TECHNOLOGY TRANSFER TO DEVELOPING COUNTRIES: A QUANTITATIVE APPROACH

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DEDICATED TO

MY DEAR WIFE, **SHAHLA**

MY DEAR DAUGHTER, **SHAHRZAD**

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IN THE NAME OF THE GOD

ABSTRACT

Technology transfer is extensively believed to be one of the major debates in the literature on development economics. The experiences of some successful countries in rapid economic and industrial development, in particular, some East-Asian Newly Industrialised Countries (NICs) show that the acquisition of a significant amount of foreign technology has played a crucial role. This crucial role includes promoting their managerial and technical expertise as well as increasing their productivity level through the adoption of a set of appropriate policies and strategies. These experiences could have valuable lessons for other countries who wish to follow similar strategies to achieve rapid industrialisation and technological development.

Although many Less Developed Countries (LDCs) have realised the great importance of technological transformation for their rapid economic and industrial development, they have not designed effective and efficient policies for the transfer of appropriate and high-level technologies.

The present empirical investigation is intended to contribute to the large existing literature on technological transfer and the role that Multinational Corporations (MNCs) play in this. Its major contribution lies in demonstrating rigorously that the integration of foreign technologies is greatly affected by the socio-economic conditions of the recipient countries.

The present study attempts to identify the main socio-economic characteristics of countries involved in assimilating transferred technology. It first identifies the critical success or failure factors for effective technology transfer and the rapid industrialisation of the LDCs in general. Then, it provides a quantifiable metric index of the rate of the technological absorption. Selection of relevant variables and choosing the sample of countries are summarised. The model, which is based on the multiple regression analysis as well as other statistical techniques, is identified.

The four-variable-model derived from the stepwise regression results gave a statistically significant R-sq = 70.71% and R-sq (adj) = 66.7% and satisfies the principle of parsimony, was chosen as the preferred model. This has as explanatory variables transport and communications and gross national savings as economic indicators - Christian religion and natural disasters

(negative concept) as social indicators. The results suggest that countries with the above indicators are more able to absorb and integrate foreign technologies. In general, the results reveal that the rate of technology integration varies greatly with the level of socio-economic development.

Some intangible factors that cannot as yet be quantified and may be expected to have significant effects on the rate of technological integration, such as political and managerial factors are discussed.

The analysis of results is concluded with some recommendations and suggestions derived from the research findings and results for the effective and successful technology transfer of LDCs along with the technology transfer in Africa, problems of AIDS and its impact on African development.

LIST OF ABBREVIATIONS

AIDS	ACQUIRED IMMUNE DEFICIENCY SYNDROME
FDI	FOREIGN DIRECT INVESTMENT
GDP	GROSS DOMESTIC PRODUCT
GDI	GROSS DOMESTIC INVESTMENT
GIP	GROSS INDUSTRIAL PRODUCT
GNP	GROSS NATIONAL PRODUCT
GNS	GROSS NATIONAL SAVING
HEW	HEALTH, EDUCATION & WELFARE
HIV	HUMAN IMMUNODEFICIENCY VIRUS
IBRD	INTERNATIONAL BANK OF RECONSTRUCTION & DEVELOPMENT
IMF	INTERNATIONAL MONETARY FUND
LDCs	LESS DEVELOPED COUNTRIES
MNCs	MULTINATIONAL CORPORATIONS (COMPANIES)
MNEs	MULTINATIONAL ENTERPRISES
NICs	NEWLY INDUSTRIALISED COUNTRIES
NIEs	NEWLY INDUSTRIALISED ECONOMIES
OECD	ORGANISATION FOR ECONOMIC CO-OPERATION & DEVELOPMENT
OPEC	ORGANISATION OF PETROLEUM EXPORTING COUNTRIES
PQLI	PHYSICAL QUALITY OF LIFE INDEX
R & D	RESEARCH & DEVELOPMENT
SITC	STANDARD INTERNATIONAL TRADE CLASSIFICATION
TNCs	TRANSNATIONAL CORPORATIONS
UN	UNITED NATIONS
UNAIDS	JOINT UNITED NATIONS PROGRAMME ON HIV/AIDS
UNCTAD	UNITED NATIONS CONFERENCE ON TRADE & DEVELOPMENT
UNCTC	UNITED NATIONS CENTRE FOR TRANSNATIONAL CORPORATIONS
UNDP	UNITED NATIONS DEVELOPMENT PROGRAMME
UNESCO	UNITED NATIONS EDUCATIONAL, SCIENTIFIC & CULTURAL ORGANISATION
UNIDO	UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANISATION
UNRISD	UNITED NATIONS RESEARCH INSTITUTE FOR SOCIAL DEVELOPMENT
WHO	WORLD HEALTH ORGANISATION

CHAPTER 1: Introduction

1.1 Introduction

It is widely acknowledged that transfer of technology has played a key role in the economic and industrial development of any nation. It seems that Less Developed Countries (LDCs) can increase their productivity and efficiency levels through the acquisition of technical knowledge and skills from the developed countries. The effective transfer of technology enables these countries to utilise their natural and human resources efficiently through transformation of inputs into outputs. It also enables them to build up their technological capabilities by importing and adopting foreign technology. Technology transfer is also seen as an important strategic variable which must be integrated into the national development planning of LDCs. As the experiences of some East Asian countries during the past three decades show, these countries could increase their output, upgrade the skills of their labour force, and accelerate the process of industrialisation through the adoption, adaptation, and absorption of imported technologies.

Technological change has also played a key role in the overall economic and industrial growth of developed countries in the past. For example, it is estimated that technological progress contributed as much as 65% to Japanese economic growth. Moreover, about 29% of the growth in manufacturing industry in Japan during the period between 1955-1979 could be attributed to technological progress [1].

The fact that the current developed countries could increase their technological levels over the last two centuries indicate that LDCs can also catch up with technologically advanced countries. It can be said that LDCs in the current situation can take the most advantage from the availability of existing technological resources and therefore do not need to reinvent the wheel.

The transfer of technology has introduced high-productivity techniques and in many cases encouraged technical change in LDCs. The acquisition of foreign technology can also contribute to improving competitiveness in the local as well as the international markets for these countries. However, while the development of indigenous technology should be encouraged, technology transfer can be considered as a vital process of industrialisation for

LDCs. In other words, industrialisation is a process of acquiring technological capabilities in the direction of consistent technological change [2].

Despite the great importance of technology transfer in the process of industrial and technology development of LDCs, there have been some general problems in the process of effective and successful technology transfer. These problems, which include mainly the lack of absorptive capacity in the recipient country and unwillingness of the transferor in transferring real technology and technical know-how, have led to unsuccessful technology transfer. Therefore, it is necessary for these countries to promote their local technological capability in order to adapt and absorb foreign technologies efficiently for their local needs. LDCs should also identify and improve those elements of technology in which they are weak, such as developing an appropriate industrial and technological infrastructure. The imported technologies should also be adapted and matched with the existing technologies, which can lead to the rapid process of industrialisation.

Having recognised the great importance of technology for their development and industrialisation, LDCs seem to be unable to exercise real choice in designing effective strategies for their technological transformation. Many developing countries do not appear to have established the necessary procedures and criteria to choose the effective technology transfer policy needed for a rapid industrialisation and technological development.

Problems of technology transfer can generally be discussed from different points of view. For example, the major problem from the macro-economists point of view is to investigate the appropriate technology, how to adopt and adapt it effectively and use it for the development and industrialisation of LDCs. From the point of view of managers in LDCs, the question is how they choose the technology for import and how do they decide the channels through which technology will be transferred? Managers also consider how to utilise their limited resources efficiently in order to promote their technological capability. Engineers and scientists are also more concerned about the technical and scientific aspects of the subject, the process of an effective indigenous technological development, industrial and technological research, and promotion of the skills and productivity of the labour force. It seems that LDCs prefer to adopt and assimilate new technologies rather than trying to generate and create them, since, it needs less traditional R&D, but they still require a high level of technical skills. Unfortunately, there have been few attempts to formulate and design the appropriate plan and strategies for effective and successful technology transfer and development. The specific strategy and policy for technology transfer in a country cannot be separated and isolated from the overall national plan for its economic, industrial, and social development. Therefore, the major aims of technology transfer policy should be concentrated on finding the most appropriate methods to use technology in order to achieve rapid economic and industrial progress. In this way, the LDCs will reduce the technological dependency on developed countries. In designing appropriate strategies for their technology transfer and development, LDCs can also draw valuable lessons from the successful experiences of some Newly Industrialised Countries (NICs) in East Asian and Latin America.

1.2 General Background to the Study of Technological Transfer

For many less developed countries, a significant factor contributing to the persistence of low living standards, rising unemployment and growing income inequality is the highly unequal distribution of economic and political power between rich and poor nations. These unequal strengths are manifested not only in the dominant power of rich nations to control the pattern of international trade but also in their ability often to dictate the terms in which technology, foreign aid, and private capital are transferred to developing countries.

Other equally important aspects of the international transfer process serve to inhibit the development of poor nations. One subtle but nonetheless very significant factor contributing to the persistence of underdevelopment has been the transfer of first and second world values, attitudes, institutions, and standards of behaviour to third world nations. Examples include the colonial transfer of often inappropriate educational structures, curricula, and school systems; the formation of Western-style trade unions; the organisation and orientation of health services; and the importation of inappropriate structures and procedures for public bureaucratic and administrative systems. Of even greater potential significance may be the influence of rich-country social and economic standards on developing-country-salary scales, life-styles, and general attitudes toward the private accumulation of wealth. The penetration of rich-country attitudes, values and standards also contributes to a problem widely recognised and referred to as the "international brain drain", and the migration of professional and skilled personnel, who were often educated in the developing country at its great expense. Examples include doctors, nurses, engineers and economists [3].

The transfer of technology is a complex phenomenon involving a wide variety of forms including, the classical, and perhaps the most dominant form which is the transfer by multinational corporations, in either partly or wholly owned subsidiaries. This will be discussed in detail in chapter 3. Another form would be export and import of capital goods. Although these forms of technology transfer are widely used among the developed market economies as well, they may not be particularly efficient ways of transmitting the use of modern technologies between economies at different levels of development. Some would take the view that they may widen the gap in development between exporters and importers of technology.

Transferring technology from the developed to the developing countries is an obvious alternative which should aid the promotion of both economic development and international peace. However, the situation is not as simple as it seems. The main obstacle is the absence of a skilled labour force. Some countries like India and China have this resource, but most others have not. In addition, social, cultural, and political factors inhibit this transfer. Multinational corporations expedite the transfer, but they create many additional problems. It is important to examine all these factors critically to determine an appropriate strategy for economic development [4].

1.3 The Objectives of the Research

Although a large amount of empirical research has been devoted to the problems of development in general, there are very few specific empirical investigations with regard to technological transfer, which is at the core of the development problem.

The present research is aimed at identifying those technology factors that significantly affect the rate of successful technological integration. For this purpose, appropriate statistical methods are used to analyse a set of specific data.

It seems there are two considerations that suggest the desirability of using quantitative techniques as tools for exploring the structure of the underlying phenomena involved in any problem of development, and in particular, the problem of technological transfer. First, the amount of even approximately validated knowledge relating to the issues governing this phenomenon is small. Second, there are a number of controversial attitudes towards this problem, which may make it difficult to establish a defined hypothesis. So, empirical research may then increase one's understanding of certain aspects of the phenomenon.

One may attribute the success or failure of technology transfer (which will be discussed in detail in chapter 3) to a number of factors without knowing their relevance in practical terms. Also, as a theoretical model, it may be lacking in specifying more or less exactly the amount of influence. Thus one cannot be certain of its theoretical formulation.

Hence, an attempt to model such a phenomenon may be very useful and may complement the existing literature in providing more empirical evidence.

The main reason that made the author approach the problem in the above manner, was an awareness that the effectiveness of technology transfer is highly influenced by the social and economic conditions of the recipient countries. It is therefore intended to explore these conditions and to gain a quantitative insight as well as more empirical knowledge by using the statistical data. Examples of techniques which have been used in this study are multiple regression analysis, stepwise regression, best-subsets regression, factor analysis and cluster analysis.

A considerable number of social indicators are included in the model. This is because of the increasing importance given to the study in this area by development economists such as Streeten, P., Seers, D., Bauer, R.A., Stone, R., Rice, S., Galtung, J. and Moser, C.

Such indicators fall into two groups – those that seek to measure development in terms of a normal or optimal pattern of interaction among social, economic and political factors and those that measure development in terms of the quality of life [5].

One of the major studies on the first group of composite indicators was carried by the United Nations Research Institute on Social Development (UNRISD) in 1970 [6]. The result was the construction of a composite social development index. Originally, 73 indicators were examined. However, only 16 core indicators (9 social and 7 economic indicators) were ultimately chosen. The study concluded that social development occurred at a more rapid pace than economic development.

Another well-known endeavour in this area was the development of the Physical Quality of Life Index (PQLI) undertaken by Morris. Three indicators – life expectancy at age one, infant mortality and literacy were used to form a simple composite index. While the study found that countries with low per capita GNPs tended to have low PQLIs and countries with high per capita GNPs tended to have high PQLIs, the correlations between GNP and PQLI were not substantially close. For more description, see the work by Morris [7].

Eighteen social and economic variables and thirty-four countries are included in the analysis. The intention was to include as many "developing countries" as possible (according to the data availability) in order to have an adequate representation and appropriate generalisations of results could be made.

Some oil-producer countries are included in the analysis, but only those which have been classified amongst the low and lower-middle income, such as Ecuador, Gabon, and Iran. Oil exporting countries which are characterised by huge surpluses that can finance not only the imports of capital goods but also the imports of manpower required have been excluded from the analysis.

Some countries are characterised by the fact that they produce part of their own machinery and equipment and also export them to developed countries. They are not so dependent on foreign technology as are most of the other developing countries. Significant examples of the success of the countries of Southeast Asia in exporting manufactures to the developed world suggests this strategy may be of more general applicability [8]. So, these kinds of countries such as South Korea, Taiwan, Hong Kong and Singapore are also excluded from the analysis. Communist countries are also excluded from analysis. They mostly import and export from more advanced communist countries. Apart from the excluded countries already described, most of the remaining countries seem to be suitable for analysis. However, many countries had insufficient data and hence, had to be discarded. This will be discussed in detail in chapter 4.

As mentioned, the number of countries included in the analysis on which data was generally available is thirty-four. A list of countries is provided in Appendix A, Table 4. Among these there are 9 Asian countries, 6 South American, 15 African and 4 Central American.

1.4 Limitations of the Present Analysis

As in much research, the present study has some limitations mainly due to the availability of data.

1) The main limitation of this study is the inability to include some important variables which seem related directly to the technological transfer, such as management and productivity factors, political implications and policies. It is realised, however, that the entire question of data collection suffers from finding a way to quantify the above aspects. However, some variables have been input as "dummy variables", but for some others there is no data available at all. Variables such as natural disasters including drought, famine, floods and earthquake or kind of religion including Christian, Muslim, Buddhism and Indigenous Beliefs have been included as dummy variables [9].

2) The data which has been used, has been taken from various published sources. Therefore, the reliability of the results depends on the accuracy of this data.

3) The analysis is over a period of ten years, 1983-1992. Complete data was not available for a few variables (missing data), for every year of the period, and for a few countries. For example, the data was not available for each year for the variables school enrolment ratios for first and second level, number of scientists and engineers engaged in R&D and expenditure for R&D. Where possible, the developing countries which have been included have the most complete data available.

4) We have averaged the data in the period of ten-year, 1983-1992, in order to give a single value for the whole ten-year period for input into the analysis.

Business managers often use an average to represent a set of values. They select one value as typical of the whole set of values, such as average sales, average price or average production per hour. In economics, the term "per capita" is a measure of central tendency, e.g., GNP/capita and income/capita of a certain district. Taking average is easy to compute and explain, and it has several mathematical advantages. However, it has to be noted that taking the average of a data set does not always give a representative figure because, for example, there may be extreme values which distort it.

5) At the time we collected the data, the period of our study, 1983-1992, was the most recent period offering relatively complete data.

6) In some instances, data from different sources show different figures for a specific indicator or for a specific year. Where it was not possible to verify which was the most accurate, we had, for example, to average those figures.

7) Careful analysis of data leads to better prediction and more accurate assessment of dimensionality. Missing data (information not available for some part of subject or case), generally is a difficulty for researchers and may result from data entry errors or data collection problems.

1.5 The Structure of the Thesis

This thesis is divided into seven chapters. It begins with an introductory overview of the research topic explaining the general background to the area of the study and its importance. The objectives and the limitations of the area of research are discussed.

Chapter two is devoted to a review of the most current literature on technology and technology transfer, growth, and development.

While the development of indigenous technology should be encouraged, technology transfer can be considered as a vital process of industrialisation for LDCs. In other words, industrialisation is a process of acquiring technological capabilities in the direction of consistent technological change

The main objectives of this chapter are:

1) To find the most appropriate channel of technology transfer in which the recipient can effectively acquire the package of technology, the know-how, and the managerial skills needed for the assimilation of the technology to its local condition

2) To choose the method that enables the recipient countries take maximum advantage of the imported technology. It depends on the indigenous industrial and technological capability of recipient country.

3) To focus on ways of development economics to bring about rapid and large-scale improvements in levels of living for the masses of poor people in The Third World nations.

The third chapter discusses the role of Multinational Corporations (MNCs) in international transfer of technology. MNCs account for a large part of world trade, both in commodities and technology. The factors affecting the success or failure of transfer of technology is also considered.

Chapter four identifies a metric for technological integration and transfer. Its relation to socio-economic variables is discussed and the variables to be used in the study are defined.

Chapter five outlines a structural approach to multivariate model-building. Factor analysis and multiple regression analysis (including stepwise regression and best-subsets regression) are discussed. Data for thirty-four countries has been collected covering 1983-1992.

Chapter six presents the results, analysis and theoretical interpretation of fitting multivariate models to the data in order to determine which factors influence most significantly how developing countries integrate imported technology.

Chapter seven, the final chapter, contains discussion, conclusions, and recommendations for further research. Technology transfer in Africa has been discussed. In particular, the problem of AIDS which was not a significant variable during the period of this study is now impacting economically on countries in Africa and this issue is discussed. Further research on technology transfer would need to take account of this.

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CHAPTER 2: Conceptual Issues of Technology, Technology Transfer, Growth and Development

2.1 Definitions of Technology

The mere presence of the traditional economic inputs of land, labour, and capital is no longer enough to ensure economic growth in a nation. What is now important is the rational application of these resources to productive purposes by means of technology.

Both the industrialised and developing nations recognise the fact that technology plays a significant role in economic growth and the improvement of living standards of their countries.

