible determinants of the value of trade. But there remain some empirical questions that have attracted very little or no the interest of researches. The first is to assess empirically with the use of a general equilibrium analysis what determines
the changes in the volume of trade for a country. Economic theory tells that the answer lies in changes both in the production and consumption side of the economy. Hence, the factors that determine the production and consumption pattern of a country affect simultaneously the volume of its trade. That is, changes in the world prices of commodities, changes in the endowments of the economy, technological changes both in the production and consumption and finally income changes.

A change in the world price for a commodity has two opposing effects on the volume of net exports of a country. A decrease in the world price of a commodity will increase the quantities exported for the country producing the commodity, but at the same time will increase its consumption and consequently its volume of imports. The final result is an empirical question and depends on the price elasticities of supply and demand. On the other hand, changes in the endowments of the economy will change only the output produced and consequently will alter the volume of net exports in the same direction. Technological change in the production side of the economy, usually a positive one, will increase output and consequently will increase exports. But technological change on the demand side and in particular changes in the preferences of consumers towards commodities could either increase or decrease their consumption depending on the direction of the change on the preferences. While changes in income lead to higher consumption for all normal goods and consequently less net exports. All the above show that theoretical predictions are necessary, but not sufficient for determining what actually drives the changes in the volume of net exports in an economy. It is necessary to have estimates about the production and consumption structure of the economy in order to be able to offer definite answers on the question what determines changes in its volume of net exports.

In this chapter, first I define an equilibrium where the economy is allowed to trade with the rest of the world within the neoclassical trade setup of a small country. This implies no impediments to trade, exogenous world prices for the commodities, no immigration of factors of production, all countries producing all goods, a linearly homogeneous technology in production and also homothetic preferences at the home country. A production equilibrium is then defined with the use of a revenue function and similarly a consumption equilibrium is represented using an expenditure function. This allows
us to determine the trade equilibrium for the economy and consequently to disentangle the different parts that explain a country's volume of net exports.

The first contribution of the chapter, is the fact that I include both sides of the economy, production and consumption, in the analysis and that I can identify the signs and also magnitudes of the different effects that theory predicts. The second contribution is that following a general equilibrium analysis I am able to decompose the changes of the volume of net exports into five different components. The first is a terms of trade effect that depends on the price elasticities of demand and supply. The second reflects the changes in the endowments of the economy. The third represents the effects of technological change in production. The fourth refers to the effects on net exports arising from changes on preferences over time. The last one is the component that captures the effects of income changes on the volume of net exports. Higher income levels imply higher consumption levels for all normal goods and consequently less net exports. Finally, I allow for a more general technology in the production side that permits the presence of jointness in output quantities (see Woodland 1977 and Kohli 1991). In addition, this broader definition of production's technology that is usually avoided in return for a more tractable theoretical predictions seems to be supported by the data.

This chapter draws its simple theoretic model from the work of Dixit and Woodland (1982), but neither focuses on the special case of an autarky equilibrium nor is investigating only the effect of a change of factor endowments on the volume of trade. I follow the empirical implementation of Harrigan (1997) and Kohli (1993). I first estimate a system of output equations (exportable, importable and non-tradable) derived from a Symmetric Normalised Quadratic Revenue function introduced by Kohli (1991, 1993) using a Three Stages Least Square (3SLS) estimation. Equivalently a system of consumption equations derived from an expenditure function of a Gorman-Polar type, (Diewert and Wales 1988) is estimated using again 3SLS. Then it is possible to calculate the fitted volume of net exports for the economy and to proceed to the decomposition discussed above. With such a decomposition and also with the estimates obtained from the revenue and expenditure function the signs and also the magnitude of all the five different components can be constructed. Hence, I can explain the reasons for which the
net exports of a particular commodity has been observed to move in a specific direction. In particular, I find that the positive growth, 9.52% on average from 1966 to 1991, of net exports for the exportable good is mainly explained by better terms of trade and progressive technological change in the production, despite a very large income effect. In contrast, the negative growth, -17.11% on average over the whole period, of net exports for the importable good is due to a modest improvement in the terms of trade, small positive benefits through the endowments and preferences components, accompanied by a negative impact of technological change in the production side and a sizeable income effect. Finally, the net exports for the non-tradable good grew rapidly, an average of 106% for the period 1966-1991. This seems to be the result of a combination of very good terms of trade and benefits arising from the change in the economy's endowments regardless of large opposing effects in production from regressive technological change, in preferences and income changes.

The chapter is organised in seven sections. Section 3.2 describes the theoretical model for the economy, a trade equilibrium. The third discusses the econometric specification for both the revenue and the expenditure function. Section 3.4 briefly describes the data used, while the fifth discusses the estimation methods implemented and the results obtained. Section 3.6 involves the decomposition of the changes in the volume of net exports for the US economy for the period 1965-1991 and finally Section 3.7 concludes the chapter.

3.2 The Model

Let $F(y, v, t) = 0$ be a transformation function for an economy with a linearly homogeneous technology, which produces $y = (y_1, ..., y_n)$ goods with the use of $m$ inputs, $v = (v_1, ..., v_m)$, in a perfect competitive environment where $t$ is a time index that captures technological change. Then, at given international prices $p = (p_1, ..., p_n)$ and domestic inputs $v$, there exists a competitive production equilibrium. In such equilibrium we can think of the economy as one that maximizes the value of total output subject

---

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\[91\]Table 3.1 contains the 2 digit SIC codes of industries and their corresponding aggregate good.
to the technological and endowment constraints. In other words there is a revenue or GDP function such that:

\[ R(p, v, t) = \max_y \{py : F(y, v, t) = 0\} \] (3.1)

The revenue function is increasing, linearly homogeneous and concave in \( v \) and non-decreasing, linearly homogeneous and convex in \( p \). In addition if \( R(p, v, t) \) is differentiable then from Hotteling's Lemma (Diewert 1974) the equilibrium output is:

\[ y(p, v, t) = R_p(p, v, t) \] (3.2)

On the consumption side the economy's preferences defined over the \( n \) goods are represented by an expenditure function, which is continuous and twice differentiable in prices:

\[ E(p, u, t) = \min_c \{pc : u(c, t) \geq u\} \] (3.3)

where \( u \) is the level of utility and \( c = (c_1, \ldots, c_n) \) is the consumption bundle and \( t \) is a time index that captures shifts on the expenditure function due to changes in preferences for the consumers. The expenditure function is non-decreasing, linear homogenous and concave in prices and increasing in \( u \). In addition, it is assumed that the expenditure function is homothetic:

\[ E(p, u, t) = \frac{E}{E}(p, t) u \] (3.4)

From Shepherd's Lemma (Diewert 1974) the consumption vector of the economy is:

\[ c(p, u, t) = E_p(p, u, t) \] (3.5)

where \( E_p \) is the first partial derivative of the expenditure function with respect to product prices.
The trade equilibrium is defined as

\[ TIMB = R(p, v, t) - E(p, u, t) \] (3.6a)

\[ T = R_p(p, v, t) - E_p(p, u, t) \] (3.6b)

that is the difference between total value of production and total expenditure for the economy gives the trade imbalance \((TIMB)\) for the economy and the difference between production and consumption gives the economy's vector of the volume of net exports, \(T\).

In equilibrium the Hicksian demand function, \(c^H(p, u, t) = E_p(p, u, t)\), has always the same value as the Marshallian demand function, \(c^M(p, m, t) = H_p(p, m, t)\), where \(m\) indicates total nominal expenditure for the economy, assuming that there is an indirect utility function \(H(p, m, t) = u\). Hence, I can substitute the Marshallian for the Hicksian demand function in equation (3.6b)

\[ T = R_p(p, v, t) - c^M(p, m, t) \] (3.7)

Differentiating totally equation (3.7) I get

\[ dT = R_{pp}dp + R_{pv}dv + R_{pt}dt - c^M_p dp - c^M_m dm - c^M_t dt - c^M_m dt \]

where \(dp, dv, dm\) and \(dt\) are respectively the change in product prices, factor endowments, income and technology between two years. \(R_{pp}\) is the matrix of the second partial derivatives of the revenue function with respect to prices and \(R_{pv}\) is the matrix of the second partial derivatives of the revenue function with respect to prices and endowments respectively. While \(c^M_p, c^M_t, \) and \(c^M_m\) are the matrices of the first partial derivatives of the Marshallian demand function with respect to prices, technological change and income respectively.