Technology is a word in widespread use, especially in conjunction with other words such as development, growth, and industrialisation. Technology means different things to different observers. Its definitions vary from simple dictionary explanations to complex elaboration. Many definitions and descriptions of technology are very broad and sometimes almost all encompassing. However, in almost all definitions of technology, the key phrases that feature include social aspects (people), knowledge, information, and skills of various kinds. A selection of definitions will be considered to cover the various dimensions of technology. Technology, which is a combined word originating from the Greek words of "transferring" (art, craft) and "logos" (word, speech), refers to all the ways in which people satisfy their needs and desires through the systematic study of techniques and use of inventions and discoveries. Many scholars define technology as knowledge of particular techniques, for example, the art of industrial production. Definitions of this type are of limited value, however, because the meaning and use of the word technology has changed over time. It is used differently by different schools of thought and between different languages, its common use is random, and the definition does not convey much of the complexity of meaning attributed to the term in the literature.

The Concise Oxford Dictionary, in a similar manner to other dictionaries, defines technology as "the study or use of the industrial and mechanical arts and applied sciences" [1]. This definition does not include other areas, because industrial art is not by any means the only area in which technology plays a role. According to Jantsch (1967) [2], technology denotes the broad area of purposeful application of the contents of the physical, life, and behavioural sciences. It comprises the entire notion of techniques as well as medical, agricultural, management, and other fields with their total hardware and software contents. Schon (1967) [3] defines technology as "any tool or technique, any product or process, any physical equipment or method of doing or making, by which human capability is extended". According to Thompson (1967) [4], technology is a design for instrumental action that reduces the uncertainty in the cause-effect relationships involved in achieving a desired outcome. Galbraith (1967) [5] defines technology as the systematic application of scientific or other organised knowledge to practical tasks. Merrill [6] and Root [7] all emphasise the importance of knowledge and skills in their definitions. Merrill argues that technology is a body of skills, knowledge, and procedures for making, using, and doing useful things. Root sees technology as the body of knowledge that is applicable to the production of goods and the creation of new goods. Peno and Wallender (1977) [8] define technology as knowledge embodied in products, process formulas, and techniques needed for managing operations. According to Barquin (1981) [9], technology is the set of disciplines, methods, techniques, and supporting instruments, which make up the process by which a tangible product is elaborated. In another definition used by the Organisation for Economic Co-operation and Development (OECD), technology means systematic knowledge for the manufacture of a product, for the application of a process or for the showing of a service, including any integrally associated managerial and marketing techniques [10]. Dahlman and Westphal (1981) [11] define technology as a collection of physical processes, which transforms inputs into outputs. This definition is also similar to that of the "Technology Atlas Team", which consider technology as a black box where inputs in the form of natural resources go into the box and outputs in the form of produced resources come out from the other side. Thus, one can say that technology performs as a transformer of inputs into outputs [12].

In its broadest definitions, Evans (1984) [13] defines technology as the means by which man undertakes to change or influence his environment. Dosi (1984) [14] sees technology as a set of segments of knowledge, containing directly practical and theoretical know-how, procedures, experiences of successes, and points out that technologies consist not only of hardware but also comprise the technical knowledge and skills of participants of an organisation. Dunning (1993) [15] defines technology as the output of technological and organisational capacity, which determines the way (or ways) in which tangible and intangible resources may be physically converted into intermediate and finished goods and services.

It becomes almost obvious from these extensive technology definitions that technology is seen by many as the most significant factor in improving productivity, quality, and competitiveness. The main feature of most definitions is that they indicate one or more specific aspects of technology such as its type, method and subject. Moreover, the various definitions for technology emphasise its multidimensional characteristics such as flexibility, institutional, organisational, and cumulative nature.

2.2 Definitions of Technology Transfer

The literature offers several definitions in respect of technology transfer, which indicate its importance. Technology transfer has been defined initially as the process whereby technology is moved from one physical or geographic location to another for the purpose of application toward an end product [16]. This transfer can take place either domestically from one sector or firm to another or, it can take place across national boundaries, from one country to another, which is generally accepted as international technology transfer.

According to Gee [17], technology transfer is the process by which technology developed for one purpose is employed either in a different application or by a new user. Kayak [18] has defined technology transfer as the transition of know-how to suit local conditions, with effective absorption and diffusion both within a country and from one country to another.

According to another definition, technology transfer is "the utilisation of an existing technique in an instance where it has not previously been used" [19].

Derakhshani (1983) [20] defines technology transfer as the "acquisition, development, and utilisation of technological knowledge by a country other than that in which this knowledge originated". This definition is similar to that presented by Van Gigch [21]. He believes that technology transfer involves the acquisition of "inventive activity" by secondary users. It shows that technology transfer may not always involve the transfer of machinery or physical equipment. Knowledge can also be transferred through training and education, which could include training on how to effectively manage technological processes and changes [22].

Samli (1985) [23] believes transfer of technology is the transmission of know-how to suit local conditions, effective absorption, and diffusion both within a country and from one country to another. As such, technology is not just one source of growth and vitality for individual enterprises and entire nations, but the central source in many cases. Fransman (1986) [24] defines the international transfer of technology as a process "whereby knowledge relating to the transformation of inputs into outputs is acquired by entities within a country (for example, firms, research institutes, etc.) from sources outside that country".

Chesnais [25] defines technology transfer as the transition of the capability to manufacture a product or process from firms in one country to firms in another. He argues that this transfer includes not only the technical knowledge needed to produce the products, but also of the capacity to master, develop, and later produce autonomously the technology underlying these products. Larsen et. al. [26] define technology transfer as the process by which technological innovations are exchanged between individuals and organisations who are involved in R&D on one hand, and in putting technological innovations into use on the other hand.

According to Meissner [27], transfer of technology is the act of sharing know-how by such devices as constancy, joint ventures, gifts, licenses, franchises, and patents. Aggrawal [28] on the other hand, views technology transfer as the communication, adaptation and use of technology from one place or economic region into a second region. He also adds that this technology has to be adapted to local conditions by the receiver to fit to its social, political, cultural, economic, and educational environment.

There are several fundamental characteristics concerning technology transfer deriving from the above definitions:

First, technology has many components and dimensions and almost always involves more than one element of technology. Various elements of technology involved in a particular case interact with each other as if they constitute a system. In addition, the technology package must be periodically re-evaluated as conditions change, as the project cycle advances, and as new information becomes available. Thus, technology transfer is a dynamic process. Second, the effective transfer of technology requires an adequate infrastructure, which may include scientific institutions, R&D facilities, vocational, technical and management training institutes, and skilled personnel of different specialisations, within the recipient country. It also requires a suitable cultural environment. Both the infrastructure and the cultural environment are basic determinants of the effectiveness of technology transfer. Third, technology developed in a specific context can hardly ever be introduced into a new environment without at least some degree of modification. Modification and further development of technology are thus very often an integrated part of transfer. This often involves changing the scale of a production process and the adaptation of products to local market characteristics.

Tyre (1991) points out that new process introductions often involve considerable problem solving and even innovation at the plant level. The degree of changes in the technology is affected by the attributes and business environments of the units involved in the transfer [29].

2.3 Technology Classifications and Components

Technology can be classified according to many variables, e.g., the cost of its supporting hardware, the type of end-product obtained, or the complexity of its methods and techniques. Hall and Johnson [30] distinguished three kinds of technology:

1. General technology includes technical information common to companies operating in the same activity.
2. System specific technology corresponds to the knowledge and know-how firms develop for solving particular industrial problems. In other words, system-specific technology refers to the information possessed by a firm or an individual in a firm, which might have been acquired through engaging in certain tasks or projects. A system-specific technology is acquired by a firm in one industry, and usually not by other firms in the industry manufacturing the same item or engaged in the same activity. It gives the firm a competitive edge or differentiation.
3. Company-specific technology covers the corporate skills and capabilities deriving from the general activity and experience of each individual firm. In other words, it refers to knowledge, which a firm acquires beyond the general knowledge possessed by the industry as a whole. Such knowledge is not attributed to any specific item the firm produces or system it uses, but it results from the firm's overall or collective activities.

Mansfield [31] uses "embodied" (capital or physical goods and skilled labour) versus "disembodied" (soft goods such as, industrial property, know-how, technical data, technical services and technical assistance) technology. Madeuf [32] has elaborated this classification as capital embodied, human embodied, and disembodied technology.

According to another classification, technology is divided into production and consumption technology. Production technology considers the methods and processes for production of goods and services, whereas consumption technology considers methods, processes and techniques by which a particular need or demand may be satisfied. For example, the need for inland transport satisfied by using the horse, automobile, train, bicycles or a subway system [33].

According to Simon (1991) [34] technology falls into multiple categories. First, those technologies that are explicitly related to purely civilian commodities or the harvesting and production of these commodities such as, textiles and agricultural products. Second, those technologies that are directly linked to military items such as weapon systems. The third type of technology is not really technology at all, but is best labelled scientific or basic research. The last type of technology and perhaps the most controversial, is what is called dual use technology. Dual-use technologies are those, whose development and applications are intended for civilian purposes, but could have potential application in the defence sector. Much of what is called high technology items, such as super-computers, would fall in this category.

According to another classification, technology is classified into visible and invisible messages. While the former include drawings, specifications, manuals, documentation, computer programs, data-base, and patents, the latter represents know-how, skills or software that are not easily transferable in a descriptive form [35].

The Technology Atlas Team [36] identify four components of technology:

1. Object-embodied technology which can be called "Techno-ware" and consists of tools, equipment, machines, vehicles, and physical facilities.
2. Person-embodied technology, which can be called "Human-ware" and refers to experiences, skills, knowledge, wisdom, and creativity.
3. Document-embodied technology, which can be called "Info-ware" and includes all kinds of documentation pertaining to process specifications, procedures, theories, and

observations.

4. Institution-embodied technology, which can be called "Orga-ware" and consists of management practices and linkages.

In any technology transfer process, all components of technology are required for transformation of inputs into the outputs. In other words, both hardware (machinery and equipment) and software (the know-how for using those machinery and equipment) are needed in order to facilitate effective technology transfer. Moreover, the skilful labour force (Human-ware) and managerial and organisational expertise (Orga-ware) can also promote the level of recipient adaptation and absorption of imported technologies.

2.4 Technology Transfer Classifications

International technology transfer has been classified according to different criteria. Useful classification is provided by Mansfield [37], who distinguished between material transfer, design transfer, and capacity transfer.

Material transfer consists of the transfer of materials, final products, components, equipment, and even turnkey plants. In brief, this is a transfer of the technological artefact (a product of human art) itself. It is not so much a transfer of knowledge as it is the transfer of the results of knowledge. The receiving country is merely a passive consumer of the knowledge produced by others which it cannot produce by itself. The main objective is to produce and supply the physical capacity of their desired products.

Design transfer basically involves the movement of designs, blueprints, and the know-how to manufacture previously designed products or equipment. The major objective here is to provide the basic information, data, and guidelines needed to create a desired capability. In other words, foreign items are imported in order to copy their designs and the recipient nation begins to produce domestically the artefact formerly imported in the material type of transfer. Nevertheless, it still remains dependent upon technological knowledge produced elsewhere.

Capacity transfer includes provision of the know-how and software not simply to manufacture existing products but, more importantly, to innovate and adapt existing technologies and products, and ultimately design new products.

Another classification distinguishes between two basic types of technology transfer, vertical and horizontal transfer. Vertical transfer refers to the transfer of technical information within the various stages of a particular innovative process, ie., from basic research to applied research, from applied research to development, and from development to production. In other words it is the transition from the principle to practice, or from pure science to its practical application. Since vertical technology transfer entails technological progression from science to a completed product, there seems to be tend toward organising R&D by vertical integration. Horizontal transfer occurs when technology is used in one place, organisation, or context, and is transferred and used in another place [38].

2.5 Channels and Mechanisms of Technology Transfer

Most definitions of technology transfer do not consider the modes of transfer.

We do not make a distinction between technology transfer channels and mechanisms of technology transfer. They have been specified in a thorough overview of this issue by Autio and Laamanen [39]. The technology transfer mechanism has been defined as any specific form of interaction between two or more social entities during which technology is transferred, and a technology transfer channel as the link between two or more social entities in which the various technology transfer mechanisms can be activated [40].

Despite its negative inference, United Nations Conference on Trade and Development, (UNCTAD) [41] implied the existence of different modes of technology transfer. It is defined as the transfer of systematic knowledge for the manufacture of a product, for the application of a process or for the rendering of a service and does not extend to the transactions involving the mere sale or lease of goods.

There are numerous dimensions, which can be used to classify technology transfer. Criteria like vertical and horizontal, formal (market mediated) and informal (non-market mediated), embodied and disembodied, direct or indirect, and institutional form (investment, pure market, sales and intermediate forms) can illuminate different aspects of the transfer process.

Technology transfer among nations (international technology transfer) can take place through a number of different channels and mechanisms that may in some cases exist independently of other channels. Cooper and Sercovich (1971) [42] and Stewart (1979)

[43] distinguish between direct and indirect mechanisms of technology transfer. Direct mechanisms are those used when the recipient is in direct contact with the supplier of technology. Direct forms of transfer include direct contracting of individual experts and consultant companies. They are engaged in engineering design and plant construction enterprises, training nationals for specific production projects, technical information activities, and transfer of the process technology embodied in capital goods by importation of equipment purchased directly from machine manufactures. Indirect mechanism of technology transfer occurs when, for example, a company in an advanced country plays an intermediary role packaging the technology for the developing country.

Generally, indirect mechanisms tend to be adopted where a country lacks the capacity to undertake direct purchase, where proprietary technology is involved which will not be released, or where (for marketing or other reasons) the recipient wishes to acquire trade marks.

Buckley (1985) [44] divides the modes of international technology transfer into two main categories, internal and external. Specifying ten forms of technology transfer:

1. Wholly owned foreign subsidiaries (conventional form of foreign direct investment)
2. Joint ventures
3. Foreign minority holdings
4. "Fading-out" agreements
5. Licensing agreements
6. Franchising
7. Management contracts
8. Turnkey contracts
9. Contractual joint ventures
10. International subcontracting

The first type, wholly owned foreign subsidiaries, is the conventional form of foreign direct investment for technology transfer. The mode of transfer for the first three forms is internal. The forms of 5, 6, 7, 8, and 10 are external. The mode of the fourth form is internal at the beginning but become external when the period of agreements ends. The mode of transfer is mixed for the ninth form.

Erdilec and Rapoport [45] refer to formal (market mediated) and informal (non-market mediated) channels of technology transfer. The formal mechanisms of international technology transfer are licensing agreements, direct foreign investment, sale of turnkey plants, joint ventures, co-operative research arrangements, and co-production agreements. The informal mechanisms are those which do not involve an actual agreement between supplier and receiver of technology. For example, export of high-technology products and capital goods, reverse engineering, exchange of scientific and technical personnel, science and technology conferences, trade shows and exhibits, education and training of foreigners, commercial visits, open literature (journals, magazines, technical books, and articles), industrial espionage, end-user or third country diversions, and government assistance programs. International technology transfer through most of these channels is very difficult to detect and monitor. Formal channels usually involve the market mechanism and design an explicit value to international technology transfer.

A study by UNCTAD [46] distinguishes between commercial and non-commercial channels of international technology transfer. The commercial transfer involves payment of a direct and indirect price for technology and thus generates more complicated issues in the international arena than non-commercial transfer. For instance, friction between the supplier and recipient of technology often arises in regard to price, range of technology supplied or teaching and learning attitudes. Moreover, interaction between the supplier and recipient through technology transfer is a long process, unlike the transaction of a physical commodity. Therefore, the nature, method, and means of interaction can take various forms, appropriate or inappropriate. The commercial channels include foreign direct investment, joint ventures, licensing, franchising, marketing contracts, technical service contracts, turnkey contracts, and international subcontracting.

The non-commercial modes of international technology transfer include the review of technical journals and the training of foreign students, exchange of scientists and engineers, co-operative research and development.

Olukoshi [47] discusses the international technology transfer mechanisms regarding elements of embodied and disembodied technology. He summarises the international technology transfer channels as: flows of books, journals and other published materials; movement of people between countries including immigration, return emigrants, study visits, and foreign courses. He also adds import of machinery and equipment for production such as, production technology, licensing, patents, and know-how agreements; technical co-operation at bilateral and multinational levels; and import of consumer goods, i.e., consumption technology. He explains that each of these forms contains elements of embodied and disembodied technology or a complex combination of both. For example, the flow of books and journals, management and financial services, are means of transferring disembodied technology while the sale by foreign corporations of patents, trademarks and licenses are an embodied form of technology transfer. However, the supply of machinery and equipment for production is a classic example of transfer of embodied technology. Here the supply of machinery and equipment goes in hand with the technical services for example and hence the transfer process can be said to involve both embodied and disembodied forms of technology. In many cases, transferred technology by Multinational Corporations (MNCs) to developing countries usually entails a complex combination of embodied and disembodied technology. We will discuss MNCs in details in the next chapter.

Kim [48] analyses the international technology transfer mechanisms by classifying them into market and non-market mediated. In market mediated, he refers to those mechanisms, which may be determined by the market. The transferor and transferee may negotiate the cost of technology transfer, either embodied in or embodied from the physical equipment. In the non-market mediated mechanisms, technology transfer usually takes place without formal agreements and payments. He demonstrates the mediated and non-mediated mechanisms of technology transfer in a useful four-cell matrix to identify and evaluate different mechanisms of international technology transfer.

As is shown in Table 2.1, those mechanisms in cell 1 are among the most important technology transfer modes, where the supplier of technology has exercised an active role in directing the technology transfer process. They include control over the quality and quantity of know-how being transferred, and the possible restriction imposed on the use of know-how.

The channel of technology transfer, which is shown in cell 2, indicates those market-mediated modes where the supplier of technology plays a relatively passive role with less control over the way in which technology and know-how being transferred.

Cells 3 and 4 refer to the non-market-mediated modes, where the supplier of technology plays either a relatively passive or active role in transferring technological know-how respectively.

Table 2.1: The Modes of Foreign Technology Transfer

market mediated	direct foreign investment, foreign licensing, turnkey plant, technological consultancy, made-to-order machinery (cell 1)	standard (serial) machinery purchase (cell 2)
non-market mediated	technical assistance by foreign buyers, technical assistance by foreign vendors (cell 4, active role of supplier)	imitation (reverse engineering) observation, trade journals, technical information service (cell 3, passive role of supplier)

Source: Kim, L., 1991, "Pros and Cons of International Technology Transfer: A Developing Country view", Oxford University Press, Oxford, pp.223-239.

Tho [49] has classified the channels of international technology transfer into two broad categories, public and private. In the first category, technologies can be considered as public goods, and the transfer is conducted by public organisation, such as government of advanced countries and international agencies. The transfer of such technologies is conducted as a part of the technical assistance or economic co-operation provided to LDCs. The private channels of transfer relate to technologies that are developed by private firms and transferred on a commercial basis. The multinational corporations are usually the suppliers of such technologies, which usually transfer their technologies through such channels as Foreign Direct Investment (FDI), licensing agreements, plant export, and original equipment manufacturing. He also argues that the importance of each channel depends on some factors such as strategy of MNCs supplying the technologies, the characteristics of the technologies, and the policies, absorptive capacity, and managerial resource endowments of the recipient countries. He adds that MNCs prefer FDI with whole or majority ownership when the newly developed technologies are transferred. On the other hand, recipient countries usually use licensing agreements, when the environment is considered risky. Moreover, the choice of original equipment manufacturing as a channel of technology transfer depends on the technological level of the recipient country.

The effectiveness of each channel depends on the nature of technology that is being acquired, the type of the organisation, and the absorptive capacities of the recipient. Thus, the various methods of transfer can be determined by the following factors [50]:

1) Motivation, purpose, criteria, and benefits agreed upon between recipient and donor on technology transfer.
2) Technology-vending strategy of donor.
3) Technology level and managerial capacities of recipients.
4) Available information sources and bargaining power of the recipient.
5) Technology and trade policy of the recipient's nation.

So, the recipient of technology should keep in mind that effectiveness of technology importation is significantly affected by the forms and mechanisms of technology transfer.

The various mechanisms and channels of international technology transfer have been examined from different points of view so far. Now, it is essential to describe and explain each of these methods, in order to examine their applications according to different situations and circumstances.

2.5.1 Foreign Direct Investment (FDI)

It is believed that Foreign Direct Investment (FDI) is one of the most important channels of technology transfer [51]. Foreign Direct Investments (FDIs) are those that are made outside the home country of the investor, but inside the investing company. In national income accounts, FDI includes all flows, whether direct or through affiliates, from the investor. It also includes reinvested earnings and net borrowings, as well as equity capital. Control over the use of resources transferred remains with the investor, giving it an effective voice in the management of the foreign firm [52].

As Dunning [53] notes, FDI consists of a package of assets and intermediate products, such as capital, technology, management skills, access to markets and entrepreneurship.

While Transnational Corporations (TNCs) were previously identified solely with FDI, the rise of minority-owned investments and new forms of investments during the 1970s and

1980s led to rather complex patterns of technology transfer [54]. Transnational corporations today engage in diversified types of relationships and arrangements of which FDIs are only a part. According to UNCTAD (1997), a range of co-operative agreements involving joint ventures, subcontracting, franchising, marketing and manufacturing are complements to traditional FDI [55]. Dunning [56] suggests the TNCs act as transaction cost minimisers (by co-ordinating a number of separate value-adding activities) and network mobilisers (the organisation of technology, not necessarily the innovator). Yet the link between FDI and technology transfer has weakened because of a multiplicity of new forms of investment, according to Lall [57]. However, it is still strong due to an increasing technology gap and the spread of FDI in Newly Industrialising Countries (NICs).

There is considerable general literature on the advantages and disadvantages of FDI for developing countries. One of the main advantages of FDI is that it brings in new knowledge, technical know-how, marketing and entrepreneurial skills. Hence this complete package of knowledge and skills can certainly have a major impact on the recipient country. The importance of FDI as one of the major mechanisms for technology transfer can be seen in the preference of this method over the other channels by both receiver and supplier of technology. It is argued that through the 1960s, the establishment of a wholly owned foreign subsidiary or a majority-owned foreign affiliate was the predominant method of MNCs' direct investment and a prime source of technology transfer to LDCs [58]. However, many LDCs proposed rather more restrictive policies towards MNCs - in particular their whole ownership, as most of these countries wished to strengthen their indigenous industrial and technological capability, which enabled them to adapt and assimilate foreign technologies more efficiently.

The choice between exports and FDI as channels of technology transfer is more complex. One might expect that export would be the preferred choice as suggested by product cycle theory. However, it can be seen that in many respects, firms in LDCs prefer direct investment for technology transfer [59].

According to Dunning [60], what makes a firm (MNC) enter a foreign investment activity instead of exporting its products is the exploration of the location specific advantage and the ownership specific advantage. In other words, the main reasons for a firm to be involved in foreign investment are to control enterprises in other countries and also to use the firm's competitive advantage abroad.

The importance of FDI as a mechanism for technology transfer has been important for many developing countries. This is particularly, the case for the East Asian countries, except for South Korea where FDI has been an important source of technology in specific industries such as chemicals, electronics, and petroleum refining [61].

The aggregate flow of FDI to all developing countries exceeded £38 billion in 1992, and £80 billion in 1993. This is an increase of 100% over the previous two years and a 400% increase since the mid-1980. As a source of external capital for developing countries, FDI makes up more than 75% of the total. While global FDI flow declined slightly in the beginning of the 90s decade, the flow to developing countries has increased in absolute amounts and in its share from less than 12% of the total in 1987 to over 22% by the end of 1991 [62].

Within the developing countries, the bulk of FDI flow goes to Asia which, attracts over 60% of the total [63]. However, this still constitutes less than 10% of the world's FDI flow. In contrast, developing countries in Latin America attract no more than 5% of the world's FDI flow. In addition, over the last decade, there has been a slight shift of FDI flow from Latin America to Asia. There are several reasons for this, including the international debt crisis, the increased attractiveness of Asian economies to FDI, and the better macroeconomic prospects of Asian economies. Table 2.2 gives a picture of the changing pattern of the top-ten FDI recipients in the developing countries since 1970.

As is shown in Table 2.2, during the 1970s, Asia had five recipients in the top-ten but this increased to six and seven during the 1980s and early 1990s respectively. The top slot switched from Brazil in 1970s to Singapore in 1980s, and has recently shifted to China in early 1990s. One can also see that the average share of Asia in the top-ten increased from only 5% to 58%.

Table 2.2: Top 10 Annual Flow of FDI to LDCs. ($ billions)

Recipients	1970-1980	Recipients	1981-1990	Recipients	1988-1992
Total FDI flow to LDCs	20.6	Total FDI flow to LDCs	18.7	Total FDI flow to LDCs	164.5 (estimated)
Brazil	11.3	Singapore	2.3	China	25.6
Mexico	0.6	Mexico	1.9	Singapore	21.7
Egypt	0.3	Brazil	1.8	Mexico	18.4
Malaysia	0.3	China	1.7	Malaysia	13.2
Nigeria	0.3	Malaysia	1.1	Argentina	10.0
Singapore	0.3	Hong kong	1.1	Thailand	9.5
Indonesia	0.2	Egypt	0.9	Hong kong	7.9
Hong Kong	0.1	Argentina	0.5	Brazil	7.6
Iran	0.1	Thailand	0.7	Taiwan	6.0
Uruguay	0.1	Taiwan	0.5	Indonesia	5.6
Share of flow to top 10 (%)	66	Share of flow to top 10 (%)	68	Share of flow to top 10 (%)	75

Sources: Columns 1-4, 1992, World Investment Report, United Nations
Columns 5-6, Oct. 1994, The Economist, p.29

While the composition of these 10 has changed over the years, the aggregate flow of FDI to developing countries has increased about twice as fast as the rate of growth of their GDP during the latter half of 1980s and early 1990s. In 1989, Japan emerged for the first time as the world's largest investor. The slow-down of the global FDI outflow after 1990, was largely caused by a drop in Japanese FDI outflow from $ 48 billion in 1990 to $ 31 billion in 1991. Japan's share in global FDI outflow increased from 10% for the period 1980-1985 to 20% for 1986-1990, surpassing the UK (17%) and the USA (14%). MNCs from Japan became the world's most important move's of international capital and the world's most important source of technology transfer. Japanese MNCs have tended to concentrate their investment in North America and the European Countries, which together accounted for more than half of Japan's total investment outflow in manufacturing during the period 1950-1990 [64].

2.5.2 Joint Ventures

A joint venture is a business association between two or more parties who agree to share the provision of equity capital, investment risk, control and decision-making authority, and the profits or other benefits of the operation [65]. In other words, joint ventures can be defined as collaboration or new investment involving shared ownership between local firms in host country and its foreign partner [66].

With many developing countries adopting some restrictive policies toward the MNCs, foreign investment, in particular, in the form of whole ownership, has been shaped. The local and foreign partners were interested more in entering a new formal agreement for transfer of technology and managerial expertise, which both parties share in the decision-making, control, and benefits of the operation. Therefore, the elements of technology provided by MNCs under joint venture agreement can include any or all of those provided under foreign direct investment. However, the parties involved in a joint venture contract, agree to share the provision of equity capital, investment risk, control and decision-making authority, and the other benefits of the operation [67].

A joint venture is often important, not only to introduce new technologies but also to diffuse them because partners abroad try to follow quickly the success of fellow-companies in the same industry and to introduce similar technologies into new joint ventures. Joint ventures certainly have an advantage in learning technical know-how and obtaining necessary resources from the parent companies, so that they are usually very quick in catching up. Often these joint ventures are equipped with the latest models of machines which are even better than those used by their parent companies in home countries as some Thai and Indonesian managers reported [68].

Joint venture agreements have been classified into different types. Killing [69] distinguishes between two ways in which a local firm in the recipient country can use a joint venture to acquire technical and managerial expertise from a potential technology supplier. One is to form a dominant parent joint venture, which is passive with the technology supplier. The other is to enter a shared management venture with the technology supplier. He stated that while there is a possibility of very good technology transfer in a shared management venture for both local and foreign partners, the probability of failure is much higher in a shared joint venture than a dominant parent venture.

UNCTAD [70] and many others, have made a distinction between two types of joint ventures: the equity joint venture in which assets, rights, and liabilities are shared through joint ownership of an incorporated enterprise, and non-equity joint venture where the co-operation between partners is established on a contractual basis. Non-equity joint ventures include all types of collaborative contracts and production sharing agreements.

There are generally some advantages and disadvantages for joint ventures. Joint ventures represent a significant change in industry structures and in competitive behaviour. Joint ventures permit firms to create new strengths. They permit firms to share in the use of technologies they could never afford to explore alone. A joint venture may also create lower operating costs and become more efficient than a wholly owned subsidiary because of complementary skills, economies of scale and scope, and the local partner's knowledge of the local environment. The importance of joint ventures in comparison with other channels of technology transfer has recently increased because product lives are shorter, cost advantages are becoming more pronounced, and greater numbers of firms which operated formerly only in domestic markets are becoming global competitors. Joint ventures have been important in the development of new industries [71].

2.5.3 Licensing Agreements

Licensing is the sale of manufacturing technology by a multinational enterprise (licensor) to a non-controlled entity located outside the home country of the multinational enterprise (licensee) [72]. In other words, a licensing agreement is a legal contract under which the licensor confers certain rights upon the licensee for a specified duration in return for certain payments (usually royalties) [73]. The rights may consist of permission to use industrial property rights, such as patents, trade marks, brand names, and copy-rights. It can include secret un-patented know-how, such as methods of production, scheduling, and quality control, which are usually combined with the provision of technical services. Licensing is believed to be the most versatile mechanism for transferring technology, as it offers flexibility in the choice and opportunity for the recipient country to require its needs through the negotiation [74].

The major difference between license agreements and joint ventures is that, in the former, there is no sharing of equity by the firms involved. The licensor agrees to provide the required technology through the complete capital investment by the licensee. One can also refer to two different types of license agreement. The current technology agreement, by which the licensee can only access the available technology at the time of signing the agreement. The other type is the current and future technology agreement, in which licensee and licensor agree that the available technology will be developed in a specific product area before transferring it to the licensee. Although the current and future agreement can provide the opportunity for an effective technology transfer, however, they are usually offered only for older products [75].

Frankel [76] recognises some incentives for both licensee and licensor in entering into a licensing agreement. The major impetus of the licensee is to obtain more advanced technology with lower costs and shorter time rather than becoming involved in its own development of similar technology. In other words, from the licensee's point of view, licensing results in faster commercial development and market entry or enhanced market share than costly internal R&D would permit [77]. The main objective of the licensor, however, can be attributed to its willingness in getting help for financing the development of technology and in sharing the risk of technology development and its application with others, in particular the licensee. As Frankel states, licensing is a strategic decision for both licensee and licensor, which needs effective market, technology, cost valuation, and forecasting. Therefore, it is vital for the licensee to develop an effective strategy of choice, timing, method of application, and benefit objectives [78].

It is believed the main advantage for both licensee and licensor is that the license agreement allows transfer of technology to take place without risks associated with financial involvement [79]. Moreover, licensing affects the development of new technology and may encourage or discourage new research and development. The advantages of licensed technology depend heavily on how current the technology is, and whether the licensee is permitted to retain the rights to any improvements made [80]. Moreover, some of the important factors, which determine the propensity to license are size of local market, the stage of industrial development in recipient country, the availability of skilful and capable labour force in the host country, a level of political risk, and knowledge of the new market [81].

As Holstius [82] has argued, there is often a possibility for the licensee to become a competitor for the licensor by using the expertise gained through the licence.

The main reason for the increasing proportion of licensing as a vehicle for the sale and transfer of technology to LCDs is their unwillingness to permit unrestricted or unnecessary FDI. There has recently been a greater tendency among more advanced countries such as Japan and European countries to use technology licensing rather than foreign equity participation. This is because of the increased competition among suppliers of technology and the resulting need to sell existing technology to be able to finance future R&D [83]. It is also believed that these countries are able to make full use of licensed technology with little technical assistance from the transferor [84].

The ability of a licensee to absorb and improve upon licensed technology depends greatly on its capability to understand and control embedded technology as well as embodied technology. In other words, the licensee or the user of licensed technology needs technical expertise nearly equal to that of licensor or supplier of technology in order to absorb the technology more effectively. This knowledge includes contract administration and patent management, which are generally considered to be managerial, rather than technical skills [85].

2.5.4 Patents and Patents Agreements

Patents are considered as one of the main types of licences. As defined by Prasad, a patent is a temporary monopoly granted by a state to an inventor justified by the grounds that such monopolies provide essential incentives for innovation and risk-taking [86]. In other words, a patent is government protection given to an inventor providing the exclusive right of manufacturing, exploiting, using, and selling the invention for a specified period of time [87].

According to Saghafi Nejad [88], patents are widely used by developed countries as one of the most important forms of industrial property, which give them the rights to prohibit unauthorised use. This right, however, can be easily passed on to the licensee to use it as a major source of marketing strength. Patents play a key role in providing the legal barriers to competitive imitation, thus, shielding the innovator long enough to gain from dynamic efficiency.

The tendency towards the methods for protecting intellectual property varies among different countries and among different industries. For example, Japan enterprises tend to rely more heavily on patenting than their American and European counterpart. The role of patents in LDCs, on the other hand, is relatively different with that of developed countries. In developing countries, the licensee's main need through a patent license agreement is usually more focused on access to technology know-how, technical assistance, and markets rather than patent rights. It is also argued that patents in many LDCs, tend to prevent competition and local innovation rather than encourage it. This is because the vast majority of the patents issued to foreigners by LDCs, are not exploited [89].

2.5.5 Know-how and the Know-how Agreement

Know-how is a body of industrially useful, secret, novel, and valuable information and associated with technical and other information and skills. It can be said that know-how agreement is among the most important methods of technology acquisition for LDCs, which may cover various processes, formulae, and industrial techniques. It is argued that know-how agreements with MNCs enable LDCs enterprises potential access to developments in products and processes. This is mainly because know-how agreements usually provide LDCs' firms with a package of technical information needed for efficient adaptation and assimilation of imported technologies [90].

2.5.6 Trademark and Trademark Agreement

Trademark is a sign or a special name, which serves to distinguish a manufacture's goods from others. In other words, trademarks are distinctive visual and sometimes aural devices, words or symbols, or a combination of them that a firm applies to the goods it trades in, or to the services it performs, or to indicate to the public that they are the firm's goods and services [91].

Trademarks can assist the consumers to distinguish between products of different manufactures. Also, they can assure them about the quality of the products and therefore, play an important role in the market place. Most trademarks in LDCs are registered by developed countries, which are more prevalent in consumer goods and of lesser significance for capital and intermediate goods [92].

2.5.7 Technical Assistance Contracts

Technical assistance agreements may be considered as the most unpacked form of technology transfer. It normally includes manufacturing drawings, maintenance and repair of machinery, obtaining specifications, assistance in setting up production facilities, advice on process know-how, engineering services such as procurement of materials and equipment, personnel training, consultation with manufacturing, quality control procedures, and testing of final products. Hence, technical assistance is usually required by a firm in a developing country which has less experience in operation and setting up of any productive activity. The advantage of this method of technology acquisition is that it may enable the recipient country to access the foreign technology easily and quickly with the technical assistance of the supplier of technology [93].

2.5.8 Turnkey Contract

Implantations of operational (turnkey) technology theoretically permit the recipient to make a product equivalent to that produced by the technology supplier. Although, in practice, the production efficiencies and quality levels achieved vary widely [94].

A turnkey contract is one in which the contractor of a firm undertakes the responsibility for carrying out all the technical and managerial operations and activities needed for the planning, construction, and installation of a technical project before handing it over to local ownership in exchange for a fee [95]. Therefore, the contractor of turnkey is responsible for the completion of the whole project and delivery of a fully operational production system [96]. In other words, turnkey agreements provide for the complete physical package of technology, from one party to another. Less developed countries usually use turnkey plant in the early stages of their industrialisation. The turnkey contracts are also widely used in transferring technology in heavy industries including chemical and petrochemical industries, metallurgy and iron and steel industries, and construction materials such as cement and glass. However, as the technological capability in many developing countries increases, there is a gradual tendency towards replacing turnkey contracts with technology license agreements for manufacturing technology and know-how. This method may accelerate the process of transferring machinery and hardware to the recipient country. From the other side, as the experiences of some LDCs has indicated, in most cases when the whole package together with its design and operation is installed through a turnkey plant, the recipient country has failed to acquire the know-how and software for that machinery and hardware [97].

2.5.9 Management Contracts

A management contract is an arrangement under which operational control of an enterprise is vested by contract in a separate enterprise. It performs the necessary managerial functions in return for a fee, such as production management, personnel management, procurement of goods and services, and marketing [98].

Management contracts are often part of other agreements including joint ventures, turnkey plants, or accompany a technical assistance or license agreements. They are widely used in such industrial sectors as transportation, mining and oil projects, heavy engineering, basic industry, and other manufacturing ventures. The management contracts are also employed in service activities such as tourism, telecommunications, and port management [99].

The advantage of management contracts as a means of technology transfer is that a substantial amount of organisational skills can be transmitted to the recipient country through specific personnel training programmes or by working together with the supplier. These contracts also provide the possibilities for the recipient to have access to high expertise of the supplier personnel, R&D activities, and other technology sources of supplier. Some disadvantages include the diverging objectives of the parties regarding the operation and duration of the project, and the intense control by the management contractors, which may not differ from a turnkey contract or a wholly owned joint venture [100].

2.5.10 International Subcontracting

Subcontracting is an informal mechanism of technology transfer, which has been, and still is, neglected as an analytical issue. It is a mechanism through which a number of developing countries began export-led growth in 1960s and 1970s, especially in electronics [101]. Subcontracting is defined as contracting that partially contributes to carrying out a major contract. The firm awarding the contract to a subcontractor is the prime contractor. Also, it denoted by the original equipment manufacturer, assembler, customer, purchaser, top firm, principle employer, or primary manufacturer. Subcontracting is a type of source, where the host country's supplies are provided by an independent supplier and are part of the production chain of the principal [102].

The essential characteristic of subcontracting is the coupling of export and technology. It functions as a training school where knowledge inputs are received through production specifications and requirements [103].