Equation (3.8) is a decomposition of the changes in the volume of net exports into five components:

\[ dT = (R_{pp} - c^M_p dp + R_{pv}dv + R_{pt}dt - c^M_t dt - c^M_m dm \]

\[ \text{Figure 3.4 depicts the net exports for the three aggregate goods in billion of USD 1970 prices.} \]
• the first, \((R_{pp} - c^M_p) dp\), is a component similar to changes in terms of trade\textsuperscript{43} (\textit{tot}) and depends on the substitutability and complementarity of the goods in production and consumption.

• the second, \(R_{pv} dv\), consists of the effect of changes in endowments on output and the entries of matrix \(R_{pv}\) can have all possible signs under the more general technology that allows jointness in output quantities.

• the third, \(R_{pt} dt\), captures technological change in production. The sign of \(R_{pt}\), the effect of technological change on the supply of a good is positive, if technological change is progressive.

• the fourth, \(-c^M_t dt\), incorporates the effect of changes in preferences over time. But the sign of \(c^M_t\) cannot be determined a priori. Preferences towards a good can change in either direction over the passage of time.

• the last one, \(-c^M_m dm\), is an income effect component. For all normal goods \(c^M_m\) is positive and the total effect depends on the direction to which income is heading.

Better terms of trade will increase the net exports for the exported good and decrease the net exports for the imported assuming that only the price of the exported good has increased. If both prices change in a fashion that results to better terms of trade, it is not clear what happens to the net exports of either good. The final outcome depends on the substitutability and complementary of the goods in production and consumption. The reason is that the matrix \(R_{pp} - c^M_p\) is positive semidefinite, since the revenue function is convex in prices and the expenditure function concave respectively. The diagonal elements are all positive, while the signs on the off diagonal elements depend on the substitutability and complementarity of the commodities in both production and consumption. Hence, it is an open question and rests on the estimation of the parameters of the revenue and the expenditure function.

Increases in endowments lead to increases in net exports as long as the endowment increase enhances output. In the standard neoclassical trade model with two goods and two inputs the Rybczynski theorem identifies the signs of the elements of matrix \(R_{pv}\).

\textsuperscript{43}The ratio of prices between an exported and an imported good.
states that an increase in the endowment that is used relatively more intensively in the production of a good will cause an increase in its production and hence its net exports. But if we depart from the $2 \times 2$ dimension to more goods and inputs and also allow for jointness in output quantities then no a priori prediction can be made. The signs of the elements in $R_{py}$ can have either sign and once again everything depends on the estimates obtained from the revenue function.

A progressive technological change of Hicks-neutral type on the production, implies a positive $R_{pt}$ and equiproportionate changes for all goods, this leads to increases in trade, since it allows for a rise in commodity supplies. In other words, as long as technological change is progressive, output $y$ will increase and because net exports is by definition output minus consumption, net exports will also increase for given consumption levels. Hence, technological improvement in production always increases net exports.

While technological change in the consumption side or changes in the preferences does not have a definite expected sign. It could be either positive or negative. It depends on the direction to which consumers change their preferences towards a specific good as time passes. For example, if consumers have changed their preferences and tend to prefer more (less) of a specific good now than before, then consumption will increase (decrease) and net exports will fall (rise).

Finally, the effect of a change in income on consumption, $c^M$, is positive for all normal goods. Hence the sign of the fifth component depends on whether income is increasing or not. More income will imply more consumption and hence less net exports for every normal good and vice versa.

The above discussion has made clear, the reason both sides of the economy should be included in the analysis. Furthermore, it has stressed the necessity to obtain estimates of the revenue function and Marshallian demand functions that will allow us to decompose the actual changes of a country’s volume of net exports.

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\footnote{See Woodland (1977), pp. 526.}
3.3 The Econometric Specification

3.3.1 The Revenue Function

In this section I discuss the functional forms of the revenue and expenditure functions that are estimated. The revenue function is assumed to have the symmetric normalized quadratic functional form as discussed in Kohli (1991, 1993):

\[
R(p, v, t) = \frac{1}{2} \left( \sum_{j=1}^{M} \psi_j v_j \right) \left( \sum_{i=1}^{N} \sum_{h=1}^{N} \alpha_{ih} p_i p_h \right) \left( \sum_{i=1}^{N} \theta_i p_i \right)^{-1} \\
+ \sum_{i=1}^{N} \sum_{j=1}^{M} \left( c_{ij} p_i v_j \right) + \frac{1}{2} \left( \sum_{i=1}^{N} \theta_i p_i \right) \left( \sum_{j=1}^{M} \sum_{k=1}^{M} b_{jk} v_j v_k \right) \left( \sum_{j=1}^{M} \psi_j v_j \right)^{-1} \\
+ \left( \sum_{j=1}^{M} \psi_j v_j \right) \left( \sum_{i=1}^{N} d_i p_i \right) t + \left( \sum_{i=1}^{N} \theta_i p_i \right) \left( \sum_{j=1}^{M} e_j v_j \right) t \\
+ \left( \sum_{i=1}^{N} \theta_i p_i \right) \left( \sum_{j=1}^{M} \psi_j v_j \right) \left( \frac{1}{2} h_{tt} t^2 + h_{tt} t \right) \\
\]  

(3.9)

where \( p \) and \( v \) are the product prices and input endowment vectors respectively and \( t \) is an index of exogenous technological change. There are \( N(N-1) + M(M-1) + (N \times M) + 2 \) unknown parameters \( \alpha_{ih}, b_{jk}, c_{ij}, d_i, e_j, h_t \) and \( h_{tt}, \) where \( i, h = 1, \ldots, N \) and \( j, k = 1, \ldots, M. \) There are also \( N + M \) predetermined parameters \( \theta_i \) and \( \psi_j. \) In particular, \( \theta_i \) and \( \psi_j \) are set equal to the share value of each product and input respectively at the base year. In order for the revenue function to be flexible, namely all its first and second derivatives to be defined, symmetry conditions are imposed \( \alpha_{ih} = \alpha_{hi}, b_{jk} = b_{kj} \) that reduce the estimated parameters and consequently improve the efficiency of the estimates, because of higher degrees of freedom. In addition the assumption of linear homogeneity in \( p \) and \( v \) requires some additional restrictions:

\[
\sum_{i=1}^{N} \theta_i = \sum_{j=1}^{M} \psi_j = 1, \text{ and } \sum_{h=1}^{N} a_h = \sum_{k=1}^{M} b_{jk} = \sum_{i=1}^{N} d_i = \sum_{j=1}^{M} e_j = 0 \\
\]  

(3.10)

This functional form is attractive because it is flexible and retains its flexibility under the imposition of convexity and concavity in prices and endowments, respectively. The
necessary and sufficient condition for global concavity in inputs is that the matrix $B = [b_{jk}]$ is negative semi-definite and for global convexity in product prices is that the matrix $A = [a_{ikh}]$ is positive semi-definite. If these are not satisfied then they are imposed following Diewert and Wales (1987) without removing the flexibility properties of the revenue function. More specifically, as Diewert and Wales (1987) have shown global concavity on inputs can be imposed if matrix $B$ is replaced by the negative product of a lower triangular matrix $\Phi$ and its transpose $\Phi'$. That is $B = -\Phi \Phi'$, where $\Phi = [\phi_{jk}]$ and $\phi_{jk} = 0$ for every $j < k$; $j$ indicates rows and $k$ indicates columns of the matrix. In the same manner, global convexity on product prices can be imposed if matrix $A$ is replaced by the product of a lower triangular matrix $\Omega$ and its transpose $\Omega'$. Then $A = \Omega \Omega'$ with $\Omega = [\omega_{ih}]$ and $\omega_{ih} = 0$ for $i < h$.