2.5.11 The Franchising Agreement

A franchise is a particular form of licensing agreement indicating an agreement between the franchiser and franchisee in which the franchiser provides rights, usually including the use of a trade mark or brand name, plus the services of technical assistance, training, merchandising, and management in return for certain payments. In other words, franchising is a system of distributing goods or services that is often associated with high-reputation trade and service marks in which the franchiser supports, trains, and to some extent controls the franchisee in selling the goods or in rendering the services. In developed countries, franchising is today one of the most rapidly growing forms of licensing. One of the most recent examples of franchising in developing countries is the hotel chain franchise [104].

One can see that there are similar features between a franchise agreement and trademark and management contracts. However, LDCs' governments prefer the management contract mode when the franchiser is a foreign firm. This is mostly because the institutional structures in some LDCs are not adequate enough to protect franchising.

2.5.12 The Imports of Capital Goods and Machinery

The import of capital goods and machinery is among the major modes of technology transfer for building industrial infrastructure and strengthening the recipient country's technological capability. This channel of technology transfer, which is used by many LDCs particularly the East Asian Newly Industrialised Countries (NICs), assisted these countries in accessing the advanced technologies embodied in the machinery and equipment. However, the success of this method of technology transfer in the development of the recipient country's local technological capability relies on the level of industrial development together with the degree of technical and managerial expertise and its absorptive capacity [105].

In addition, among all goods, capital goods are regarded as those whose technological content is the highest [106]. According to UNCTAD 1990 [107] the value of capital goods imported into developing countries was $110bn in 1980-86, which was about seven times the average annual FDI and over 14 times the magnitude of technical co-operation grants. Meanwhile, S. Korea is among the major East Asian NICs which used capital goods imports extensively as a method of transfer of technology and in 1987 had capital goods imports equal to 31% of its GDP [108].

2.6 Analysis of the Channels

It appears from the previous discussion of some technology transfer mechanisms that no single method is appropriate for all situations. Methods vary depending on the nature of the technology and the specific circumstances prevailing in each case. The effectiveness of the different approaches differs in terms of the ability of the technology recipient to learn and to acquire increased technological know-how. It is generally the combination of the desire of the transferor to supply technology and know-how in a particular form and the ability of the receiver to acquire it in that form, which determines the mechanism of transfer in a particular case [109].

It is also argued that the technological content of the operations in the industry, the extent of barriers to entry, the degree of competition, and the bargaining power and policies of host countries can also be considered among major determinants of the methods of technology transfer. Moreover, as indicted earlier, the recipient's absorptive capacity to utilise the imported technology effectively may also affect the choice of appropriate channel for the acquisition of technology. The importance of the choice of technology transfer mechanisms has made many developing countries examine various methods of technology acquisition in order to select the most suitable one. This will enable these countries to reduce the cost of technology and to absorb and assimilate the imported technology more efficiently to their local condition [110].

One can generally identify that FDI, joint ventures and licensing agreements are the most important channels of technology transfer to LDCs. Therefore, it can be said that LDCs should generally attempt to find the appropriate conditions for effective transfer of technology whether such a transfer occurs in the form of FDI, joint ventures, or technology licensing [111].

2.7 Growth and Technology Transfer

Economic growth is the steady process by which the productive capacity of the economy is increased over time to bring about rising levels of national income.

Economists and politicians from all nations, rich and poor, capitalist, socialist, and mixed, have worshipped at the shrine of economic growth. At the end of every year, statistics are compiled for all countries of the world showing their relative rates of GNP growth. Gross National Product (GNP) measures the total domestic and foreign output claimed by residents of a country.

The major factors in or components of economic growth in any society are:

1. Capital accumulation, including all new investments in land, physical equipment, and human resources.
2. Growth in population and thus, although delayed, growth in the labour force.
3. Technological progress.

Algebraically, these components can be written in the standard neo-classical production function format as $Y = f(L, K, t)$ where Y is national output, L is labour, K is capital and t is technological progress. Let us look briefly at each component before discussing the production function.

2.7.1 Capital Accumulation

Capital accumulation results when some production of present income is saved and invested in order to increase future output and income. New factories, machinery, equipment, and materials increase the physical "capital stock" of a nation (i.e., the total net real value of all physically productive capital goods). They make it possible for expanded output levels to be achieved. These directly productive investments are supplemented by investments in what is often known as social and economic "infrastructure" -roads, electricity, water and sanitation, and communications, which facilitate and integrate economic activities. For example, investment by a farmer in a new tractor may increase the total output of the vegetables he can produce, but without adequate transport facilities to get his extra product to local commercial markets, his investment may not add anything to national food production.

2.7.2 Population and Labour Force Growth

Population growth and the associated, although delayed, increase in the labour force has traditionally been considered a positive factor in stimulating economic growth. A larger labour force means more productive manpower, while a large overall population increases the potential size of domestic markets. However, it is questionable whether rapidly growing manpower supplies in "labour surplus" developing countries exert a positive or negative influence on economic progress. It will depend on the ability of the economic system to absorb and productively employ these added workers, an ability largely associated with the rate and kind of capital accumulation and the availability of related factors, such as managerial and administrative skills.

2.7.3 Technological Progress

To many economists, technological progress is the most important source of economic growth. In its simplest form, technological progress results from new and improved ways of accomplishing traditional tasks such as growing maize, making clothing, or building a house. There are three basic classifications of technological progress: neutral, labour saving, and capital saving. Neutral technological progress occurs when higher output levels are achieved with the same quantity and combinations of factor inputs. Simple innovations like those that arise from the division of labour can result in higher total output levels and greater consumption for all individuals. In terms of production-possibility analysis, a neutral technological change which, say, doubles total output is conceptually equivalent to a doubling of all productive inputs.

On the other hand, technological progress may either be labour saving or capital saving (i.e., higher levels of output can be achieved with the same quantity of labour or capital inputs). The use of electronic computers, automated textile looms, high-speed electric drills, tractors, and many other kinds of modern machinery and equipment can be classified as labour saving. Capital-saving technological progress is a much rarer phenomenon. But this is primarily because almost all of the world's scientific and technological research is conducted in developed countries, where the mandate is to save labour, not capital. In the labour-abundant (capital-scarce) countries of the Third World, however, capital-saving technological progress is what is most needed. Such progress results in more efficient (i.e., lower cost) labour-intensive methods of production, For example, hand- or rotary-powered weeders and threshers, foot-operated bellows pumps, and back-mounted mechanical sprayers for small-scale agriculture. The indigenous LDC development of low-cost, efficient, labour-intensive (capital saving) techniques of production is one of the essential ingredients in any long-run employment-oriented development strategy [112].

2.8 The Production Function

In addition to low living standards, developing countries are characterised by relatively low levels of labour productivity. In simple words, a production function is a technological or engineering relationship between the quantity of a good produced and the quantity of inputs required producing it [113].

Production function analysis will be used to identify the sources of output growth and to estimate the contribution of each of these to the measured growth rate of output. This analysis is based on the concept of the production function from the theory of the firm.

A firm's production function shows the technological relationship between the inputs of factor services it uses in production and the quantity of output obtained per period of time. It can be written as:

$$q = q(f_1, \ldots, f_m) \qquad (2.1)$$

where q is the quantity of output produced by the firm and $f_1, \ldots, f_m$ are the quantities of m different factors used in production over a period of time. In general, technical progress will increase the output possible from given quantities of factors of production.

If a production function can be written for a firm, so can one be done for the economy as a whole? The output of the economy will then be a function of the factor inputs available for the country as a whole and the technology prevailing. It can be presented as:

$$Q = f(R, K, L, T) \qquad (2.2)$$

where Q is aggregate output and R, K, and L the total supply of land, capital, and labour respectively (all expressed over a period of time) and T the prevailing technology. The production function analysis used to study the causes of aggregate output growth is thus derived from, and consistent with the theory of the firm [114].

Robert Solow has contended that technology is the main source of economic growth. He said that technology alone was responsible for raising the real income of the developed countries nearly ten times over the last century. According to Solow, technology is assumed to be a public good, i.e., something that is available to everyone everywhere free of charge. Solow used the aggregate production function method and fitted it to the U.S. data for the period 1909-1949. His results showed that of the increase in output per head only 12.5% was due to increased capital per person, leaving no less than 87.5% of the growth rate as being due to technical progress. At first this seemed a very surprising result, as it implied that if capital per head had remained constant over the 40 years, output per head in the U.S. would still have increased by 87.5% of the increase which actually took place. This was due to the assumption that technical progress is disembodied. Technical progress has to be embodied in new machines and other capital equipment before it can take advantage of the role of investment in growth increases.

Solow later developed a vintage model in which each machine embodied the technology of its vintage. The effect was to increase the significance of investment [115].

In short, production function analysis identifies three broad sources of output growth: increases in the supply of factor inputs, increasing returns to scale from large-scale operation, and technical progress. In order to make use of this analysis to estimate the contributions of these three sources to output growth, there is a need to choose a specific form of the aggregate production function. This form of aggregate production function should satisfy all the properties of a production function, fit the empirical data reasonably well and be easy to estimate. Such a production function is the Cobb-Douglas production function [116].

2.8.1 The Cobb-Douglas Production Function

Without doubt the most widely known production function is the Cobb-Douglas function. It owes part of its name to Professor Paul Douglas who, from empirical observations, inferred its properties, and part to his colleague Cobb, a mathematician, who suggested the mathematical form. Douglas had drawn a graph of the capital stock, total labour force, and GNP for the U.S. manufacturing industries for the period 1899-1922. He discovered that the difference between the log of capital and the log of GNP was always about three times greater than the difference between the log of the labour force and the log of GNP [117]. It was this constant that caused Cobb to suggest the form:

$$Q_t = T_t K_t^{\alpha} L_t^{\beta} \qquad (2.3)$$

where Q is real output, T an index of technology, K is an index of the capital stock measured in constant prices, and L is an index of labour-time. The subscript refers to the period t.

The constant α $(0<\alpha<1)$ measures the elasticity of output with respect to capital, when the supply of labour is held constant. A one per cent increase in capital will increase output by α per cent, if the supply of labour remains the same. Similarly the constant β measures the elasticity of output with respect to labour, when the supply of capital is held constant. A one per cent increase in labour will increase output by β per cent, if the supply of capital remains constant. If both capital and labour are increased by one per cent, then output will expand by $(\alpha + \beta)$ per cent. If the sum of α and β is greater than one, then increasing returns to scale will be present. If it is less than one, then decreasing returns, and when it is equal to one, constant returns.

Changes in technology are assumed to be determined exogenously and independent of changes in the supply of factor inputs. They are also assumed not to affect the factor-intensity of production, that is, that technical progress is neutral.

The identification of the three sources of output growth is best achieved by rewriting equation (2.3) so that the growth rates of the variables are present. This can be done, by taking the logarithms of the variables and differentiating with respect to time, to produce the following discrete approximation:

$$\dot{Q} = \dot{T} + \alpha\dot{K} + \beta\dot{L} \qquad (2.4)$$

where $\dot{Q}$ is the growth rate of output, $\dot{T}$ the growth rate of total factor productivity or technical progress, $\dot{K}$ the growth rate of capital, $\dot{L}$ the growth rate of labour, and α and β the partial elasticities of output with respect to capital and labour respectively. All measured over a period of time. The equation simply says that the growth rate of output is made up of the growth rate of total productivity, the growth rate of capital weighted by α and the growth rate of labour weighted by β.

Once the values of $\dot{Q}$, $\dot{K}$, $\dot{L}$, α and β have been obtained, the contributions of the three sources to output growth can be worked out. For example, suppose $\dot{Q}$, $\dot{K}$, and $\dot{L}$ are 10, 5, and 3 per cent per annum, respectively, and α and β are 0.25 and 0.75, respectively. the contribution of capital to output growth is (0.25 . 5)/10, which is 12.5%, while that of labour is (0.75 . 3)/10, which is 22.5%. The contribution of technical progress, obtained as a residual, then works out to be 65%. In this example there is no contribution from increasing returns to scale, constant returns being assumed by the value of one given to the sum of α and β (0.25 + 0.75 = 1) [118].

The rate of growth of labour is generally constrained by the rate of growth of population. For industrialised countries, the rate of growth of the labour force is seldom higher than 2% per annum, even with international migration. Consequently, the rate of growth of capital (physical and human) and technical progress, have been found to account for a significant proportion of economic growth by a long line of distinguished economists: Abramovitz, Denison, Griliches, Jorgenson, Gollop, and Fraumeni [119].

2.9 Growth Performances

What was actually achieved over the 1950-75 period exceeded all expectations. Table 2.3 shows that the per capita GNP of developing countries as a group grew at an average of 3.4% per annum. This not only surpassed the growth rate of the developed countries over the same period but also that achieved by the developing and developed countries over any comparable period before 1950.

Table 2.3: GNP/Capita and Its Annual Growth Rate (1950-75)

		GNP/Capita		
Region	Population 1975 (Millions)	1950 (1974 US $)	1975 (1974 US $)	Annual Growth Rate 1950-75 (%)
South Asia	830	85	132	1.7
Africa	924	170	308	2.4
Latin America	304	495	944	2.6
East Asia	312	130	341	3.9
China	820	113	320	4.2
Middle East	81	460	1,660	5.2
Developing Countries	2,732	160	375	3.4
Developed Countries	654	2,378	5,238	3.2

Source: Morawetz (1977, p. 13) [120].

Morawetz pointed out that the average annual growth rates of the per capita GNP of 17 of the sample of 66 developing countries exceeded the 3% said to be not achievable.

Table 2.4 takes the story of growth performances up to more recent times, when international economic conditions have become very difficult. While the growth rate of developing countries has slowed in the years since 1975 it still exceeded or kept pace with that of developed countries. The growth performances of countries in East Asia and the Pacific were particularly impressive.

Table 2.4: GNP/Capita and Its Annual Growth Rate (1965-90)

Region	Population 1990 (Millions)	GNP/Capita 1990 (US $)	GNP/Capita Annual Growth Rate 1965-90 (%)
Sub-Saharan Africa	495	340	0.2
East Asia & Pacific	1,577	600	5.3
South Asia	1,148	330	1.9
Europe	200	2,400	n.a.
Middle East & North Africa	256	1,790	1.8
Latin America & The Caribbean	433	2,180	1.8
Developing Countries	4,146	840	2.5
Developed Countries	816	19,590	2.4

Source: World Bank (1992, p. 219) [121].

The use of official exchange rates to convert estimates of the GNP per capita in national currencies to a single common denominator, usually the US dollar, does not give an accurate picture of the relative domestic purchasing powers of the converted incomes. This is largely because the prices of non-traded goods, mainly personal services, are higher in rich countries than in poor ones. The per capita GNP figures of Tables 2.3 and 2.4 would therefore exaggerate the income gap between the rich and the poor countries. To produce meaningful comparisons of the income gap and of the growth rates of the income levels, purchasing power parities instead of exchange rates have to be used in the conversion exercise. The purchasing power parity conversion factor is simply the number of units of a country's currency that is required to buy the same amounts of goods and services in the domestic market that could be bought with one dollar in the United States. By using it, cross-country comparisons of GNP and its growth rate will reflect differences in the quantity of goods and services and in its rate of change, free of any price-induced differences.

Another useful Table is Table 2.5, which gives the average annual growth rates of the GNP per capita of 15 developing economies of Asia over varying periods. Figures have been converted by using the official exchange rates and the purchasing power parities. The economies are presented in 4 groups: newly industrialising, Southeast Asian, South Asian, and China. No matter which series is used, the growth performances of the Newly Industrialising Economies (NIEs) stand out. The Southeast Asian countries, with the exception of the Philippines, have also done well, as has China. The South Asian economies have tended to lag significantly behind the others, except when purchasing power parity figures were used for the 1980-88 period. In this period, some of them did better than the Southeast Asian ones.

The NIEs have also done well in income distribution and the quality of life, two other important indicators of economic development [122].

Table 2.5: Average Annual Growth Rates of GNP/Capita of Asian Developing Economies, 1950-90 (%)

	Converted by Official Exchange Rate		Converted by Purchasing Power Parity		
Region	1950-75	1965-90	1960-73	1963-85	1980-88
NIEs					
Hong Kong	5.0	6.2	7.0	5.9	6.0
Singapore	6.4	6.5	6.4	6.1	4.9
South Korea	5.1	7.1	6.7	5.2	6.9
Taiwan	5.3	n.a.	7.5	6.3	5.3
Southeast Asia					
Indonesia	2.0	4.5	n.a.	6.7	2.3
Malaysia	2.6	4.0	3.9	6.0	0.8
Philippines	2.8	1.3	2.5	3.2	-0.5
Thailand	3.6	4.4	3.8	4.2	3.8
South Asia					
Bangladesh	n.a.	0.7	-1.0	3.1	0.8
India	1.5	1.9	0.2	0	2.8
Myanmar	2.3	n.a.	2.2	3.2	3.2
Nepal	0.7	0.5	0.2	1.9	1.2
Pakistan	n.a.	2.5	1.9	1.3	4.0
Sri Lanka	1.6	2.9	-0.1	2.1	3.1
China	4.2	5.8	2.3	3.7	7.8
Developing Countries	3.4	2.5	2.8	2.2	0.8

Sources: Morawetz [123], World Bank [124], Summers & Heston [125].

Also in a study of 34 developing countries, Riedel [126] ranked them according to the household income shares of successive cumulative quantile aggregates. He found that Taiwan has the best income distribution, surpassing even that of Sri Lanka, while Singapore, South Korea, and Hong Kong are placed in the top third of the sample.

2.10 Development and Technology Transfer

Development is the process of improving the quality of all human lives. Three equally important aspects of development are: (1) Raising people's living levels, i.e., their incomes and consumption levels of food, medical services, and education through relevant economic growth processes. (2) Creating conditions conductive to the growth of people's self-esteem through the establishment of social, political, and economic systems and institutions which promote human dignity and respect. (3) Increasing people's freedom to choose by enlarging the range of their choice variables, e.g., increasing varieties of consumer goods and services [127].

Churchman, the acclaimed management philosopher, offers a perspective on the definition of development. He notes that a country in which thousands of people, including babies, are starving is surely underdeveloped [128]. It could be also added that a country, which believes that it must keep a large arsenal of weapons - both nuclear and non-nuclear - in fear of military power of another country - is also underdeveloped [129]. This definition implies that rarely can any country in the world today be classified as developed. Human society, like any other living organism, is always growing or evolving into different forms. It never achieves static equilibrium. However, when we employ the term development in relation to human societies, implicit in the term is the concept that growth has a positive rather than a negative value. Thus, all societies can be classified as developing societies. Each society faces different constraints that limit the extent to which development is achieved. Economic growth does not always lead to social development. Both the economic gains and social costs associated with technology are better analysed through the use of more integrative methods such as the quality of life index.

Economic development is one of the goals a nation intends to achieve through technology transfer. Economic development is achieved if productivity is improved. Many economic benefits derive from the successful transfer of technology. For example, employment opportunities, increased GNP as a result of improved productivity, direct foreign investments, balanced budgets, and increased gold reserves are all signs of economic development. Economic prosperity, is not totally a result of the transferred technology. As one may imagine, there is a huge cost associated with the transfer of technology, especially in terms of patent fees. LDCs should be able to develop, modify, and enhance the transferred technology if they intend to achieve long-term economic growth [130].

Arndt [131] asserts that the following satisfies the objectives of development: higher living standards, rising per capita income, increases in productive capacity, mastery over nature, freedom through control of man's environment, economic growth with equity, elimination of poverty, basic needs satisfaction. Also, catching up with the developed countries in technology, wealth, power, and status, economic independence and self-reliance and liberation satisfies the objectives of development.

Generally, there is no simple formula for economic development. A great part of the human race has existed for thousands of years without achieving any perceptible degree of economic progress. Even today, assured progress is confined to a few areas and the course of development within these areas has been very far from uniform. Some of the developing countries had, at the start, thinly scattered population, e.g. the USA and Canada, whilst some were very densely populated, e.g. Holland and Belgium. In some countries economic development has been accompanied by a high rate of population growth, e.g. the United Kingdom and Japan whereas in others, like Sweden, the growth of the population has been slow. In most countries economic development was accompanied by a high rate of capital accumulation. In Japan, e.g. between 1913 and 1939, real capital is estimated to have increased between five and six fold. But in France over a similar period there was probably no increase in aggregate capital and capital per head of the working population.

The undeveloped countries are even more diverse. They include areas like India and China with long traditions of civilisation, as well as the African tribal societies. There are a number of countries rich in mineral resources and land, like many parts of Latin America, and countries badly endowed by nature. There are countries which will certainly become rich and countries which will probably remain poor. They include not only the densely populated countries of Asia, but as countries like Brazil with thinly scattered populations.

There are not only areas which are desperately short of capital, but countries like Venezuela and Iraq in which funds are plentiful [132].

All these facts suggest that economic development is an immensely complicated process. It is not just a matter of natural resources, capital and labour. It is part of the whole social development of a society.

2.11 Industrialisation

In simple words, industrialisation is the process of building up a country's capacity to process raw materials and to manufacture goods for consumption or further production [133].

The term "industrialisation" is the organisation of production in business enterprises. It is characterised by specialisation and the division of labour and involves the application of technology and mechanical and electrical power to supplement and replace human labour.

All sectors of the economy, that is, the production of consumer goods and capital equipment, agriculture, and service activities, can thus be industrialised. Considered in this way, it is therefore the rational approach to the production process itself that is of significance and not merely the production of commodities, considered to be industrial [134].

At the end of 50s, the developing countries had almost no industrial capacity. The social and physical infrastructure of many, were severely deficient and therefore the building of such capacity was seen to be difficult. Their lack of experience in economic management added to the problems of initial industrialisation.

In the manufacturing sector, the developing countries lacked the necessary capital, technical knowledge and entrepreneurial and managerial skills. But these problems were to be overcome, mostly by the multinational corporations' direct investment particularly in the form of the wholly and majority owned subsidiary, which will be discussed in detail in the next chapter. Also, industrialisation was to be the key to catching up with the higher standards of living and the political stage of advancement of the more industrialised countries.

Industrialisation was seen as a necessary feature for continued growth, promoting national growth, improving the standard of living in a country. It was regarded as an instrument, that could transform agriculture, construction, transport, and other service industries into highly productive sectors [135].

Why is it that economists typically do not associate technological development with the industrialisation of developing countries? Perhaps, an important possible explanation is because invention, the central aspect of global technological development, plays only a minor part in the process. Most technology introduced into developing countries is transferred in one way or another from industrially more advanced countries. But because industrialisation adds to the variety of products produced and processes used in a country, it surely does involve technological development in the sense of gaining mastery over products and processes that are new to the local economy. The minor role of invention simply means that much technological development consists of assimilating foreign technology.

It is impossible to discuss technological development meaningfully without reference to the objectives sought. Trade in the elements of technology is an important consideration in assessing these objectives. Most technological development is import-substitution to replace foreign capability with indigenous capability in activities related to local production and investment. The benefits of this technological development can – and often do – extend beyond simple import-substitution to include the ability to adapt technology. Moreover, such development can increase exports, including exports of the elements of technology, as it has in all semi-industrial economies.

To summarise, trade in the elements of technology is a critical dimension of any strategy for technological development, which in turn is an important correlate of industrial strategy. Industrial strategies are often discussed simply in terms of the sectoral composition of industry and the market orientation of industrial activity versus foreign trade [136].

2.12 Summary and Conclusions

Having analysed the conceptual issues of technology transfer channels, one may not find a direct answer to the question of which mode of international technology transfer is more appropriate for the successful acquisition of foreign technology. However, as the experience of some LDCs show, the major source of technical and managerial knowledge for these countries in their early stage of industrial development was the multinational corporations direct investment. It was particularly in the form of the wholly and majority owned subsidiary. Multinational corporations will be discussed in next chapter. Since the 1960s and 1970s, LDCs employed some less packaged methods of international technology transfer. These include joint ventures (share ownership and control), licensing agreements (the ownership and management responsibility with the host country, but with the supervision of the licensor), franchise contracts (sale of the use of the brand name and technical and managerial support), management contracts (supply of management personnel together with technical and managerial training for the local personnel), and know-how and patents agreement (supply of knowledge and skills of production and the rights for manufacturing certain products).

The choice of an appropriate method for international technology transfer depends on some important factors. They include the stage of development and absorptive capacity of the recipient country, the national and trade policy of the host nation, the nature of technology being transferred, and the motivation and strategy of the supplier of technology. Therefore, the most appropriate channel of technology transfer would be the one in which the recipient can effectively acquire the complete package of technology.

Industrialisation was seen as a necessary feature for continued growth, promoting national growth, improving the standard of living in a country, and was regarded as an instrument that could transform agriculture, construction, transport, and other service industries into highly productive sectors.

Most LDCs regard industrialisation of the economy as the fundamental objective of development and cautiously tailor their commercial policies to achieve it as rapidly and effectively as possible.

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CHAPTER 3: Multinational Corporations and International Technology Transfer

3.1 Introduction

MNCs (Multinational Corporations) account for a large part of world trade, both in commodities and technology.

One of the most important phenomena characterising the modern world economy is the MNCs and the FDI (Foreign Direct Investment) undertaken by them - in fact, the activities of some 40,000 TNCs (Transnational Corporations) and their approximately 250,000 foreign affiliates. With a total outward FDI stock of $2.6 trillion in 1995 and global sales of $5.2 trillion in 1992 by foreign affiliates associated with it, TNCs are assumed to have a leading role in international economic transactions.

By spreading the position of their business operations over the world, TNCs play a significant and growing role in the organisation of the modern world economy. They considerably affect the social and economic well being of individuals in developed, developing, and transitional economies alike. Policy-making in recent years has generally taken a favourable view of the impact of these corporations on economic development, regarding the TNC as an additional source of investment, technology, innovation and employment, fostering the upgrading of labour and management skills and enabling a better integration into the world economy [1].

Technology transfer is greatly facilitated by the operations of MNCs. Corporations augment capital, develop associated industries, and provide more foreign exchange. However, MNCs may cause damage to indigenous industries and put pressure on the availability of local capital, labour, and raw materials. The profit motive of the multinationals may transform the country into a dependent state. Most of the developing countries in the world have a strong public sector, and the role of the private sector is quite limited. In fact, the role of the government, its political philosophy, and also the international political situation greatly determine the amount and nature of the technology transfer. It is well known that Western countries are quite hesitant to transfer the technology to some developing countries because they are afraid that it will be transferred ultimately to the former Communist bloc countries.

Since technology transfer is a give-and-take process, the sender must also be willing. This willingness is possible if the sender also benefits from such a transaction. Technology is not only machinery. It basically means knowledge, which can be used to produce goods. Thus, in addition to the tangible assets such as machinery, hardware and software, the means of transferring knowledge should be discussed [2].

International activities are critical elements in corporate strategy. A report from a study of 200 principal American MNCs shows that 40% of them conducted more than 25% of their operations abroad. This is not restricted to U.S. based MNCs. The corresponding figures for 200 MNCs with parent firms in the U.K., Germany, Japan, Sweden, Canada, France, and Italy were that 80% of them had more than 25% of their interests abroad [3].

3.2 Multinational Corporations: Historical Perspective

Over the past decades, research into the history of TNCs has emerged as one of the most exciting and dynamic areas of the study of international business. When TNCs were first identified by economists in the 1960s, it was assumed (with a few notable exceptions) that they were a post-1945 phenomenon originating in the United States. Historical research has shown this not to be the case. Even in the late nineteenth century there were hundreds of TNCs in the manufacturing sector, while international business activity involving FDI can be traced back to the Middle Ages in Europe. However, establishing the chronology of TNC development has been the least important aspect of historical research on the phenomenon. More important has been the contribution of scholars to identifying the diversity of institutional and contractual forms that have and do exist in international business. This can bring a wealth of empirical data into debates on the role of TNCs which, so often, are clouded by prejudice and ignorance. Also, it provides a testing ground whereby theoretical models developed by economists and others can be judged against in-depth research on actual events.

Two main academic disciplines have made a distinctive contribution to historical research on TNCs. The initial pioneering work, and much subsequent analysis especially of aggregate data, was undertaken by economists with an interest in change over time [4].

In the United States, government agencies and academics began to distinguish between portfolio and FDI in the inter-war years. As a result, studies of direct investment by United

States corporations appeared [5]. During the 1950s and 1960s, concern over the consequences of inward direct investment on host economies led to studies of the subject in the United Kingdom, Canada and elsewhere. The work of the British economist, John Dunning, deserves special mention in this respect. In 1958, Dunning published a monograph on United States direct investment in British manufacturing industry. Although that study did not use the term "transnational corporations" or "multinational corporations", which had yet to be coined, it carefully documented the origins and impact of United States investment in the United Kingdom back to the mid-nineteenth century [6].

Much of Dunning's subsequent work has shed light on TNC history. But, particular mention should be made of his estimates in 1971, of the foreign direct capital stock in the United States. Also, of his 1983 estimates of changes in the level and structure of the world capital stock over the past 100 years [7].

Among other things, those latter estimates confirmed the view of Svedberg and the others that a high percentage of international investment in the nineteenth century was direct, rather than portfolio [8].

Dunning suggested that the stock of accumulated FDI in 1914 amounted to $14,302 million or over a third of total world foreign investment. He estimated that the stock had risen to $26,350 million by 1938, before soaring in the 1950s to reach $66 billion in 1960. Before the Second World War, at least 60% of this FDI had gone to developing countries, mainly in Latin America and Asia, and were largely located in the extractive sector. By contrast, after the Second World War, the proportion of FDI located in the developing world fell sharply to around 32% by 1960. Possibly the most interesting aspect of Dunning's estimate was his data on countries of origin. Dunning showed that, before the Second World War, the United Kingdom had been the world's largest foreign direct investor. It accounts for 45% of the stock in 1914 and 40% in 1938. The era of American predominance came only after the Second World War. By 1960, the United States accounted for 49% of the stock and the United Kingdom 16%. However, the United Kingdom continued through the 1960s and 1970s to be the world's second largest foreign direct investor, despite the relative decline of its economy [9].

3.3 Multinational Corporations and Less Developed Countries

A very salient feature of the operation of MNCs is their large investment in LDCs. In 1968 it accounted for about one third of the total book value of foreign investment outside the centrally planned economies. Lately, most of this investment has been used in the manufacturing industries and is coupled with technological inputs. This situation has been the result of changes, both in the nature of technology and the MNCs.

LDCs, have preferred to use the most up to date, sophisticated technology whenever possible and the MNCs have developed organisations large enough to develop and transfer such technologies [10].

Many authors find in MNCs a perfect answer to the "demands" of LDCs. This point of view has been summarised in the following:

Modern MNCs provide the most efficient organisation for transferring certain classes of technology internationally. They have marketing units throughout the world for seeking out human and institutional needs for products and services. They have research organisations searching world wide for new scientific and technical possibilities. They would have sufficient world wide-markets and resources access to benefit fully from economies of scale in any or all aspects of their business [11].

By the late 1970s it became clear that joint ventures had became far more important as a vehicle of overseas investment by MNCs. Moreover, other new forms of interface between MNCs and developing countries are emerging and spreading. The direct investment package is rapidly giving way to complex joint-venture agreements, production-sharing agreements, management and marketing contracts, service agreements, technology licensing contracts, and turnkey contracts. While the coverage of the available data on these phenomena is not as wide as that on FDI, it seems that a marked rise in the relative importance of such new relationships is occurring.

This growing shift of a fundamental qualitative nature in the principal ways in which MNCs engage in transactions in the world economy is in part a response to a number of structural shifts and policy changes in the international environment in which these enterprises operate. There was a wave of nationalisation in the petroleum and extractive industries in the early 1970s. Following this, many of the newly created state-owned enterprises found it suitable to negotiate contracts for the provision of management, marketing, and technical services with their former MNC owners, so as not to disrupt production and marketing flows and to maintain access to foreign technology [12].

Foreign subsidiaries operating in the LDCs tend to divide sharply into three categories. The exporters of natural resources and resource-based products need no explanation: they go where the resources are. The second class is made up of exporters of manufactured goods or components. The third class comprises producers largely engaged in serving the LDC's domestic market. An important point of fact is the sharpness of the distinction between the second and the third groups [13]. The theory of MNCs' locational choices indicates that, given scale economies and the very small domestic markets of most LDCs, a foreign subsidiary will locate there either to serve the market or to export extensively. But it will not serve the domestic market and export "a little" [14]. This pattern is affirmed in the data. The 80 projects analysed by Reuber et al. [15], were divided into export-oriented projects (26) and those serving the domestic market (54). This pattern is not intrinsic to LDCs but rather to small national markets generally. It also happens in countries such as Ireland [16]. Accordingly, generalisations that span the export and domestic-market subsidiaries are somewhat suspect.

3.4 Private Foreign Direct Investment and the Multinational Corporations

The growth of private FDI in the Third World was extremely rapid during the recent decades. It rose from an annual rate of $2.4 billion in 1962 to $17 billion in 1980, to $31 billion in 1990 and to over $80 billion in 1993. Almost 60% of this total goes to Asia. Table 3.1 shows both the rapid recent growth of FDI and its concentration among 10 recipient nations that together account for 94% of all investment flows. Africa received less than 5% of the total, and the LDCs received under 2%.

Where debt problems are severe, governments are unstable, and economic reforms are only in the beginning, the risks of capital loss can be high. We must recognise that MNCs are not in the development business - their objective is to maximise their return on capital. This is why over 90% of global FDI goes to other industrial countries and the fastest growing Third World Nations. MNCs seek out the best profit opportunities and are largely unconcerned with issues such as poverty, inequality, and the lessening of unemployment [17].

Table 3.1: Net FDI in Developing Countries (1970-1993) and 10 Major Recipients of FDI (1988-1992), (US billions of dollars)

Year (1970-1993)	Net FDI	Ten Major Recipients of FDI	FDI Received (1988-1992)
1970	3.1	China	25.6
1980	10.9	Singapore	21.7
1990	31.0	Mexico	18.4
1991	38.7	Malaysia	13.2
1992	42.5	Argentina	10.6
1993	80.0	Thailand	9.5
		Hong Kong	7.9
		Brazil	7.6
		Taiwan	6.0
		Indonesia	5.6

Sources: 1) UN Development Programme, Human Development Report, 1994
2) Economist, Oct. 1994, Fig. 4.1, p.23

The appropriateness theory is a natural outgrowth of the industrial organisation approach to international direct investment developed by Hymer (1960), Vernon (1966), and Caves (1971) on the creation and appropriateness of the returns from private market investments in information. The appropriateness theory suggests that MNCs are specialists in the production of commercial information (technology), which is less efficient to transmit through markets than within firms. Also, MNCs produce sophisticated technologies because appropriateness is higher for these technologies than for simple ones [18].

There is an extensive literature on the factors that influence the level of FDI investment by TNCs (Transnational Corporations) and the effects of this investment in high-income countries. There is also a growing literature on the relationships between market structure in developing countries and the levels of TNC ownership in their industries and the effects of this investment on the economies of these countries [19].

The marginal rate of return on capital for the TNC investment in a country may depend on three groups of factors:

1. Factors in the host country, such as changes in the value of natural resources, changes in wage rates, the size and growth of its domestic market, and the growth rate of the labour force.

2. Factors within the TNC such as, proprietary technology, access to markets, capital cost, and management expertise.

3. Factors that influence the return on direct investment abroad relative to retaining investment in the home country and servicing other countries via exports and licensing such as, transaction costs and barriers to trade [20].

While TNCs were previously identified solely with FDI, the rise of minority-owned investments and new forms of investments during the 1970s and 1980s led to rather complex patterns of technology transfer [21].

TNCs today engage in diversified types of relationships and arrangements of which foreign direct investments are only a part. A range of co-operative agreements involving joint ventures, sub-contracting, franchising, marketing, and manufacturing are complements to traditional FDI [22].

Dunning suggests the TNCs act as transaction cost minimisers (by co-ordinating a number of separate value-adding activities) and network mobilisers (the organisation of technology, not necessarily the innovator) [23].

Another implication of the transaction costs approach is that MNEs (Multinational Enterprises) reduce the cost of organising cross-border interdependencies, which are those attempts by governments to ban or limit their operations. These operations have generally negative consequences for the efficiency of the international organisation of interdependencies. They involve knowledge, reputation, distribution services, raw materials and components, and capital. In this respect, transaction costs theory leads to conclusions and recommendations that are diametrically opposed to those made by the proponents of the new forms of investment. Indeed, transaction costs scholars have shown that the development of non-traditional forms of trade, such as counter-trade, can be seen as a second-best attempt by firms. These firms located in countries where governments discouraged the establishment of hierarchical links between home firms and foreign partners to recreate some of the incentives inherent in MNCs [24].

According to Lall [25], the link between FDI and technology transfer has weakened because of a multiplicity of new forms of investment. However, it is still strong due to an increasing technology gap and spread of FDI in NIEs (Newly Industrialising Economies). NIEs or NICs (Newly Industrialising Countries) are a small group of countries at a relatively advanced level of economic development with a substantial and dynamic industrial sector and with close links to the international trade, finance, and investment system. They include Argentina, Brazil, Greece, Mexico, Portugal, South Korea, Hong Kong, Singapore, and Taiwan [26]. Asian countries which include the first-tier NICs, known as tigers or dragons, namely South Korea, Taiwan, Singapore, and Hong Kong along with the second generation of NICs, Thailand, Malaysia, and Indonesia. They have experienced an average annual growth rate of GNP per capita of near 7% during the period between 1965-1990. They have also obtained 73.5% of developing countries' manufacture exports in 1990 [27].

3.5 Multinational Corporations and Economic Development

The overall impact of TNCs (transnational corporations) is very difficult to assess, partly because of the complexity of issues involved and the smallness number of data, and partly because of conceptual problems in defining strategic counterfactuals. It is clear, nevertheless, that plausible counterfactuals will depend crucially on the level of development already achieved in the relevant country. That would depend, in tern, on the stage of development of indigenous skills and capabilities, infrastructure and institutions and the policy orientation and administrative efficiency of the government. The realistic alternative to TNCs in the LDCs may not be a competitive private sector, while in some middle-income countries it may be feasible to conceive of strategies to promote indigenous enterprise in demanding areas by restricting TNC entry [28].