Based on equation (3.9) the reward of the $j$th factor becomes:

$$w_j = \frac{1}{2} \psi_j \left( \sum_{i=1}^{M} \sum_{h=1}^{N} \alpha_{ih} p_i p_h \right) \left( \sum_{i=1}^{N} \theta_i p_i \right)^{-1} + \left( \sum_{i=1}^{N} \theta_i p_i \right) \left( \sum_{k=1}^{M} b_{jk} v_k \right) \left( \sum_{j=1}^{M} \psi_j v_j \right)^{-1}$$

$$- \frac{1}{2} \psi_j \left( \sum_{i=1}^{N} \theta_i p_i \right) \left( \sum_{j=1}^{M} \sum_{k=1}^{M} b_{jk} v_j v_k \right) \left( \sum_{j=1}^{M} \psi_j v_j \right)^{-2} + \sum_{i=1}^{N} c_{ij} p_i + \psi_j \left( \sum_{i=1}^{N} d_i p_i \right) t$$

$$+ e_j \left( \sum_{i=1}^{N} \theta_i p_i \right) t + \psi_j \left( \sum_{i=1}^{N} \theta_i p_i \right) h_1 t + \frac{1}{2} \psi_j \left( \sum_{i=1}^{N} \theta_i p_i \right) h_1 t^2$$

(3.11)

The output supply of good $i$th is:

$$y_i = \frac{1}{2} \theta_i \left( \sum_{j=1}^{M} \sum_{k=1}^{M} b_{jk} v_j v_k \right) \left( \sum_{j=1}^{M} \psi_j v_j \right)^{-1} + \left( \sum_{j=1}^{M} \psi_j v_j \right) \left( \sum_{h=1}^{N} \alpha_{ih} p_h \right) \left( \sum_{i=1}^{N} \theta_i p_i \right)^{-1}$$

$$- \frac{1}{2} \theta_i \left( \sum_{j=1}^{M} \psi_j v_j \right) \left( \sum_{j=1}^{M} \sum_{h=1}^{N} \alpha_{ih} p_i p_h \right) \left( \sum_{j=1}^{M} \psi_j v_j \right)^{-2} + \sum_{j=1}^{M} c_{ij} v_j + d_i \left( \sum_{j=1}^{M} \psi_j v_j \right) t$$

$$+ \theta_i \left( \sum_{j=1}^{M} e_j v_j \right) t + \theta_i \left( \sum_{j=1}^{M} \psi_j v_j \right) h_1 t + \frac{1}{2} \theta_i \left( \sum_{j=1}^{M} \psi_j v_j \right) h_1 t^2$$

(3.12)

Equations (3.11) and (3.12) together with restrictions equation (3.10) form the system of equations to be estimated.

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15 For more details about imposing global concavity or convexity see Wiley, Schmidt and Bramble (1973).
3.3.2 The Expenditure Function

Assume the expenditure function $E(p, u, t)$ of the economy to be homothetic of the Gorman-polar form, Diewert and Wales (1988):

$$E(p, u, t) = \sum_i a_i p_i + \left[\sum_i \beta_i p_i + \frac{1}{2} \left(\sum_i \sum_j \gamma_{ij} p_i p_j \right) \left(\sum_i g_i p_i\right)^{-1} + \sum_i \delta_{it} p_i t\right] u$$

where $i = E, I, N$ indicates output, $u$ is the utility level and $t$ indicates changes on preferences. The parameters $g_i$ are predetermined and $a_i, \beta_i, \gamma_{ij}$ and $\delta_{it}$ are the unknown ones. For well behaved preferences, we need to assume linear homogeneity and concavity in prices and also that expenditure function is non-decreasing with respect to utility. If concavity is not satisfied then it is imposed following the method of Diewert and Wales (1987) that was discussed before for the case of the revenue function. At the point of normalization, prices are set to one, $p^*$ is a unitary column vector, the following restrictions are necessary to guarantee standard preference choices for the consumers:

$$\sum_i a_i = \sum_j \gamma_{ij} = 0; \quad \sum_i g_i = 1$$

Using Shephard's lemma, the Hicksian demand function ($c^h_i$) for the $i$th good is given by:

$$c^h_i = \frac{\partial E(p, u, t)}{p_i} = a_i + \left[\beta_i + \sum_j \gamma_{ij} p_j \left(\sum_i g_i p_i\right)^{-1} - \frac{1}{2} g_i \sum_j \gamma_{ij} p_j p_j \left(\sum_i g_i p_i\right)^{-2} + \delta_{it} t\right] u$$

---

$^{46}$ $g_i$ is set equal to the share of value for each good on total consumption.
Setting equation (3.13) equal to the total nominal expenditure, \( TNE = \sum p_i c_i \), and then solving for the utility \((u)\) I get the indirect utility function

\[
u = g(p, t, TNE) = \frac{TNE - \sum a_i p_i}{\sum \beta_i p_i + \frac{1}{2} \left( \sum_j \sum_i \gamma_{ij} p_i p_j \right) \left( \sum_i g_i p_i \right)^{-1} + \sum \delta_{u} p_i t}
\] (3.16)

Then substituting the indirect utility function (3.16) into the Hicksian demand (3.15) I get the Marshallian demand function \( c_i^m \) for the \( i \)th good

\[
c_i^m = \frac{TNE - \sum a_i p_i}{\sum \beta_i p_i + \frac{1}{2} \left( \sum_j \sum_i \gamma_{ij} p_i p_j \right) \left( \sum_i g_i p_i \right)^{-1} + \sum \delta_{u} p_i t}
\left[ \sum_j \gamma_{ij} p_j \left( \sum_i g_i p_i \right)^{-1} - \frac{1}{2} g_i \sum_j \gamma_{ij} p_i p_j \left( \sum_i g_i p_i \right)^{-2} + \delta_{u} t + \beta_i \right] + a_i
\] (3.17)

In order to identify all parameters, I impose further normalisations that imply more restrictions. I set technological change equal to one at the base year and I impose restrictions on the parameters such that the denominator of the ratio in equation (3.17) is equal to unity \( \sum \beta_i p_i + \frac{1}{2} \sum \gamma_{ij} p_i p_j \left( \sum g_i p_i \right)^{-1} + \sum \delta_{u} p_i t = 1 \). Hence, I impose the following restrictions

\[
\sum_i \beta_i = 1 \text{ and } \sum_i \delta_u = 0
\] (3.18)

So the base year is considered as the reference point that any previous or future changes on preferences are compared with. The Marshallian demand equations (3.17) together with restrictions (3.14) and (3.18) form the system of equations to be estimated.

The expenditure function in equation (3.13) is a money metric utility function, \( m(p, c) = e(p, u(c)) \) (Samuleson, 1974). It provides information on how much money all consumers would need at given prices \((p)\) in order to consume the observed bundle of goods \((c)\). For fixed levels of product prices the money metric utility functions, \( m(p, c) \), is equivalent to a utility function. The expenditure function is increasing in utility, hence for given product prices the only way to attain higher utility is to increase
your spending. An important feature of the money metric utility function is that depends on observed variables, prices and consumption bundles. On the other hand the Gorman-polar form implies the assumption of the representative consumer model for aggregating preferences over all the consumers of the economy.

3.4 Data

There are three inputs in our model, capital, $v_K$, skilled labour, $v_S$, and unskilled labour, $v_U$. Data for the value ($VAD_{ij}$) and price of capital and aggregate labour ($P_{ij}$), at a 2-digit SIC87 analysis are obtained from Dale Jorgenson's database for the period 1963-1991\(^{47}\), where $j = K, L$ and $i$ indicates the 2-digit industry. I construct the value added for capital and aggregate labour for the whole economy, $VAD_j = \sum_i VAD_{ij}$, by adding the value added for capital and labour for all the 2-digit industries, respectively. Then the aggregate price of capital and labour is calculated as a weighted average of their prices in each 2-digit industry with weights the share of each input in every 2-digit industry, $W_j = \sum_i \frac{VAD_{ij}}{VAD_j} W_{ij}$. I get the quantity of capital and aggregate labour for the whole economy by dividing their value added by their price, $Q_j = \frac{VAD_j}{W_j}$, respectively.