Given the strategic counterfactuals, the impact of TNC investment depends, as with other investment, on the incentive and capability structures within which they exist. The incentive structures that are most conducive to efficiency are those associated with stable macro-economic regimes, export-oriented trade strategies, liberal internal competition policies, and relatively open policies to international flows of services and knowledge. The capability structures that enhance investment efficiency are those that provide high-quality skills, a supplier network that permits specialisation and cost competitiveness, and a suitable physical, scientific and institutional infrastructure [29].

Given the incentive and capability structures of the host economy, and considering only marginal changes in FDI, it would appear that TNCs generally offer benefits to host developing countries. Their behaviour does not differ significantly from that of comparable local firms, but they possess certain ownership and internalisation advantages over local counterparts. If the host country can induce these advantages to be transferred and deployed by TNCs, it is likely to benefit from the presence of TNCs. Exceptions to that generalisation are nevertheless possible. That is, when TNCs engage in undesirable practices like tax evasion (e.g., by transfer pricing), or predatory behaviour to local competition, or where they give inadequate attention to potential local suppliers, or do not strike up links with local technological institutions. Also, they may invest too little in local research and development, or fail (for strategic reasons) to exploit the export competitiveness of their affiliates.

There may be grounds to expect different strategies and welfare effects from TNCs of different origins. Firms from some countries favour classic FDI (majority or wholly foreign-owned ventures), while others are more amenable to joint ventures or selling technologies to unrelated firms. Some TNCs are very export-oriented because they specialise in serving world markets with products that are becoming un-competitive at home. Also, they have global networks of supply to exploit location and internalisation advantages – others are more geared, for example, to serving domestic markets. These differences are generally traceable to technological and structural characteristics of their home countries, though over time the differences may be disappearing as firms interact in a common arena. The growth of developing country TNCs has created expectations that they would offer special benefits in terms of appropriate technology, management and skills, more local source, and better corporate behaviour. There may well be some such benefits and a great deal of FDI from the newly industrialising countries of East Asia is currently very export-oriented (as their economies adjust to rising costs). The composition of their TNCs is, however, likely to change over time and it is not clear that their more high-technology firms would be any different from TNCs from developed countries.

The critical issues of whether TNCs as a whole contribute to technology, skills, efficiency or exports in host developing countries ultimately depend on the strategic counterfactuals. The fact that this is largely an area of ignorance is perhaps a reflection on how narrowly TNC research has been defined and how market failures in host countries have been relatively neglected [30].

3.6 Why Do MNCs Transfer Technology to Less Developed Countries?

Various authors agree upon a number of possible factors influencing the decision of MNCs to transfer technology to the LDCs. Many LDCs, compelled by their national interests have imposed restrictions on imports and are pursuing a policy of import substitutions. Faced with a possibility of losing their market, the MNCs are forced to establish manufacturing facilities in the LDCs. In many cases they might be forced to enter into joint collaborations, although they prefer setting up a branch or subsidiary [31].

International rivalry among the MNCs may also force them to invest in a LDC, strengthening their position against rivals.

The rivals may be established enterprises, and may be producers in the LDC or suppliers of competing imports.

The search for new markets and of a sufficient size, could be very important in certain regions and, all other factors may be ignored in efforts to capture a potentially big market.

Another trend has been the establishment of manufacturing facilities in the LDCs due to their cheap labour. Garment and electronics are the major examples of this kind. MNCs are often faced with higher wages at home so prefer to invest in the LDCs where the labour cost is low. Many of the activities involved in such operations are essentially restricted to assembling and packaging [32].

3.7 Advantages Enjoyed by the Multinational Corporations

MNCs control more than 70% of that trade and dominate production, distribution and sale of many goods from developing countries; e.g., tobacco, cereals. They have become in effect "global factories" searching for opportunities anywhere in the world. Many MNCs have annual sales volumes in excess of the GDP of the developing nations in which they operate. For example, the largest MNC in 1993, American GM (General Motors) had sales revenues in excess of the GDP of Thailand. After GM, there are Ford Motors (U.S.), Exxon (U.S.), Royal Dutch/Shell (U.K./Netherlands), and Toyota Motor (Japan), Respectively [33].

Now, it is desirable to describe very briefly some of the advantages enjoyed by the MNCs in their operation in the LDCs. Most of them are the results of their enormous size and technical expertise.

The major advantages are:

1) Cost advantages:

Cost advantages arise from MNCs control over the supply of raw materials and other inputs of production at a favourable price. This is more common in some industries, such as petrochemicals. In such cases firms either own the sources of supply or have long term contracts with the supplier. Small firms are not in a position to own these sources or to convince the supplier to undertake a contract with them.

2) Advantages of product differential:

Massive advertising helps the MNCs to acquire these advantages. New products, which might differ slightly from the older ones, may be presented as a breakthrough in that field. Such claims, when backed up by heavy advertising, which only the MNCs can afford to undertake, provide the firm with a definite advantage over the smaller firms.

Other factors are the possession of patents and the reputation of their trade and brand names. Simply by owning brand names the MNCs can acquire an unchallengeable position in the market. Challenging such proprietary rights is not only time-consuming, but also extremely expensive.

3) Advantages of large scale operation:

Large-size MNCs generally have specialised divisions performing different functions. In all their operations, they enjoy substantial economies of scale. Such advantages could be the result of:

a) Already developed facilities of R&D in the home countries of MNCs. Most of the MNCs are concentrated in the technically advanced industries and are backed by massive R&D programmes. At no substantial additional cost they can utilise the results of this R&D in the LDCs. As the MNCs operate in a number of countries, the experience gained through R&D and previous operations makes them much more competitive than the smaller firms.

Connected with R&D are the facilities and capability to undertake feasibility studies, design and plant construction. For erection of a large industrial plant it is essential that the investor should have access to the necessary "know-how", expertise and organisational capability. Having acquired this, the MNCs have a distinct advantage over small competitors. Modern management skills also contribute to the cost reduction of the MNCs.

b) Access to international advertising and promotion: Many of their products are consumed in the LDCs by those who are influenced by the taste of developed countries.

The MNCs have the advantage of a ready market built by the over spills from their advertising in the developed countries.

c) International economies in organisation due to the large-size of operation and development of modern management techniques, also provides the MNCs with competitive advantages [34].

Why some firms choose to become MNCs, is an interesting and unresolved question in economics [35]. Clearly, firms that operate in foreign countries are at a disadvantage relative to their locally based foreign competitors. That is, they face additional costs, including the costs of co-ordinating activities over long distances that their competitors do not acquire. Economic theory suggests, then, that there must be special advantages to being multinational or else they would stop such operations.

These special advantages could be: Firstly, MNCs might have access to special technology. Control over this technology would enable the MNCs to compete successfully with local firms. Secondly: it is possible that there may be increasing returns to scale that accumulate to a firm that operates plants in many locations [36].

3.8 Costs and Benefits to the Less Developed Countries

There is no question that multinational firms act as effective agents of international transfer of technology from their home country to foreign host nations [37]. On the other hand, developing countries regard FDI (foreign direct investment), which includes capital, technology, export contact, managerial know-how and entrepreneurship, as a suitable package of the necessary ingredients for their industrialisation. And yet, especially in developing countries, critics say that foreign firms bring in the wrong technology or that FDIs do not function well as implementers of international technology transfer.

The arguments of those who support the case of MNCs are as follows [38].

There is a serious shortage of capital in the LDCs; the low rate of saving makes it impossible to raise enough capital domestically. Coupled with this is the fact that in most of the developing countries the production methods are unfashionable, inefficient, and hence, uneconomic. To reorganise industry, the introduction of modern, large-scale technology is essential, as such technology is not available locally. Because no industrial infrastructure exists to produce it; importation is essential. This would require a substantial amount of foreign exchange, which is actually short in the country. MNCs are considered as the only organisation capable of supplying a package of modern sophisticated technology and capital.

The supporters of MNCs also point towards the lack of trained manpower in LDCs to run these modern plants. They stress that only the MNCs are able to set up the operation of these plants as well as to train the local manpower.

The MNCs have many times contributed negatively to the two most urgent problems of the LDCs, namely, mass poverty and unemployment.

Host countries, both developing and developed, have their own social benefits [39]. They would like to spread out inflationary pressure, create new employment opportunities, increase their population's living standard, and correct their balance of payments by increasing foreign exchange earnings and savings. In developing countries, these problems are very critical and, indeed, the social benefit of their operations has been little as compared to the cost.

A study of 156 manufacturing firms in six LDCs, shows that nearly 40% of these firms have a negative effect on overall operations in the host economies [40].

3.9 Effects and Problems of Multinational Corporations' Operations in Less Developed Countries

In the following paragraphs some of the problems experienced by the LCDs because of the MNCs involvement in their economy are discussed.

3.9.1 Technological Effects

The contribution of the MNCs to the technological advancement of LDCs, if not totally negative, can be considered to have a mixed effect. The advanced, sophisticated technology brought in by the MNCs, by its nature, makes the local industry and technology dependent upon further imports.

Although the imported high technology may reduce the "technological gap" between the developed countries and the LDCs artificially, it may at the same time create difficulties in the development of indigenous technology.

The technology gap approach developed by Posner, Gomulka, Cornwall and others, emphasises the role of technology in the process of economic growth and has been discussed by Chatteji [41]. According to this approach, the international economic system is characterised by marked differences in technological levels and trends - differences, which can only be overcome through basic changes in technological, economic and social structures [42]. The basic hypotheses of the technology gap are: i) that there is a close relation between a country's economic and technological level of development, and ii) that the rate of economic growth of a country is positively influenced by the rate of growth in the technological level of a country. If there is a positive relationship between the technical level attained and economic growth of a country, then technology developed in the LDC itself should be treated differently from that developed in foreign countries. Technologies have different characteristics that affect economic growth differently.

The large gap between the technological capabilities of the recipient (LDCs) and supplier (MNCs) also makes it difficult for the LDCs to adapt and absorb the imported technology. As Jones [43] points out the indications are that the greater the difference between supplier and recipient in the respect of technical and managerial skills, management and corporate structure and industrial environment, the greater the problems in supply of technology.

Singer [44] treats TNCs as the major source of modern technology to developing countries. The cost of the transfer was then not explicitly considered (relative to other modes of technology transfer), and the appropriateness of the technology was not an issue. It is because technologies were presumably assumed to be completely adaptable, factor markets to be efficient, and TNCs to maximise profits by responding to factor prices and providing appropriate technology. The 1960s and 1970s were filled with critiques of TNCs for charging developing countries too much for technology transfers and providing inappropriate technology. It was always realised that TNCs were a powerful and effective means of transferring new and innovative technologies. It was argued, however, that the high cost of technology transfer reflected partly the scarcity of the technology (its proprietary nature), its packaging with other intangible assets, and partly the lack of technical skills on the part of the developing country purchasers [45].

The issue of appropriateness is part of a larger debate on the suitability of modern technologies to developing countries [46]. TNCs attract special attention, as they are the pioneers of modern technology and their size and marketing strength enable them to overwhelm alternative technologies and create new tastes more readily. Over time, other concerns were added: technologies did not create local linkages or build on indigenous skills. They were used to produce inappropriate products; they were rigid and un-adaptable to local conditions.

The most significant question with respect to TNCs in the field of technology and development is; what role do TNCs play in the process of technological development in host developing countries? The answer is, somewhat ambiguous. To the extent that technological development consists of mastering the know-how (operational procedures) of a given technology, TNCs may be presumed, subject to the impact of the trade and competition regimes, to have a positive effect. They transmit state-of-the art knowledge and provide the money to make it operational. Even if foreign skills are needed in initial stages, it is in the TNC's economic interest to develop cheaper local skills to take over all local tasks. It is also in its interest to make the adaptations needed to make the technology function efficiently. Finally, it is to its own benefit to continually update affiliate's technology as local circumstances dictate, providing it with the fruits of innovations created in developed countries. Moreover, a foreign presence stimulates local competitors to perform more efficiently. Thus, the ownership advantage of TNCs with respect to technology seems to offer significant benefits to countries that wish to apply that technology to production [47].

3.9.2 Restrictions Associated With Transfer

Multinational Corporations can impose serious restrictions on its further diffusion when they are obliged to transfer technology to local firms. The role of patents can be an example of this. A very large number of patents are owned by few MNCs. Such patents not only help them control the existing technology but also restrict the independent efforts of the LDCs towards developing indigenous technology [48].

Chen [49] deals with the restrictions of technology transfer considerably. While market failures clearly exist in international technology markets, attempts to lower the costs or raise the returns to developing countries by strict regulations may not be very productive. The direct cost (e.g., profits, royalties, fees) of technology imports may be reduced, but usually at the expense of restricting the inflow of direct investment or high-quality technology in other forms.

Casson and Pearce [50] note that there is a certain logic to restrictive business practices. In essence they tend to reflect the market value of the technologies in question; suppressing one mode of payment can simply lead to its substitution by another. The real issue for developing countries is not so much whether or not to regulate technology negotiations (though they should certainly increase the knowledge of buyers). It is how they might develop their domestic technological capabilities to absorb, build and improve upon imported technologies, and so enable them to be more selective in buying foreign technology.

3.9.3 Effects on Local Research and Development

In order to extend their beneficial position, multinational firms possess R&D (Research and Development) capabilities that produce a stream of new product and process technology [51]. The world-wide network of MNCs for processing raw materials gives them an additional edge in relation to indigenous firms. The ability to raise the necessary capital in international financial markets also enhances the transaction positions of multinational firms in relation to host governments and local business partners in developing countries.

In a number of cases a licensee is prevented from using the transferred technology and know-how for R&D that he might desire to undertake. Any modification or improvement in the process or product may also be forbidden. Such restrictions could effectively forbid the growth of research and development in the LDCs. The MNCs could be unable to establish R&D in the LDCs because, organisationally they are structured to facilitate transfer of know-how from a parent subsidiary and not vice versa [52].

The relationships between R&D and MNE (Multinational Enterprise) are extensive. The extent of R&D spending is an excellent predictor of MNE activity in an industry. Most formal R&D is undertaken by firms of at least moderate size, similarly, scale-economy considerations distribute officially foreign investments to the larger firms. Hence, in those industries where most R&D takes place, both the R&D and the foreign investments are likely to be concentrated among the larger firms. Just as R&D promote foreign investments, it is possible that foreign investment promotes R&D [53].

If MNEs take account of world-wide revenue potentials when setting their R&D budgets at home, they also increasingly decentralise R&D activities around the world. Part of the spread is due to government policies, for many governments aim to promote R&D activity on their own soil. The MNE must determine not only how much R&D to undertake world-wide but also where to put it. This process sheds light not just on the economics of R&D activity itself but also on the transfer-ability of technical knowledge across national boundaries [54].

3.9.4 Effects of Trade from Less Developed Countries

The forces explaining the presence of MNEs in the domestic markets of LDCs are about the same as those explaining their presence in industrial countries [55]. Helleiner, pointed out that these exports fall into four categories. First, locally produced raw materials can be subjected to further processing, and MNEs sometimes undertake this role either as an economic choice or in response to host-country inducement. Second, some LDCs have become heavy exporters of simple manufactured goods whose production processes are suitable to their factor endowments. Third, labour intensive processes in manufacturing operations may be carried on in LDCs facilities that import unfinished goods and re-export them after additional processing and in this regard, MNEs play a significant role. Fourth, in some of the larger and more advanced LDCs, some import-competing manufacturing industries have turned around to become successful exporters, and MNEs have been represented in these transformations [56].

Also, Helleiner brought academic attention to bear on the potential of TNCs as "agents of dynamic comparative advantage". The growth of offshore assembly of electronic components requiring cheap semi-skilled labour did contribute significantly to export earnings and employment, but only in a small number of countries [57]. At the same, TNCs greatly increased their exports of more complex products from established operations in large developing countries, reflecting the latter's growth in skills and capabilities as well as low wages. In overall terms, as UNCTC (1988) documents, exports by foreign affiliates rose over time as a percentage of world trade, and often as a share of the host country's total exports [58]. This is not to say, however, that TNCs were the most important agents of the developing countries' dynamic comparative advantage in general. In the East-Asian newly industrialising countries, except for Singapore, local firms accounted for the bulk of export expansion, putting together the package of local and foreign skills needed themselves. In other countries, too, the evidence on the relative export tendencies of TNCs versus local firms was mixed [59].

3.9.5 Financial Participation in the Local Firm

Opposition to the MNCs has been reported in a number of studies. This opposition is based upon financial participation as a condition for transferring technology. For various reasons such as secrecy of the technology, market control and the prestige of their trade name, the MNCs have at many times insisted on complete functional control of the enterprise, which negates the efforts of LDCs towards indigenous development of technology. Some of the LDCs have made attempts to force the MNCs to enter into financial participation with the local entrepreneur [60].

3.9.6 Welfare Impact for Less Developed Countries

International transfers of technology may figure importantly in the welfare economics of foreign investment. If multinational enterprises are a significant agent in transferring technology, the positive effect on world welfare can be large. So, it is important to consider experimental evidence bearing on the MNEs role as a transfer agent.

Welfare economics usually assumes that the proper and expected goal of national economic policy is to maximise the national income. This is expected because, the government is elected by those who receive the national income proper. A maximised income can potentially be distributed so as to make everyone better off.

National welfare maximisation is thus a basis for conflict among nations, because a distribution toward A is, of course, an exaction from B. Furthermore, the policies that will maximise national incomes taken separately are not identical with those that will maximise world income [61].

A study by Lall and Streeten [62] found that a substantial portion of FDI in a sample of developing countries had negative net social effects on their host economies. The conclusion reached was not, however, that foreign investment was worse than domestic investment, but that the social effects of both depended on the trade regime in which they operated. Investment in highly protected import-substituting environments generated much lower benefits than those that were undertaken under export-oriented regimes, or those that were exposed to significant foreign competition. That study, however, acknowledged the very considerable regime, primarily because of the difficulties of assessing the precise contribution of TNCs compared to local alternatives.

3.9.7 Other Impacts

Concern has been expressed about other possible effects of TNCs on developing countries. They include areas of culture, politics, employment and training, women, food security, environment, regional integration, and industrial location. Some of these issues (reviewed in UNCTD, 1988) are of real significance to developing host countries and will assume greater significance in the future (e.g., environment). Governments and analysts would benefit from more, and better disciplined, research in this area. A stimulating theoretical analysis of the socio-cultural impact of TNCs (Buckley and Casson, 1993) shows one direction along which work may proceed.

3.10 Factors Affecting the Success or Failure of Technology Transfer

There are some key factors that can assist the recipient country to adopt and adapt foreign technologies more effectively and efficiently. The successful experience of East Asian first-tier (such as South Korea and Taiwan) and second-tier (such as Malaysia, Thailand and

Indonesia) Newly Industrialising Countries (NICs) in rapid industrial and technology development can have valuable lessons for other less developed countries (LDCs) [63]. Here, we are going to identify some specific factors that affect the efficient acquisition and assimilation of foreign technologies that could certainly be very useful for the policy makers in the LDCs. Some of the most important factors are itemised below.