The division of aggregate labour into skilled and unskilled labour is implemented by using data from the NBER collection of Mare-Winship Data, 1963-1991. It contains data on educational levels, weekly wages, status and weeks worked for full time workers in 2-digit SIC industries. I divide workers into skilled and unskilled following Katz and Murphy (1992), a worker is treated as skilled if he or she spent at least twelve years in education. Our sample contains only full time workers, aged 16-45, that have completed their education and are working in the private sector. First, I calculate the total number of weeks worked per year and also the annual wages and salaries for skilled and unskilled workers\(^{48}\). Then I divide the annual value of wages and salaries by the corresponding total weeks worked in order to calculate the full time weekly wage for

\(^{47}\)http://post.economics.harvard.edu/faculty/jorgenson/data/35klem.html

\(^{48}\)Following Katz, L. and Murphy, K. (1992) we include only full time workers that have worked more than 39 weeks in that year. Also, top code wage and salaries were multiplied by 1.45
each group respectively. After that I calculate the share of weeks worked for skilled and unskilled workers relative to the total hours worked of all workers. Similarly, I find the shares of wages for each occupational group in the sample. Finally, these shares are multiplied with the total quantity and total wages of aggregate labour, respectively, obtained from Jorgenson’s data set in order to get the quantity and wages for skilled and unskilled workers in US.

In our model there are three aggregate products, exportable, $y_E$, importable, $y_I$, and non tradable, $y_N$. Initially the products are divided into tradeable and non-tradeables. A 2-digit industry is termed tradable if the ratio of its exports plus imports divided by its revenue is above 10%, otherwise it is termed as non-tradable\(^{49}\). Then tradable industries are grouped to exportables and importables depending on whether their net exports are positive or negative, respectively. The categorisation of the 2 digit industries into the three aggregate goods, as explained above, was made for the first year of the sample, 1965\(^{50}\). In addition, the final dataset was constructed in such a way that once a 2 digit good was incorporated into one of the three aggregate goods, it remained in this particular aggregate good even if the criteria that were used for year 1965 had changed sign or magnitude over time. The reason is that we intended to create aggregate categories with a stable composition over time, in order to avoid potential correlation between the prices of aggregate goods that might have led to econometric problems.

In Figures 3.1, 3.2 and 3.3 are depicted the net exports of the 2 digit SIC industries that are part of the exportable, importable and nontradable good, respectively. From Figure 3.1 we observe that all the 2 digit SIC industries of the exportable good had a positively and relatively small magnitude of net exports for the first year, from 14 million USD for SIC 20 to 3.88 billion USD for SIC 35, and this pattern continued for the vast majority of these industries till 1972. After that year, industries SIC 28\(^{51}\) and SIC 35 had a positive and increasing volume of net exports for most of the rest of the years in the sample. While industries SIC 20 and SIC 38 had followed a path very

\(^{49}\text{Trade data at a 2-digit SIC level were obtained online from the Centre for International Data at the University of California Davis. http://data.econ.ucdavis.edu/international/index.html}\)

\(^{50}\text{I chose the first year, 1965, as the year to which the aggregation of 2 digit products was made, because it is easier to interpret the results having as reference point the beginning of the sample. In addition, in this year the variation of the volume of net exports within each aggregate good was the smallest as it can be seen from Figures 3.1, 3.2 and 3.3 respectively.}\)

\(^{51}\text{Table 3.1 shows the SIC categories that are included in each aggregate good.}\)
similar to the one of the first eight years, that is positive and relatively close to zero net exports. At the same time the remaining two 2 digit industries of the aggregate exportable good, SIC 36 and SIC 37, had experienced a very significant drop on their net exports (actually they were net imported) until the year 1986, 43 billion and 22 billion respectively, followed by an increase in their net exports, but still the US was a net importer of these two goods. From Figure 3.2, it is clear that all the 2 digit SIC industries of the importable had negative net exports for the whole sample period, that is they were net imported and in addition most of the industries followed a relatively similar pattern of declining net exports till either 1984 (16 billion net imports for SIC 29) or 1988 (10 billion net imports for SIC 31) and then experienced a rise in the value of their net exports till the end of the sample. While Figure 3.3 shows the 2 digit SIC industries that are part of the nontradable good had a quite similar pattern of stable and small magnitude of net exports until 1982, 1.1 billion net exports for SIC 21 and 740 million net imports for SIC 32, with the exception of industry SIC 34. After 1983 only two industries, SIC 21 and SIC 27, experienced positive values of net exports for some years. The rest of the industries had a relatively rapid and high drop in their net exports from 1983 to 1989, followed by a rise in the last three years.

For the calculation of value added of the three aggregate products I again use Jorgenson’s data set. While data for output deflators are obtained from the Bureau of Economic Analysis at a 2-digit SIC level. Since these are available from 1977 onwards, the values of output deflators for years before 1977 are obtained by interpolation assuming a constant growth rate equal to the growth rate between 1977 and 1978. The aggregation of the three goods is achieved in three stages. First, I calculate each industry’s value added \( (VAD_i) \) by summing the value added of capital and labour of each 2-digit industry, \( VAD_i = \sum_j VAD_{ij} \). Then the value added of each aggregate good, \( VAD_A \); \( A \) indicates the three aggregate outputs, is constructed by adding the value added of each 2-digit industry that belongs to an aggregate product. For example, in order to calculate the value added of the exportable good, I add the value added of the following industries SIC 20, SIC 28, SIC 35, SIC 36, SIC 37 and SIC 38\(^{52}\) that have been termed as exportable following the above rule. The aggregate price of each aggregate

\(^{52}\)Look at Table 1, for an explanation of the SIC codes of 2-digit industries.
good, $P_A$; $A$ indicates the three aggregate outputs $E, I, N$, is a weighted average of the prices of all 2-digit industries, $P_i$; $i$ indicates a 2-digit industry, that belong to an aggregate good, with weights the share of each 2-digit industry, $\frac{VAD_i}{\sum VAD_i}$. The aggregate quantity of output is calculated by dividing the value of each aggregate good by its aggregate price, $Q_A = \frac{VAD_A}{P_A}$. Similarly, the volume of net exports is calculated by dividing the value of net exports for each aggregate good by its corresponding aggregate price.

After aggregation is completed, we also get the net exports in constant 1970 prices for the exportable, importable and nontradable goods for the US economy as Figure 3.4 portrays. The net exports of the nontradable varied for the period 1965-1982, had a maximum of 1.6 billion USD in 1966 and decreased to 81 millions in 1972 but were positive for all of the first eighteen years in the sample. Then from 1983 until 1987 the net exports of the nontradable declined significantly and reached a minimum of 4.26 billion USD of net imports in 1987. The last four years the net exports of the nontradable good increased, but still the US was net importing the nontrdable good. As expected the net exports of the importable were negative for all the years in the sample, implying that they were actually net imported in the US economy. They declined steadily from 5.4 billion USD net imports in 1965 for most of the years until 1986, when they reached a minimum of almost 31 billion USD. For the remaining five years they experienced an increase in their net exports, reaching to 23 billion USD of net imports in 1991. Finally, from Figure 3.4 we observe that the net exports of the exportable good were positive for the first nineteen years in the sample. US was net exporting 10.2 billion USD in 1965 of the exportable good, then the net exports of the exportable good were mainly increasing until 1980, when they reached a maximum of 18.5 billion of USD and then they began to decrease till 1986, reaching a minimum of 28.3 billion of USD of net imports. The last five years in the sample the net exports of the

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53 This seems to be the result of the significant decline for most of the 2 digit SIC industries of the nontradable as Figure 3.3 shows.
54 From Figure 3.2 we see that all the 2 digit SIC industries that are part of the importable good followed a very similar pattern.
55 From Figure 3.1 we see that this decline of the net exports of the aggregate exportable good seems to be driven by the significant drop in the net exports of three 2 digit SIC industries, SIC 35, SIC 36 and SIC 37.
exportable increased rapidly, as a consequence in 1991 US was again net exporting the
exportable good. Hence, it is clear from Figure 3.4 that the US economy was in trade
deficit for the second half of the '80s in the sample, since all the three aggregate goods
were net imported.

Data for consumption are generally not available and when available, they are usu­
ally not reliable. For these reasons, the volume of consumption for each of the goods is
calculated as the difference between the volume of output and net exports:

\[ c = y - T \]  

(3.19)

where \( y \) and \( c \) is the vector of production and consumption respectively.

### 3.5 Estimation

I estimate the equation sets (3.11) and (3.12) together with the parameter restrictions
(3.10) in order to get the parameters of the revenue function. Although only estimates
of (3.12) are necessary for the decomposition. I am estimating both equations (3.11)
and (3.12), because it improves the efficiency of the estimated parameters. The reason
is that the number of estimated parameters does not alter when equation (3.12) is
jointly estimated with equation (3.11) and as a result the degrees of freedom\(^{56}\) increase.
The errors related to equations (3.11) and (3.12) are assumed to be identically and
independently distributed with zero expected value and a positive definite covariance
matrix. These equations are jointly estimated by the iterative Three Stages Least
Square (3SLS) estimator\(^{57}\) applied to data for the US manufacturing sector over the
period from 1965 to 1991. There are six equations, three relating to outputs and three
relating to factor rewards. The goods are exportables, importables and non-tradeable
and the three factors of production are capital, skilled and unskilled labor.

\(^{56}\)The degrees of freedom, under the 3SLS estimation, are defined as the product of the number of
years observed times the number of equations estimated minus the number of the estimated parameters.

\(^{57}\)I use one year lagged values of product prices and endowments as instruments.
Table 3.2 shows the estimated parameters of the revenue function and the $R^2$ for the system of the six equations. Most of the parameters are significant and the system $R^2$ is 0.98, indicating that the overall estimation seems to appear robust. Linear homogeneity in prices ($p$) and inputs ($v$) is satisfied, but initially convexity for prices was not satisfied and was imposed following Diewert and Wales (1987). Three hypotheses have been tested using the Wald test that follows a chi-squared distribution with $n$ degrees of freedom $X^2(n)$, where $n$ is the number of restrictions imposed. The first is the hypothesis of no convexity, in order to check whether the imposed convexity is accepted by the data. At 5% significance level and 2 degrees of freedom I reject the null of no convexity, since the Wald Statistic, 24.7, is greater than the critical value of 5.991. The second test is implicitly testing the assumption of the more general technology on the production side of the economy that allows for the presence of jointness in output quantities. The null hypothesis of a production technology without jointness in output quantities is rejected at a 5% level and 2 degrees of freedom, because the Wald Statistic, 30.2, is greater than the critical value of 5.991. The last hypothesis that is tested is that of a specification for the revenue function that would not involve technological change as one of the explanatory variables. Once again the null hypothesis of no-technological change is rejected at the 5% level of significance, since the chi-square critical value with two degrees of freedom is smaller, 5.991, than the Wald Statistic of 74.1, implying that specification that includes technological change is consistent with the actual data.

Table 3.4 and Table 3.5 show the mean price elasticities of output ($\epsilon_{ih}$) and the input ($\omega_{ih}$) and technology ($\omega_{it}$) elasticities of output, respectively. All own price elasticities are positive, which is a necessary but not sufficient condition for convexity in prices. They range from 0.222 for the importable good to 0.022 for the exportable, which implies that the supply for all goods is inelastic. A rise in the price of the importable good decreases the supply of both the exportable and the non-tradable good, suggesting that the importable good is a substitute in the production with both the exportable and non-tradable good. While an increase in the price of the exportable leads to an increase in the supply of the non-tradable, which implies that the two goods are complements in the production.

All input elasticities of output are positive, with the exception of the elasticity of
the non-tradable with respect to unskilled labour indicating that a 1% increase in the
endowments of unskilled labour for the economy reduces the supply of non-tradable
good by almost 0.16%. From the elasticities of output with respect to technological
change it is evident that on average only the exportable good has gained from tech­
nological improvement, while the other two goods have been affected adversely. More
specifically, a 1% increase in technological change increases on average the supply of
the exportable by 0.028%, while at the same time reduces the supply of the importable
and non-tradable by 0.013% and 0.007%, respectively.

The system of equations (3.17) is estimated together with restrictions (3.14) and
(3.18) in order to obtain the estimates of the parameters for the Marshallian demand
functions using the Three Stages Least Square (3SLS) estimator\textsuperscript{58} for the same period
as above. Three equations of exportable, importable and non-tradable Marshallian
demand functions are estimated. Table 3.3 shows the estimates of the parameters of
the Marshallian demand functions and the $R^2$ for the system of equations. Most of
the estimates are significant and the system $R^2$ is 0.97. The assumption of linear
homogeneity in product prices is satisfied. But concavity for product prices ($p$) failed
initially and was imposed following the method proposed by Diewert and Wales (1987).
The null hypothesis of no concavity is rejected at a 5% level, since the Wald Statistic,
42.4, is greater than the critical value of the chi-square with two degrees of freedom,
5.991. This implies that the imposed concavity of the Marshallian demand function with
respect to the product prices is satisfied by the data. In addition the null hypothesis
of no shifts in preferences over time is also rejected, supporting the initial specification
for the Marshallian demand functions that involved such changes in preferences.

Table 3.6 presents the Marshallian demand elasticities with respect to prices, tech­
nology\textsuperscript{59} and income. All own prices elasticities are negative and for the case of the
exportable and non-tradable goods their demand is elastic. That is changes on the
prices of tradable and non-tradable goods cause amplified changes on their demands,
respectively. Exportable and non-tradable goods are substitutes, while each other pair
of goods is characterised by complementarity. From the technology elasticities of Mar­
shallian demand is evident that on average consumers have shifted their preferences

\textsuperscript{58} I use one year lagged values of product prices and income as instruments.

\textsuperscript{59} More precisely, changes in preferences over time.
away from importables goods and towards either exportable or non-tradable ones, but
the magnitude of these effects is quite small. Finally, the income elasticities of all three
goods are positive, suggesting that all of them appear to be normal goods as expected.
The highest average income elasticity is observed for the importable good, 1.126. While
the income elasticities of exportable and non-tradable are quite similar, 0.989 for the
exportable and 0.863 for the non-tradable.

3.6 Decomposition of the Growth Rates in US Commodity Net Exports

In this section I decompose the growth rate of the volume of net exports for the three
aggregate goods of US manufacturing, exportable, importable and non tradable, into
their five components using equation (3.41) from the Appendix 3.A. Tables 3.7, 3.8
and 3.9 present on the first two columns the growth rate of the fitted volume of net ex­
ports (Fitted) and its approximation (Approximated) using equation (3.41), while the
last five columns present the five components of the decomposition of equation (3.8) in
growth format: a) the terms of trade component (TOT), b) the endowments component
(Endowments), c) the technology component in production (Production Technology),
d) the change in preferences over time (Preferences) and e) the income component
(Income) for the exportable (E), importable (I) and non-tradable (N) good respecti­
vally (i = E, I, N).