3.10.1 Public Policies

Over the years, technology has been tightly controlled for several reasons. It can, for instance, be used as a weapon against unfriendly allies. When governments restrict the exportation of certain technology, as they normally do in the case of defence technology, they protect their allies against potential enemies. This policy has often been used by the United States, which restricts the export of advanced defence weaponry to nations such as Iraq, Libya, Syria, and Iran.

Export of super computers and super conductors is restricted even to some allies. This protects local manufacturers from foreign competition and gives them a competitive advantage.

Both external and internal public policies influence the technology transfer process. Policies such as foreign exchange limitations, trade barriers, high taxes, indigenisation policies, and legislation on foreign investments may limit the extent to which technology is transferred. The success or failure of transferred technology may depend to a large extent on the policies adopted by the receiver of technology. Policies should be carefully analysed before the public becomes aware of them [64].

Economic indicators often react to announcements by major policy makers and a good reflection of this is the stock market. Investors are frequently very sensitive to public statements or actions due to the unusually high risks that may be involved in transferring technology to unstable economies. For example, the price per barrel of crude oil rose from $38 to $40 when Saddam Hussein announced his intentions to widen the scope of the Gulf crisis by attacking Saudi Arabia and Israel in the event of US attack on Iraq [65].

Beyond supplying technology to less developed countries (LDCs), the multinational corporations (MNCs) have greater roles to play in the LDCs. If MNCs can effectively transfer appropriate technology to LDCs, the social and economic environment of the

LDCs will be improved and a more conducive business environment suitable to the MNCs' operations will be developed.

Essentially, technology transfer to LDCs should be evaluated on its long-term merits by both the transferor and the transferee.

3.10.2 Effective Management

Management is a complex process, especially in the presence of new technologies. Technology has to be effectively managed in order to achieve a society's goals. Gee [66] notes that, in order for the implementation of new technology to be effective, managers must be innovation-oriented. Thus, managers have to be both sensitive to their environment and committed to the new technology. Wallender [67] also concludes that managers in developing countries need to develop the ability to anticipate, diagnose and solve problems. Less developed countries do not operate in isolation. Their economies and subsequent social standings are influenced by what happens in other parts of the world. As such, managers should understand the interactions and the interdependencies between their environments and the global environment, and how these influence the decision-making process.

Organisations often fail because of poor management. The success or failure of any organisation depends greatly on its ability to cope and adapt. Management has a major function to play if transferred technology is to survive in the LDCs [68].

It is essential for decision-makers in the recipient country to be familiar with the most recent and up-to-date managerial expertise, which can assist them in better absorption and assimilation of imported technology. The existence of efficient managerial expertise in a LDC can also lead to an effective utilisation of its natural and human resources which in turn will result in the promotion of its productivity level [69].

The experiences of some successful countries in an effective technology transfer and rapid industrial and technological development show that the existence of a large number of well-trained and qualified managers in these countries has played a very important role in their success in the efficient adaptation and assimilation of foreign technologies. Therefore, it is essential for decision-makers in LDCs to improve their managerial expertise and skills in particular the ability to plan, organise and solve problems.

3.10.3 Education and Training

In order for the appropriate technology to be transferred and effectively maintained in the LDC, appropriate educational systems and personnel training must be developed. In the absence of these, the LDC will continue to be largely dependent on the transferor to supply the right labour force, to carry on technological innovations, and to engage in research and development. The educational system and training programs must address the needs and the problems of the LDC and how they may be solved through technology. Singh [70] emphasises that effective research and development (R&D) activities are influenced by appropriate educational systems.

Unless the recipient becomes sufficiently capable of maintaining production systems it has implemented, it will never be able to enhance the capability to modify and improve its technology [71].

In the advanced nations of the world, corporations spend hundreds of millions of dollars to retrain and re-educate their workers. Programmes like on-the-job training, in-house training programmes, and seminars are often carried out to keep these workers up of technological changes [72].

Andrews and Miller [73] stress the training of local manpower to provide the knowledge base for technology transfer. In their view, this will permit productive work and a transfer of skills to take place simultaneously.

Maier [74] attributes the failure of the transfer of computer technology to China to the small number of personnel trained in the computer field and also the lack of understanding of computer software.

3.10.4 Research and Development (R&D)

The research and development (R&D) activity is among the most important factors which not only assist the recipient country to modify and adapt the imported technologies to its local conditions but it may also lead to creation and generation of new technology and products.

The allocation of a substantial R&D expenditure as a percentage of gross national product (GNP) is necessary if a country wishes to promote its indigenous technological capability.

For example, some successful countries such as South Korea have increased the R&D expenditure as a percentage of GNP from 1% in 1984 to more than 2% in early 1990s which has lead this country to reach a level of technological maturity. More significantly is the contribution of its private sector to such expenditure, which rose from 32% in 1980 to 82% in 1986 [75].

Chatterji notes that it is significant, citing one survey finding that 40% of 1979 R&D expenditure resulted in technologies that were transferred back to the US. Despite this, other evidence suggests that firms are more hesitant to send processes overseas than their products because they feel the diffusion of process technology is harder to control [76]. It seems that other LDCs are also paying more attention to increasing their R&D expenditure in order to promote their absorptive capacity level, which can assist them in an effective transfer of technology.

3.10.5 Market Size

Larger firms can afford specialised engineering departments, larger R&D budgets, more expensive external advice, more complete sources of information, and so on. But what is considered large varies a great deal from one industry to another [77]. It is clear that a large machine tool firm, for example, is tiny in comparison with plants in other metalworking sectors such as automobile or consumer durable production [78]. Thus size needs to be considered in relation to the specific industrial field of activity.

A country with a relatively adequate size of market would have better learning and absorptive capability for the successful adaptation and effective transfer of technology to its local environment. The large size of the market in the recipient country can also encourage the flow of foreign direct investment (FDI) in to that country which in turn will bring about technological know-how and managerial expertise as well as marketing skills [79].

3.10.6 The Absorptive Capacity of a Recipient

The level of absorption indicates the competence of an economy that acquires technology to utilise or adapt it to its advantage. The lack of complementary assets, particularly administrative and organisational capabilities of some countries to assimilate foreign technology efficiently, is often as important an obstacle to economic development as the failure of these countries to obtain the technology in the first place.

It is clear that the location of technological capacity and technology, and how, and at what cost, technology is disseminated across boundaries, will influence the competence of any particular country to advance its own economic, social and strategic goals [80].

The absorptive capacity of a recipient country can increase through the development of its technological capability. The higher is the level of local technological capability in a country, the more this country will be able to absorb and assimilate imported technologies to its local conditions. The absorptive capacity of a recipient country can also increase through massive investment in the country's industrial infrastructure as well as the promotion of managerial skills and education and training of its labour force.

The increase in R&D can also lead to the promotion of this absorptive capacity level. Therefore, it is vital for the LDCs to develop their absorptive capacity level through enhancing, improving and developing their infrastructure including an effective communication system, transportation networks, power stations, etc.

3.10.7 Government Regulations and Policies

A government permit is often required for the adoption of new technologies [81]. The government's policy is, however, somewhat different from one country to another. For instance, the law does not require any governmental approval when a company wishes to introduce a new technology into Thailand.

The Ministry of Industry in Thailand encourages use of certain new technologies, but it controls only the construction of new factories and the expansion of existing ones.

In the United States, much of the R&D being performed by industry would not be performed at all without federal financial support. The funds are, of course, principally from agencies with specific missions which have been charged with R&D funds by Congress for the purpose of fulfilling their mission. This influence controls not only the quantity of work, but also what R&D will achieve with these funds and, to a significant degree, how R&D will be organised, managed, housed, equipped, staffed and on completion utilised.

Government contracting appears to be a vehicle for technological change. These effects differ by laboratory type and industry. This reflects, to some extent, differences in the degrees of involvement with the government, kinds of work done (research-development) and the pace of technological change in the industries [82].

The supportive role of government in the recipient country, particularly for attracting FDI and implementation of an effective policy framework, can also contribute to its success in technology transfer. The government can provide financial assistance - loans and credits - required for the large-scale industrial and infrastructure projects which are involved in the acquisition of foreign technology.

In a mixed economy with both a public and private sector, the government may establish policies for inducing the private sector to participate in the development process. Certain areas of investment may be reserved to the private sector for a limited period to test private initiative and where government intervention is necessary [83].

The government in the recipient country can also create a stable macro-economic and policy environment, which is necessary for effective and successful technology transfer. Therefore, it is crucial for the government in a LDC to introduce effective regulations for technology transfer, which allow the free flow of appropriate technology to their countries.

3.10.8 Social and Cultural Values

Social and cultural values are the other important factor which can affect the success of technology transfer. The social and cultural values of a country can include traditions, religious and ideological beliefs, historical habits and attitudes of people towards the new devices.

The Philippines is a Christian country, Thailand is a Buddhist country and Indonesia is predominantly a Moslem country. Surveys have attempted to obtain views on this difficult question of how conscious of religion businessmen are in these countries. The findings are by no means satisfactory, but they seem to confirm certain ways of thinking on the part of Southeast Asian businessmen, for instance, about the relations between material welfare and spiritual agents.

Most Westerners are Christians, and there are others; Japanese, Chinese, Indians, who bring in other religious and additional ethnic problems.

The findings of the survey seem to show significant differences among the above three countries with regard to the mode of decision making. Businessmen in Indonesia seem to be influenced by religious factors much more significantly than those in Thailand and the Philippines. From observations it seems safe to presume that Islam in Indonesia has more influence on economic affairs and technology transfer decision making than Buddhism in Thailand and Catholicism in the Philippines [84].

The awareness and understanding of LDCs' social and cultural value systems in technology transfer decision making will enhance the successful transfer of appropriate technology.

Culture is a sensitive issue in most LDCs. Analysis of culture will identify things that are of value to the people of a particular LDC and those factors which motivate them to work. Several analogies may be drawn between different cultures. It is in an attempt to protect their culture that the members of LDCs often reject technology.

Therefore, the policy makers in a recipient country should pay attention to social and cultural values when they design and formulate the overall plan for transferring foreign technologies to their countries. The higher is the cultural and social gap between supplier and recipient societies, the bigger is the need to consider the social and cultural aspects in the overall plan for the technology transfer. Therefore, it is believed that the success of a transfer of technology internationally also depends on the compatibility of the cultural values of countries involved in such transactions [85].

3.10.9 The Willingness of Transferor and Transferee

For any technology transfer to occur, there is a donor (supplier of technology) and recipient. The donor transfers an item of technology through a certain channel (licensing, turnkey operations, joint venture, patent rights, etc.). To achieve an efficient transfer, one needs to look at the supplier's needs, knowledge and skills as well as the absorptive capacity of the receiver. One obstacle to a better transfer is that persons in different countries, organisations, or departments have their own way of doing things. Making sure that the donor and the receiver are willing and able to work together in an effective manner is a major issue and a precondition of any effective transfer [86].

Both the transferor and transferee should have some goals and objectives, which they intend to achieve through technology transfer. Therefore, the compatibility and willingness of both parties are necessary for successful technology transfer.

While the recipient of technology may import foreign technology mainly because of its needs and demands, the supplier of technology may transfer its technologies for such reasons as the incentive of larger profits, wider markets, and new or additional sources of raw material supply. However, both supplier and receiver of technology may put some restrictions on technology transfer. For example, unwillingness by the recipient country may be due to a concern that the transfer of inappropriate technologies will result in heavy dependency on imports of foreign parts and components from the supplier.

Similarly, capital-intensive technologies cannot create employment opportunities for a country with large human resources. On the other hand the supplier of technology on the other hand may not be willing to transfer its up-to-date technologies to the LDCs for fear that such technology might be used in the long term on competition and rivalry in the international market.

3.10.10 Export Promotion Policies

The adoption of an export promotion policy in the LDCs is one of the most important factors for successful acquisition of foreign technology and promotion of its technological capability.

Many of the NICs of South-East Asia are in the process of moving from import-substituting industrial development to export promotion strategies. These nations are attempting to pursue the Japanese model of technological development. Japanese industry did not suddenly develop the ability to cut the advantages associated with vigorous export market penetration. Even though export specialisation was pursued as a cautious goal early on in Japan, policy makers realised that an extended period of protectionism (including exclusion of foreign goods and foreign direct investment wherever possible) would be necessary. For this, it needed to build a strong home market before its domestic industry could reach internationally competitive production volumes and otherwise become effective in exporting [87].

Implementation of an export promotion policy can accelerate the efficient utilisation of the LDCs' natural and human resources in order to compete in the international market. It can be said that the faster exports grow in a LDC, the more rapidly new technology can be transferred into that country. This close relationship between the expansion of growth and the acquisition of foreign technologies is mainly because of current competitive international markets. These markets necessitate a country to transfer in high level and modern technologies in order to shift its comparative advantage from labour-intensive to more skill and technology-intensive industries so as to become more capable of competing in the international market.

The experiences of some East Asian first and second-tier newly industrialising countries in successful technology transfer and rapid industrialisation have provided a strong support for the role of the expansion of exports in their rapid productivity growth and technological up-grading [88].

3.10.11 Human Resource Development Policies

Most economists would probably agree that it is the human resources of a nation, not its capital or its material resources, that ultimately determine the character and pace of its economic and social development [89]. For example, according to the Fredrick Harbison of Princeton University:

"Human resources...constitute the ultimate basis for the wealth of nations. Capital and natural resources are passive factors of production; human beings are the active agents, who accumulate capital, exploit natural resources, build social, economic and political organisations, and carry forward national development. Clearly, a country which is unable to develop the skills and knowledge of its people and to utilise them effectively in the national economy will be unable to develop anything else [90]."

The existence of a well-educated and highly skilled labour force seems to be essential for a country to assimilate and absorb the foreign technologies and technical know-how more effectively. As the experiences of some South-East Asian first and second-tier newly industrialised countries (in particular South Korea and Taiwan) shows, it was massive investment in their people's education and their technological capability and closed the gap with technologically advanced country training and development of their human resources.

This huge investment enabled them to strengthen very quickly. So, LDCs should place more emphasis on designing various human resource development programmes - in particular, the expansion of education and training at all levels both quantitatively and qualitatively.

Also, they need to pay more attention to training at the higher education level in order to increase their university graduates especially in science and engineering. This would allow them to increase the numbers of technicians, engineers and scientists which are required for the efficient adaptation of imported technologies to their local conditions as well as promotion of their indigenous technological capability [91].

3.10.12 Resource Availability

Resource availability may enhance or hinder socio-economic development. Some poor nations shelter themselves by blaming their impoverishment on a lack of natural and mineral resources. They consider adequate resources a necessity for any meaningful socio-economic development. Most of these countries continue to depend largely on foreign aid to sustain their growing population.

On the other hand, some of the nations endowed with mineral and natural resources are among the biggest debtors, and their economies are still not necessarily ideal. Typical examples of this latter case are some members of the Organisation of Petroleum Exporting Countries (OPEC) that relied heavily on crude oil proceeds but did not anticipate the potential oil overload and the strategies in the West to combat the high prices of crude oil in the early seventies. Their total dependence on crude oil negated the importance of other industrial sectors. Thus, the availability of resources may have the opposite effect to that desired if these resources are not properly managed [92].

Switzerland is a land-locked nation with a high cost for labour, strict environmental laws, and few natural resources, least of all cocoa. Yet, it is a world leader in chocolate, not to mention pharmaceuticals, banking, and specialised machinery.

Switzerland is not the exception. Nations like Japan and Taiwan have achieved tremendous economic progress by coping with their disadvantages. Thus, the key is not exploiting "abundance but creating it, not enjoying advantage but coping with disadvantage" [93].

Finally, to effectively transfer technology, the less developed countries (LDCs) should look at the history of other nations that have similar characteristics and structures that have benefited greatly from technology transfers.

3.10.13 Quality of Life

The LDCs seek technology in order to improve their weak social and economic conditions. The ultimate aim is to improve their quality of life. Unfortunately, many authors continue to assess the success or failure of technology transfer by evaluating only the LDCs' economic indicators using measures like GNP. Such measures, including per capita income, are often inadequate as the structural differences of these countries are rarely made part of a formula.

Much of the population of the LDCs continues to reside in rural areas where statistical data are often very difficult to obtain. Many of the economic transactions such as trade by barter and exchange of goods (i.e., food) for services almost never show up in government records. Thus, economic indicators are considerably misleading, and often a false picture of the economies of the LDCs is given to investors [94].

The resort to purely quantitative approaches such as GNP and econometric models has been criticised by other authors. Eschenbach and Geistauts [95] note that the forecasting environment of developing regions is very dynamic due mainly to their dependence on resource development. Economic growth and diversification in developing countries is influenced by several factors including socio-economic, cultural ethical values, and political. In order to develop an efficient model to measure economic progress and even predict the future of technological developments, these factors must be considered.

Thus, existing economic models, are often unreliable in the context of the LDCs. Moreover, these models rely heavily on data collection and historical trend data that are often crude and unreliable.

Economic growth does not always lead to social development. Both the economic gains and social costs associated with technology are better analysed through the use of more integrative methods such as the quality of life index [96].

3.11 Summary and Conclusions

Sometimes there are conditions of an imperfect market, where only the MNCs and other large firms possess the technology desired by the entrepreneurs of the LDCs and where the MNCs are doing their utmost to transform hostile consideration in the host countries to more favourable market conditions. In these cases, it is difficult to imagine situations, which could help the LDCs acquire technology on better terms.

By employing a variety of modes and methods, the international firm seems able to effectively transfer many different kinds of technology under many different circumstances. The results of different kinds of technology transfer offer some managerial implications for firms involved in international technology transfer. While the manufacturing experience, size and R&D to sales ratio of the transferee were identified as statistically significant determinants of transfer costs for the sample, there was also evidence to suggest that any firm with such characteristics would be a good candidate to absorb the technology at low cost.

Another result is related to the efficiency of the multinational firm in technology transfer. Although there were no observations available to allow comparisons of transfer costs by organisations other than multinational firms, it was possible, however, to collect estimates on variation in total project costs according to the organisational form of the transferee (subsidiary, joint venture, independent enterprise, government enterprise). The results suggest that total project costs increase considerably as control declines.

Yet even if the multinational firm is a relatively efficient instrument for allocating world resources, the money coming in for this attempt may not always be received as improving world welfare. These payments will nevertheless have important effects on the world distribution of income.

In the past, countries have adopted different policies towards inward direct investment according to how they have perceived such investment might affect national economic objectives. Two main views have been expressed. The first is that FDI speeds up the process of economic development and restructuring. It does so both by providing technology, entrepreneurship and organisational skills at a lower cost than any alternative usage of resources and by its competitive stimulus and spill over effects on the rest of the economy.

The compositions of both FDI and trade changes with the process of industrialisation. As MNEs become more regionally or internationally integrated in their value-added activities, so trade switches from being based on traditional factor endowments. It becomes based more on created-country-specific assets and capabilities, demand characteristics and actions taken by governments.

Countries are constantly changing their views on the importance of environmental issues, particularly as it affects economic development. Also, MNEs are developing and building environmentally-friendly acts into their competitive strategies. There is little doubt that MNEs have the resources and the competences both to help develop environmental management policies and programmes, and to prevent the rate of environmental deterioration.