From Table 3.7, we see that the average growth rate of the fitted volume of net
exports and the average growth rate of the approximation by equation (3.41) have the
same sign for each sub-period and are also very close in terms of magnitude. This
suggests that the approximation used in equation (3.41) is a good representation of
the estimated model. The volume of net export for the exportable good increased by
an average of 48% for the period 1966-1978. If only product prices had changed then
the net exports of the exportables would have increased by 258 %, as it is seen from
the terms of trade (TOT) component. The endowments component has increased the
growth rate of net exports of the exportable by 42%, ceteris paribus. The effect of technological change in the production raised the growth of net exports by 128% while the effect of changes in preferences is also positive, but smaller in magnitude 22%. The only negative effect was observed for the income component that resulted to a decrease of net exports of exportables by 403%. Hence, the strong positive effect of the first four components on the growth rate of net exports for the exportable was weakened by the very strong negative income effect. For the period 1979-1991 the volume of net exports decreased on average by 29% and this is consistent with the actual drop of the net exports for the exportable good as it is shown in Figure 3.4. This is the result of a relative worsening of the terms of trade component, despite the much smaller magnitude of the income component compared with the previous period, while all the other three components remained relatively stable. The terms of trade component led to an increase of net exports by 21%, ceteris paribus, for the years between 1979 and 1991, while for the previous period its contribution was almost twelve times greater. It worths noticing that the terms of trade and income component were the highest among all products for the period 1966-1978.

The average growth rate of the volume of net exports for the importable good and its components are presented in Table 3.8. The values of the first two columns, indicating the fitted growth rate and the approximated growth rate of the net exports of the importable from equation (3.8) are very close. This is similar to the case of the exportable good and suggests that the approximation implemented in equation (3.A1) is very close to the estimated model. The net exports of the importable good were decreasing in a stable rate over the two sub-periods. An approximately 20% and 14% decrease in the net exports of the importable good for the first and second sub-period, respectively. The terms of trade component experienced a relative worsening for the importable good, since it fell from a 48% increase for the years 1966-1978 to a 34% increase for the second sub-period. Similarly, the Endowments and Preferences components were positive but decreased in magnitude over the two sub-periods. From 26% to 10% for the first and from 4% to 3% for the second. In the case of the importable good the Production Technology component was negative in both sub-periods, suggesting that technical change is regressive for the production of the importable good. Hence, if
only technical change had occurred then the net exports of the importable would have fallen by 9% on average for the whole period. The income component was negative as in the case of the exportable, but much smaller in magnitude, an average of 70% for the period 1966-1991.

Table 3.9 reports the average growth rate of the net exports for the non-tradable good. They are positive and much higher in magnitude relative to the growth rate of the two other goods. A possible explanation could be along the lines of a "catching-up" argument. Since the level of the net exports of the non-tradable were much smaller than the other goods, then it could be expected that their net exports grow faster. In particular, they grew by 106% on average over the period 1966-1991. The terms of trade component was positive and high in magnitude, 153%, but smaller than the one of the exportable. A similar story for the income effect that it was negative, -193%, but smaller in magnitude than in the case of the first good. The effect of technical change in production was negative and very big in magnitude, -180%, suggesting that technical change has worsened the productive capabilities of the non-tradable sector. Also the preferences component was negative, -120%, implying that the consumers changed positively their preferences towards the non-tradable good that resulted in higher consumption and lower net exports, ceteris paribus. Finally, the Endowments component was positive and very large in magnitude. In a hypothetical scenario that only endowments had been altered in US manufacturing for the period 1966-1991, then the net exports of the non-tradable good would have increased by 447%.

3.7 Conclusion

In this chapter, I extend the work of Dixit and Woodland (1982), on the factors that determine changes on the volume of net exports (T). First, the model focuses on a trade equilibrium that allows trade imbalances. Second, it incorporates the effect of changes in commodity prices, while it does not rule out the jointness in output quantities. A general equilibrium analysis is implemented where the revenue (GDP) function and the expenditure function are estimated for the US economy for the period 1963 to
1991. Then a decomposition of the changes of the net exports is implemented. It involves a terms of trade component, an endowment component, a technological change both in production and consumption and an income component. I also allow for a more general technology in the production side that permits the presence of jointness in output quantities (see Woodland 1977 and Kohli 1991). This broader definition of production’s technology that is usually avoided in return of more tractable theoretical predictions is supported by the data.

I follow the empirical implementation of Harrigan (1997) and Kohli (1992). I first estimate a system of output equations derived from a Symmetric Normalised Quadratic Revenue function introduced by Kohli (1991, 1993) using a Three Stages Least Square (3SLS) estimation. In addition a system of Marshallian demand functions derived from an expenditure function of a Gorman-Polar type, (Diewert and Wales 1988) is estimated using again 3SLS. Then, it is possible to calculate the fitted volume of net exports for the economy and to proceed to its empirical decomposition into a terms of trade component, an endowment component, a technology component in production, a change in preferences component and an income component as shown in equation (3.8).

It is evident that the mainly positive growth rate of the net exports of the exportable good for the first thirteen years is explained by better terms of trade combined with a strong positive production technology effect, despite the highest income effect observed for all the three goods and periods. The following time period the volume of net exports for the exportable decreased by 28% mainly due to a relative worsening in the terms of trade of the exportable good, despite a weaker negative income effect.

On the other hand, the negative growth rate of the net exports of the importable good are attributed to a sizeable negative income effect, a slower improvement in the terms of trade for the importable and a negative production technology effect. The negative sign of the production technology component that implies a regressive technical change for the production of the importable is consistent with the argument that the import-competing sector in the US has lost in terms of competitiveness the last years due to adverse technological change. This results into diversion of resources from the import-competing sector to the rest of the economy and consequently to a decrease in the volume of its net exports.
The net export of the non-tradable grew with a high rate of 106% over the whole period. This is explained by a very strong positive terms of trade component of 153% combined with a positive and huge Endowments component of a 447% increase, despite the negative and high in magnitude effects of the rest three components. In particular, the negative sign for the Preferences component implies that domestic consumers have continuously altered their preferences in favour of the non-tradable good.

From Tables 3.7, 3.8 and 3.9 we see that the growth rate of the volume of net exports was positive for the exportable and negative for the importable good on average for the whole period. But the importable experienced a higher growth in absolute terms, which implies that the net imports of the importable grew faster than the net exports of the exportable. For the same period, the growth rate of the volume of trade for the non-tradable was very high. This suggests that the composition of net exports between the three goods has changed over time, with the non-tradable to have gained a bigger share. Finally, the probably paradoxical result of the decreasing volume of trade for the exportable good for over the period 1979-1991 can possibly be explained by the big and increasing in absolute terms trade deficit of the US economy.
Appendix 3.A

Let $\text{diag}(T)$, $Y$, $P$, $CM$, $V$, $X$ and $M$ indicate the diagonal matrix of net exports, production of goods, product prices, Marshallian demands, endowments, time and income respectively. Rearranging equation (8) I get

$$dT = \left( \frac{\partial y}{\partial p} - \frac{\partial c^M}{\partial p} \right) dp + \frac{\partial y}{\partial v} dv + \frac{\partial y}{\partial t} dt - \frac{\partial c^M}{\partial m} dm - \frac{\partial c^M}{\partial t} dt$$

$$\text{[diag}(T)\text{]}^{-1} dT = \text{[diag}(T)\text{]}^{-1} \left[ YY^{-1} \frac{\partial y}{\partial p} PP^{-1} - CM \left[ C^M \right]^{-1} \frac{\partial c^M}{\partial p} PP^{-1} \right] dp$$

$$+ \text{[diag}(T)\text{]}^{-1} YY^{-1} \frac{\partial y}{\partial v} VV^{-1} dv$$

$$+ \text{[diag}(T)\text{]}^{-1} YY^{-1} XX^{-1} \frac{\partial y}{\partial t} dt$$

$$- \text{[diag}(T)\text{]}^{-1} C^M CM MM^{-1} \frac{\partial c^M}{\partial m} dm$$

$$- \text{[diag}(T)\text{]}^{-1} C^M \left[ C^M \right]^{-1} XX^{-1} \frac{\partial c^M}{\partial t} dt$$

$$\hat{T} = \left[ Y \text{[diag}(T)\text{]}^{-1} \epsilon_{yp} - C^M \text{[diag}(T)\text{]}^{-1} \epsilon_{cp}^M \right] \hat{p}$$

$$+ Y \text{[diag}(T)\text{]}^{-1} \epsilon_{vy} \hat{v} + Y \text{[diag}(T)\text{]}^{-1} \epsilon_{yt} \hat{t}$$

$$- C^M \text{[diag}(T)\text{]}^{-1} \epsilon_{cm} \hat{m} - C^M \text{[diag}(T)\text{]}^{-1} \epsilon_{ct} \hat{t}$$

(A1)

where $\hat{T}$, $\hat{p}$, $\hat{v}$, $\hat{t}$ and $\hat{m}$ indicate the growth rate of net exports, product prices, endowments, technological change and income respectively. While $\epsilon_{yp}$, $\epsilon_{cp}^M$, $\epsilon_{vy}$, $\epsilon_{yt}$, $\epsilon_{cm}^M$ and $\epsilon_{ct}^M$ are the elasticity of output with respect to product prices, the elasticity of consumption with respect to product prices, the elasticity of output with respect to inputs, the elasticity of output with respect to technical change, the Marshallian elasticity of consumption with respect to income and the Marshallian elasticity of consumption with respect to technological change. Equation (A1) is the equivalent of equation (8) in a growth format. The five components are:

- the terms of trade component ($TET$) is $\left[ Y \text{[diag}(T)\text{]}^{-1} \epsilon_{yp} - C^M \text{[diag}(T)\text{]}^{-1} \epsilon_{cp}^M \right] \hat{p}$.

- the Endowments component is $Y \text{[diag}(T)\text{]}^{-1} \epsilon_{vy} \hat{v}$.

- the Production Technology component is $Y \text{[diag}(T)\text{]}^{-1} \epsilon_{yt} \hat{t}$.

- the Income component is $- C^M \text{[diag}(T)\text{]}^{-1} \epsilon_{cm} \hat{m}$ and

- the Marshallian component is $- C^M \text{[diag}(T)\text{]}^{-1} \epsilon_{ct} \hat{t}$.  

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• the Preferences component is $-CM \left[ \text{diag} \left( T \right) \right]^{-1} \varepsilon_{ct}^{\text{M}}\tilde{t}$. 
### Table 3.1: SIC Codes for Aggregate Goods

<table>
<thead>
<tr>
<th>Aggregate Goods</th>
<th>SIC Code Category</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Exportable</strong></td>
<td></td>
</tr>
<tr>
<td>Food &amp; Kindred Products (SIC 20)</td>
<td></td>
</tr>
<tr>
<td>Chemicals &amp; Allied Products (SIC 28)</td>
<td></td>
</tr>
<tr>
<td>Industrial &amp; Commerce Machinery &amp; Computer Equipment (SIC 35)</td>
<td></td>
</tr>
<tr>
<td>Electronic &amp; Other Electric Equipment (SIC 36)</td>
<td></td>
</tr>
<tr>
<td>Transportation Equipment (SIC 37)</td>
<td></td>
</tr>
<tr>
<td>Instruments, Photographic, Medical &amp; Optical Goods (SIC 38)</td>
<td></td>
</tr>
<tr>
<td><strong>Importable</strong></td>
<td></td>
</tr>
<tr>
<td>Textile Mill Products (SIC 22)</td>
<td></td>
</tr>
<tr>
<td>Apparel &amp; Other Finished Products (SIC 23)</td>
<td></td>
</tr>
<tr>
<td>Lumber &amp; Wood Products (SIC 24)</td>
<td></td>
</tr>
<tr>
<td>Paper &amp; Allied Products (SIC 26)</td>
<td></td>
</tr>
<tr>
<td>Petroleum Refining &amp; Related Industries (SIC 29)</td>
<td></td>
</tr>
<tr>
<td>Leather &amp; Leather Products (SIC 31)</td>
<td></td>
</tr>
<tr>
<td>Primary Metal Industries (SIC 33)</td>
<td></td>
</tr>
<tr>
<td>Miscellaneous Manufacturing Industries (SIC 39)</td>
<td></td>
</tr>
<tr>
<td><strong>Non-tradable</strong></td>
<td></td>
</tr>
<tr>
<td>Tobacco Products (SIC 21)</td>
<td></td>
</tr>
<tr>
<td>Furniture &amp; Fixtures (SIC 25)</td>
<td></td>
</tr>
<tr>
<td>Printing, Publishing &amp; Allied Industries (SIC 27)</td>
<td></td>
</tr>
<tr>
<td>Rubber &amp; Miscellaneous Plastic Products (SIC 30)</td>
<td></td>
</tr>
<tr>
<td>Stone, Clay, Glass &amp; Concrete Products (SIC 32)</td>
<td></td>
</tr>
<tr>
<td>Fabricated Metal Products, Except Machinery (SIC 34)</td>
<td></td>
</tr>
</tbody>
</table>

**Figure 3.1:** Net Exports of 2-digit SIC industries that constitute the exportable good in billion of USD.

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Figure 3.2: Net Exports of 2-digit SIC industries that constitute the importable good in billion of USD.

Figure 3.3: Net Exports of 2-digit SIC industries that constitute the nontradable good in billion of USD.
Table 3.2: Parameter Estimates of Revenue Function

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Estimate</th>
<th>t-stat</th>
<th>Parameter</th>
<th>Estimate</th>
<th>t-stat</th>
</tr>
</thead>
<tbody>
<tr>
<td>$a_{EE}$</td>
<td>28326</td>
<td>0.392</td>
<td>$c_{IK}$</td>
<td>20818</td>
<td>2.264</td>
</tr>
<tr>
<td>$a_{EI}$</td>
<td>-21271</td>
<td>-0.598</td>
<td>$c_{IS}$</td>
<td>46727</td>
<td>5.079</td>
</tr>
<tr>
<td>$a_{EN}$</td>
<td>-7055</td>
<td>-0.184</td>
<td>$c_{IU}$</td>
<td>1934</td>
<td>0.259</td>
</tr>
<tr>
<td>$a_{II}$</td>
<td>15973</td>
<td>0.966</td>
<td>$c_{NK}$</td>
<td>75220</td>
<td>6.574</td>
</tr>
<tr>
<td>$a_{IN}$</td>
<td>5298</td>
<td>0.224</td>
<td>$c_{NS}$</td>
<td>14737</td>
<td>1.095</td>
</tr>
<tr>
<td>$a_{NN}$</td>
<td>1757</td>
<td>0.119</td>
<td>$c_{NU}$</td>
<td>-14350</td>
<td>-1.696</td>
</tr>
<tr>
<td>$e_{K}$</td>
<td>-1342</td>
<td>-3.836</td>
<td>$b_{KK}$</td>
<td>-3762</td>
<td>-0.882</td>
</tr>
<tr>
<td>$e_{S}$</td>
<td>2080</td>
<td>9.705</td>
<td>$b_{KS}$</td>
<td>-6068</td>
<td>-3.305</td>
</tr>
<tr>
<td>$e_{U}$</td>
<td>-737</td>
<td>-2.349</td>
<td>$b_{KU}$</td>
<td>9830</td>
<td>1.641</td>
</tr>
<tr>
<td>$d_{E}$</td>
<td>4470</td>
<td>4.449</td>
<td>$b_{SS}$</td>
<td>-9785</td>
<td>-1.589</td>
</tr>
<tr>
<td>$d_{I}$</td>
<td>-1704</td>
<td>-2.735</td>
<td>$b_{SU}$</td>
<td>15854</td>
<td>3.125</td>
</tr>
<tr>
<td>$d_{N}$</td>
<td>-2766</td>
<td>-4.943</td>
<td>$b_{UU}$</td>
<td>-25685</td>
<td>-5.926</td>
</tr>
<tr>
<td>$c_{EK}$</td>
<td>-20389</td>
<td>-1.712</td>
<td>$h_{T}$</td>
<td>808</td>
<td>1.006</td>
</tr>
<tr>
<td>$c_{ES}$</td>
<td>30910</td>
<td>1.627</td>
<td>$h_{TU}$</td>
<td>134</td>
<td>2.584</td>
</tr>
<tr>
<td>$c_{EU}$</td>
<td>72065</td>
<td>6.156</td>
<td>System $R^2$</td>
<td>0.98</td>
<td></td>
</tr>
</tbody>
</table>

Hypothesis Testing

No convexity Wald Statistic $\chi^2_{0.5}$
Wald(2) = 24.7 5.991
Non-jointness Wald(2) = 30.2 5.991
No technological change Wald(2) = 74.1 5.991

Figure 3.4: Net exports of the exportable, importable and nontradable goods in billion of USD 1970 prices.
Table 3.3: Parameter Estimates of Expenditure Function

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Estimate (t-stat)</th>
<th>Parameter</th>
<th>Estimate (t-stat)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$a_E$</td>
<td>-4624 (-0.226)</td>
<td>$\gamma_{EN}$</td>
<td>0.698 (2.154)</td>
</tr>
<tr>
<td>$a_I$</td>
<td>-14683 (-1.132)</td>
<td>$\gamma_{II}$</td>
<td>-0.220 (-1.066)</td>
</tr>
<tr>
<td>$a_N$</td>
<td>19307 (1.828)</td>
<td>$\gamma_{IN}$</td>
<td>-0.297 (-1.609)</td>
</tr>
<tr>
<td>$\beta_E$</td>
<td>0.530 (4.453)</td>
<td>$\gamma_{NN}$</td>
<td>-0.401 (-2.653)</td>
</tr>
<tr>
<td>$\beta_I$</td>
<td>0.369 (5.050)</td>
<td>$\delta_{Et}$</td>
<td>-0.41E-02 (-0.736)</td>
</tr>
<tr>
<td>$\beta_N$</td>
<td>0.099 (1.671)</td>
<td>$\delta_{It}$</td>
<td>-0.14E-02 (-0.433)</td>
</tr>
<tr>
<td>$\gamma_{EE}$</td>
<td>-1.216 (1.330)</td>
<td>$\delta_{Ni}$</td>
<td>0.52E-02 (2.121)</td>
</tr>
<tr>
<td>$\gamma_{EI}$</td>
<td>0.517 (1.330)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Hypothesis Testing

<table>
<thead>
<tr>
<th>Test Statistic</th>
<th>$X^2_{0.5}$</th>
<th>System $R^2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>No concavity</td>
<td>Wald(2) = 42.4</td>
<td>5.991</td>
</tr>
<tr>
<td>No shifts in preferences</td>
<td>Wald(2) = 19.3</td>
<td>5.991</td>
</tr>
</tbody>
</table>

Table 3.4: Price Elasticities of Output ($\epsilon_{i,t}$)
(Mean values, Std. Error in parenthesis)

<table>
<thead>
<tr>
<th>Output</th>
<th>$\epsilon_{iE}$</th>
<th>$\epsilon_{iI}$</th>
<th>$\epsilon_{iN}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Exportable</td>
<td>0.022 (0.003)</td>
<td>-0.046 (0.005)</td>
<td>0.023 (0.002)</td>
</tr>
<tr>
<td>Importable</td>
<td>-0.109 (0.006)</td>
<td>0.222 (0.015)</td>
<td>-0.113 (0.011)</td>
</tr>
<tr>
<td>Non-tradable</td>
<td>0.057 (0.005)</td>
<td>-0.115 (0.007)</td>
<td>0.058 (0.002)</td>
</tr>
</tbody>
</table>

Table 3.5: Input & Time Elasticities of Output ($\omega_{i,t}$)
(Mean values, Std. Error in parenthesis)

<table>
<thead>
<tr>
<th>Output</th>
<th>Capital $\omega_{IK}$</th>
<th>Skilled Labour $\omega_{IS}$</th>
<th>Unskilled Labour $\omega_{IU}$</th>
<th>Technology $\omega_{It}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Exportable</td>
<td>0.122 (0.027)</td>
<td>0.581 (0.088)</td>
<td>0.296 (0.114)</td>
<td>0.028 (0.001)</td>
</tr>
<tr>
<td>Importable</td>
<td>0.685 (0.092)</td>
<td>0.093 (0.007)</td>
<td>0.222 (0.088)</td>
<td>-0.013 (0.003)</td>
</tr>
<tr>
<td>Non-tradable</td>
<td>0.210 (0.035)</td>
<td>0.948 (0.040)</td>
<td>-0.159 (0.073)</td>
<td>-0.007 (0.004)</td>
</tr>
</tbody>
</table>
Table 3.6: Marshallian Elasticities ($\eta_{ih}$)
(Mean values, Std. Error in parenthesis)

<table>
<thead>
<tr>
<th>Quantity</th>
<th>Exportable $\eta_E$</th>
<th>Importable $\eta_I$</th>
<th>Non-tradable $\eta_N$</th>
<th>Technology $\eta_T$</th>
<th>Income $\eta_{im}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Exportable</td>
<td>-1.155 (0.023)</td>
<td>-0.137 (0.014)</td>
<td>0.303 (0.017)</td>
<td>0.003 (4.80E-04)</td>
<td>0.989 (0.013)</td>
</tr>
<tr>
<td>Importable</td>
<td>-0.322 (0.028)</td>
<td>-0.496 (0.014)</td>
<td>-0.308 (0.016)</td>
<td>-0.012 (0.003)</td>
<td>1.126 (0.020)</td>
</tr>
<tr>
<td>Non-tradable</td>
<td>0.779 (1.449)</td>
<td>-0.323 (0.796)</td>
<td>-1.320 (0.659)</td>
<td>0.009 (0.002)</td>
<td>0.863 (0.054)</td>
</tr>
</tbody>
</table>
### Table 3.7: Decomposition for the Growth in Net Exports for the Exportable
average growth rate

<table>
<thead>
<tr>
<th>Year</th>
<th>Fitted</th>
<th>Approximated</th>
<th>TOT</th>
<th>Endowments</th>
<th>Production Technology</th>
<th>Preferences</th>
<th>Income</th>
</tr>
</thead>
<tbody>
<tr>
<td>1966-1978</td>
<td>55.91</td>
<td>47.58</td>
<td>258.28</td>
<td>42.19</td>
<td>128.02</td>
<td>22.09</td>
<td>-403.00</td>
</tr>
</tbody>
</table>

### Table 3.8: Decomposition for the Growth in Net Exports for the Importable
average growth rate

<table>
<thead>
<tr>
<th>Year</th>
<th>Fitted</th>
<th>Approximated</th>
<th>TOT</th>
<th>Endowments</th>
<th>Production Technology</th>
<th>Preferences</th>
<th>Income</th>
</tr>
</thead>
<tbody>
<tr>
<td>1966-1978</td>
<td>-20.63</td>
<td>-20.02</td>
<td>47.50</td>
<td>25.81</td>
<td>-12.23</td>
<td>3.97</td>
<td>-85.07</td>
</tr>
</tbody>
</table>

### Table 3.9: Decomposition for the Growth in Net Exports for the Non Tradable
average growth rate

<table>
<thead>
<tr>
<th>Year</th>
<th>Fitted</th>
<th>Approximated</th>
<th>TOT</th>
<th>Endowments</th>
<th>Production Technology</th>
<th>Preferences</th>
<th>Income</th>
</tr>
</thead>
<tbody>
<tr>
<td>1966-1978</td>
<td>28.46</td>
<td>56.34</td>
<td>121.21</td>
<td>537.65</td>
<td>-232.80</td>
<td>-131.21</td>
<td>-238.50</td>
</tr>
<tr>
<td>1979-1991</td>
<td>152.23</td>
<td>155.23</td>
<td>185.60</td>
<td>356.96</td>
<td>-128.76</td>
<td>-108.81</td>
<td>-149.23</td>
</tr>
<tr>
<td>1966-1991</td>
<td>90.35</td>
<td>106.05</td>
<td>153.40</td>
<td>447.30</td>
<td>-180.78</td>
<td>-120.01</td>
<td>-193.87</td>
</tr>
</tbody>
</table>
References


Centre for International Data at UC Davis.


U.S. Bureau of Economic Analysis.