Finally, at the end of the chapter, we discussed the critical success factors for international technology transfer, including effective management, public policies, social and cultural values, market size, R&D and willingness of transferor and transferee. It is believed that LDCs can learn valuable lessons from the successful experience of industrial and technological development in some East Asian and Latin American Newly Industrialised Countries (NICs). The successful experience of these countries showed that their massive acquisition of appropriate and modern technology enabled them to increase their productivity and consequently led to their rapid industrialisation. These counties such as South Korea, Taiwan, Brazil and Mexico have been industrialised mostly through borrowing and transferring foreign technology rather than by generating new products or processes. Although these countries are diversified in some overall economic indicators such as per capita income, size of economy and process of their industrialisation, the factors, which led to their success can provide insights for the other LDCs which attempt to follow the same pattern of industrialisation.

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CHAPTER 4: Identification of a Metric for Integration of Technology Transfer

4.1 Introduction

Technology is essential for the social and economic development of any nation. Most of the wealthy nations of the world, such as the United States and Japan, built their economy around technology. In fact, technology is seen by many as the most significant factor in improving productivity, quality, and competitiveness [1].

Most of the literature on the transfer of technology bases its analysis on the nature of the technology to be transferred (this is referred to as intermediate and advanced technology) and on the role of the multinationals as they represent the main body of transfer.

Most of the review, as was seen in previous chapters, treats the problem theoretically. In the present research, a complementary analysis is attempted, which consists of a statistical investigation of economic and social indicators of a large number of developing countries in relation to their integration of technology transferred.

The objective of this research is to identify the most important variables that significantly affect the rate of integration of technology imported, principally by the use of multiple regression analysis. Once those variables are identified, they can be used to explain the differences in the way the developing countries integrate the imported technology.

For this study, the measurement metric for technology integration is defined as the ratio of the growth (trend) of gross industrial product (it will be defined later) to imported technology [2]. This ratio is then regressed on a number of economic and social variables, of which only some are found to affect significantly the rate of technology integration.

The selection of variables, their definitions, calculations, and the selection of the sample of countries are described.

Data sources are indicated and the Minitab Statistical Package (Release 11 for Windows, 1996) has been employed to carry out the calculations required.

The period which the study covers is ten years, 1983-1992. At the time of collection, data was not complete for the period after 1992.

The main reason for taking the approach to the problem as desired above is an awareness that the effectiveness of technology transfer is highly influenced by the social and economic conditions of recipient countries. It is therefore intended to explore these conditions by making use of statistical data and thus gaining more empirical knowledge and further insights.

In this study, particular attention is drawn to social indicators; this is because of the increasing importance given to their study in this area by leading development economists such as Streeten [3] and Seers [4].

4.2 Definition of Gross Industrial Product (GIP)

In economic theory, economic growth results from capital formation, which increases the size of the capital stock, from expansion of the labour force and from technical progress. Structural change can also be a source of growth. This is because, arguing in the tradition of the Clark, Kuznets and Chenery thesis, labour and capital can shift from less productive uses in the primary production sector to more productive uses in manufacturing and services [5].

Many developing countries do invest in capital goods for a major part of their economies but investment in these machineries and equipments does not necessarily promote capital formation and, therefore, economic growth.

As described in the world tables [6], Gross Industrial Product (GIP) represents a measure of the output of the following five branches of activity:

- mining and quarrying
- manufacturing
- construction
- electricity, gas, and water
- transport and communications which include roads, inland and coastal waterways, sea and air transport, including the construction and maintenance of airports, and government support for operating the railways.

We must distinguish the above definition from Gross Domestic Product (GDP) that is the total final output of goods and services produced by the country's economy, within the country's territory, by residents and non-residents, regardless of its allocation between domestic and foreign claims [7].

4.3 Identification of a Metric for Technology Transfer

It is generally agreed that the economic, technological and industrial situations of the developing countries create pressure for the import of capital goods from more advanced economies to develop their manufacturing industries. In other words, developing countries have to rely on imported capital goods for industrial development.

However, the problem related to the imports of goods is to know whether the economy will be able to utilise these investments in an efficient manner to attain industrial growth.

Developing economies themselves lay great emphasis on the importance of capital accumulation, and stress the need to raise the level of investment in relation to output [8].

Capital accumulation is increasing a country's stock of real capital (net investment in fixed assets). To increase the production of capital goods necessitates a reduction in the production of consumer goods. Economic development depends to a large extent on the rate of capital accumulation [9].

A glance at any national development plan will testify to this. Development is associated with industrialisation and industrialisation with capital accumulation. Many development economists also see investment as the most important single factor in the growth process.

Kim [10] suggests two main factors that affect the use of capital goods. These are:

1) The improvement of managerial skills and administration
2) The availability of skilled workers

These factors seem obvious. However, the problem does not lie in suggestions about how to improve technological transfer but rather how does technological transfer operate and what are the determinant factors that hinder or promote it?

As we have seen above, the transfer of technology comprises two parts - the transfer of knowledge and skills and the transfer of capital goods. One may use terms disembodied technology to describe the knowledge that can be productively used and embodied technology to describe the use of capital goods. It is embodied technology that is concerned in the present study, while disembodied technology which can not be quantified, is not going to be considered here.

The analysis of technological transfer in this study is mainly based on the transfer of capital goods that are generally produced in a developed nation and bought by a developing nation. But the user nation may not possess the knowledge of how the capital goods function. This lack of knowledge on the part of the user nation may affect its ability to benefit from the embodied technology.

The fact that developing countries have to rely on imported capital goods for industrial development will be used as a hypothesis in this study. That is, a developing country is not expected to improve its industrial growth if it imports capital goods, which consist mainly of machinery and equipment for production in manufacturing industry.

It is obvious that technology integration is due not only to the economic and social factors of the developing countries but also to the political structure or governmental decisions which determine what strategies are possible in addition to effective economic and social factors [11]. Political aspects will not be considered in this study except for one indicator, revolution/war between countries.

The value assumed by important variables is also dependent on the history of the economy. For instance, the growth of industrial product at year t depends not only on the imported technology of year t, but also of years t-1, t-2, t-3, ... So, if the growth in the previous year's GIP was significant, more may be invested in the transfer of technology.

To explain the relationship between growth of Gross Industrial Product (GIP) and Importation of Technology (IMT), one needs:

1. Measurement of growth in Gross Industrial Product (GIP).
2. Measurement of Imported Technology (IMT).
3. Relationship between growth in GIP and IMT.
   a) growth of GIP = f (IMT, social and economic indicators).
   b) IMT = f (growth of GIP, social and economic indicators).

where 3a and 3b, respectively, take the form:

$$\text{growth of } (GIP)_t = a_0\,(IMT)_t + a_1\,(IMT)_{t-1} + a_2\,(IMT)_{t-2} + \ldots + f(\text{social and economic factors})$$

$$(IMT)_t = b_0 (GIP)_t + b_1 (GIP)_{t-1} + b_2 (GIP)_{t-2} + \dots + f(\text{social and economic factors})$$

Since both the growths of GIP and IMT are functions of the same variables, there will be identification problems if both equations are to be estimated simultaneously. So, it would be better and certainly simpler to estimate the following ratio instead:

$$\text{Integration of Technology Index} = \frac{\text{Growth of GIP}}{\text{IMT}}$$

This ratio will express the integration of technology in developing economies. It represents the influence that imported technology (limited to capital imports) has on industrial growth. The measurement of growth of GIP for the period of 1983-1992 and the calculations of the imported technology will be shown later.

In order to understand the usefulness of this index of measurement for technology transfer, one needs to use some representative examples. The growth of Gross Industrial Product (GIP) divided by the amount of imported technology gives a figure, which is significant in comparative analysis. For instance, if country A's annual industrial growth is 5% and its imports for the industrial sector is 20% of total imports, the value of the integration ratio would be:

$$5\% \div 20\% = 0.25$$

If for the same amount of growth, country B imports 40% of total imports for its industrial sector, the ratio would be:

$$5\% \div 40\% = 0.125$$

These two figures which represent the integration of technology show that countries A and B differ very significantly in their assimilation of technology and, therefore, in their industrial performance. For country B to assimilate technology as well as country A, it has to have an industrial growth of 10% ($10\% \div 40\% = 0.25$), double that of country A. What determines this difference in integrating technology is the major issue in this study.

It was stated that the present analysis concentrates on the industrial sector only. This is because most of the technology transfer is based on industrial machinery and equipment, which is mainly used in industry.

The number of developing countries under study is thirty-four and these were the subject of careful examination. Some countries like Brazil, Singapore and Taiwan have a relatively developed industrial sector. This measurement is not appropriate for this group of countries so they are excluded. These countries do not depend heavily on imports of technology for their development as do others. Also rich oil countries like Qatar and Saudi Arabia are excluded because their dependence on technology has different forms and they have sufficient resources to finance their economy.

As stated before, the period under study is ten years from 1983 to 1992. At the time of data collection, this is the most recent period which provided almost complete data availability. However, even for this period there was incomplete data for a few variables.

The next section describes data collection and the calculations of GIP.

4.4 Data Collection and Calculation of Growth in Gross Industrial Product (GIP)

As defined before, GIP represents a measure of the output of these branches:

- mining and quarrying
- manufacturing
- construction
- electricity, gas and water
- transport and communications (which includes roads, sea, air, ...)

A value for each of the five branches and for each single year from 1983 to 1992 was obtained [12,13].

The logarithmic transformation of the geometric growth rate equation is as follows:

$$X_t = X_0 (1 + r)^t \qquad (1)$$

where, X_t is the value of variable X (which is GIP) in year t, X_0 is the value of variable X in the starting year, r is the least-squares growth rate and t is time in year.

The least-squares growth rate, r, is estimated by fitting a least-squares linear regression trend line to the logarithmic annual values of the variable (which is GIP) in the above period [14]. The regression equation takes the form:

$$\text{Ln } X_t = a + bt \qquad (2)$$

where, $a = \text{Ln } X_0$ and $b = \text{Ln } (1 + r)$ are the parameters to be estimated.

Equation (2) is equivalent to the logarithmic transformation of the geometric growth rate equation (1), $X_t = X_0 (1 + r)^t$.

If b^* is the least-squares estimate of b, then the percentage average annual growth rate, r, is obtained as:

$$[\text{antiLn } (b^*) - 1] \times 100 \qquad (3)$$

The results of the trend of GIP (%) for all countries are shown in Appendix A, Table 1. As a sample, the graph of the trend of GIP (%) for the first country, Bangladesh, is shown in Appendix A, Figure 1.

4.5 Data on Imported Technology

The next task is to attempt to measure imported technology. As the countries differ in size, economy and so on, it is important to realise that the absolute amount of technology transferred cannot be used for a comparative study. Therefore, it is computed as a percentage of the gross industrial product (GIP).

As an example, instead of saying country C imported a certain amount of technology in money terms, one could say that country C imported 10% of its GIP. The first notion does not make any sense, as one billion dollars for example means different things to different countries. It could mean a high proportion for one country, while a low proportion for another.

Developing countries have realised the great importance of technological transformation for their rapid economic and industrial development. Any increase in productive capacity resulting from the import of foreign capital or machinery and equipment is regarded as technology transfer [15]. In developing countries, there is not enough machinery and equipment to use for different purposes, so it needs to be imported from the advanced countries. The increased rate of industrialisation creates acceleration in demand for capital goods.

Data on imported technology are as follows:

1) Machinery and equipment imports measured as a percentage of total merchandise imports. It includes machinery and transport equipment [16].
2) The value of merchandise imports in current U.S. dollars, with some exceptions cover international movements of goods across customs' borders; trade in services is not included [17].
3) Gross Domestic Product (GDP) in current U.S. dollars [18]. GDP measures the total final output of goods and services produced by the country's economy i.e., within the country's territory by residents and non-residents, regardless of its allocation between domestic and foreign claims [19].

4.6 Calculations of Imported Technology as Percentage of GIP

As data on the variable "imported technology (as percentage of GIP)" is not directly provided by the data source, some calculations were required. For this case the following formula has been used:

$$\text{IMT as \% of GIP} = \frac{\text{Machinery \& Equipment (\% of MI)} \times \text{Value of MI (current US dollars)}}{\text{GIP (\% of GDP)} \times \text{Value of GDP (current US dollars)}} \times 100 \qquad (4)$$

Where:

IMT: Imported Technology

GIP: Gross Industrial Product

MI: Merchandise Imports

GDP: Gross Domestic Product

The following procedure shows how the above ratio was calculated:

1) Data on machinery and equipment (as a percentage of merchandise imports) and also the value of merchandise imports in current US dollars were available for each single year and for each country from 1983 to 1992. An average over ten years is calculated.

2) Data was available for each of the mentioned five industrial branches and given as a percentage of GDP at current prices and for each year. To obtain GIP as an overall percentage of GDP, the five percentages were added and then an average for the ten years is computed.
3) Data for the value of GDP in current US dollars were available for each year. An average over ten years is calculated.

The results of the imported technology (% of GIP) for all countries are shown in appendix A, Table 1. As an example, the details of the calculation of imported technology for the first country, Bangladesh, is shown in Appendix A, Table 2.

4.7 Relationship Between GIP and IMT as a Percentage of GIP

It is important to note the relationship between the growth of gross industrial product (GIP) and imported technology (IMT) in ten years, which constitute respectively the numerator and denominator of the ratio used as a metric for the integration of technology.

For this purpose, a correlation analysis of the two variables was attempted. The main objective is to measure of the degree of association existing between the variables.

The value of 'R', the coefficient of correlation is 0.017, that is $R^2 = 0.0003$. So, there is only a 0.03% association between the two variables (Figure 4.1).

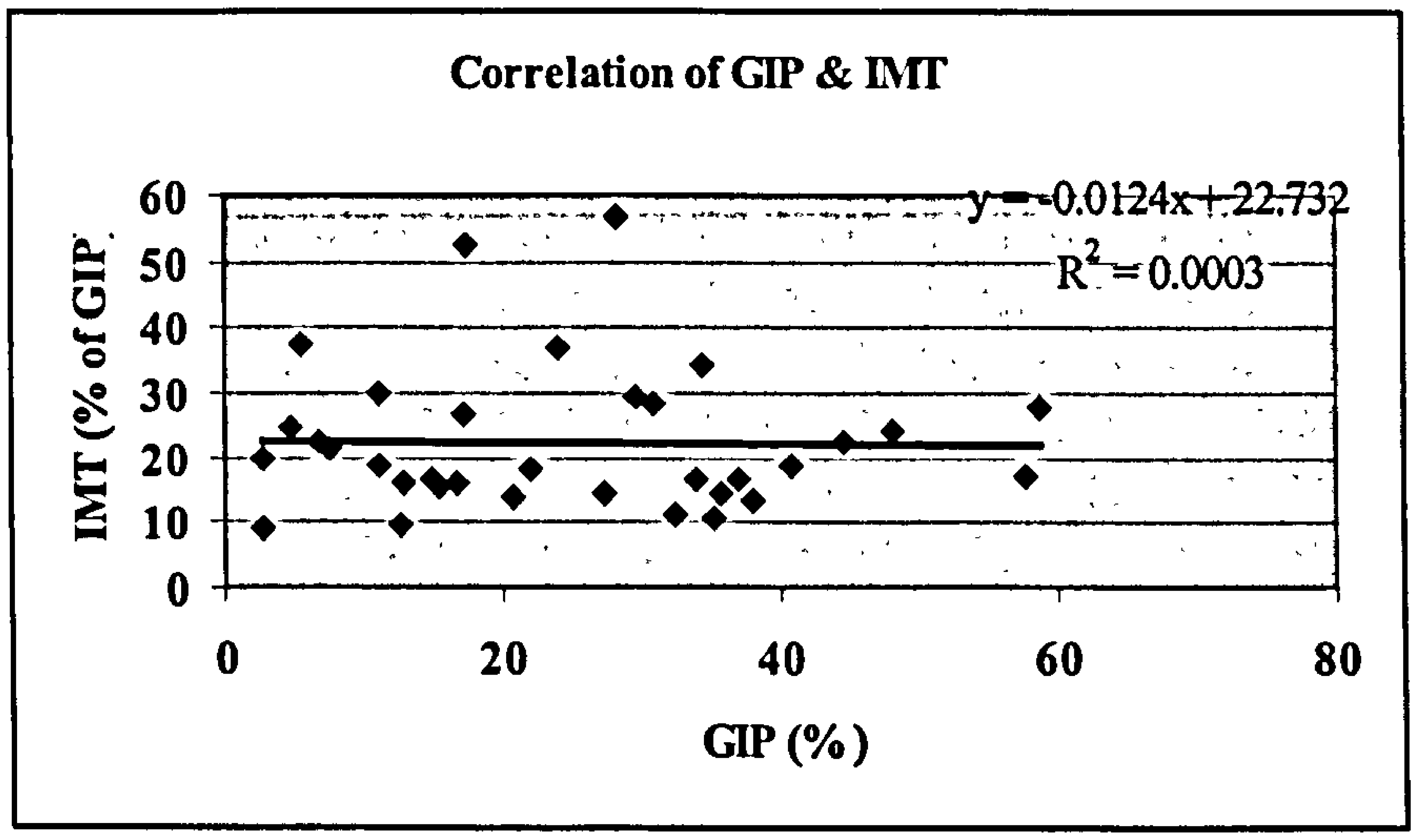

Fig. 4.1

This correlation shows that there is a very weak relationship between the imports of technology for the industrial sector and its economic growth. It seems realistic when one considers the transfer of technology and the economy of most developing countries.

Having noted that imported technology and industrial growth are not significantly related in the majority of the cases, then one may wonder about the factors that affect industrial growth and, therefore, technology integration.

The present study is concerned with exploring those factors that are most predominant in the integration of technological transfer.

4.8 Selection of Indicators

The choice of the variables in the analysis is based on the fact that technological transfer operates within a socio-economic environment.

Most relevant variables to this study have been found in the series World Development Report (World Bank) and World Tables (World Bank) but one may have offered data on one variable for three or four years for one country, and a few different years for another. For example, data for the number of scientists and engineers engaged in research and development (R&D) together with expenditure for R&D were not completely available for some countries and for whole years in the period of 1983-1992. In these cases an average for those available years, has been used.

There are some important indicators (mostly qualitative) related to technological progress but unfortunately there is no data available. For example, there is no data on education and training in the areas of science and technology which is vital in order to achieve long-term technological progress [20]. Furthermore, political aspects, the management process, cultural value systems, administrative organisations and others are also quite strongly related to technological progress [21].

The number of indicators employed in the present study is as large as possible so as to gives as accurate an economic and social profile of each country as possible. These variables will be entered in a multiple regression function, where the ratio of technology integration represents a dependent variable and a number of other variables represent independent, explanatory variables. Some qualitative explanatory variables will be included in the model using dummy variables. The technical aspects will be described later on in section 4.10.

4.9 Analysis of Economic and Social Indicators

Structural changes take place as a result of technology transfer. These changes influence both the social and economic conditions of the less developed country (LDC). Economic factors are quantitative in nature and easily measured, but changes in social variables are more difficult to measure. These changes are easily enough identified with phrases such as "there is a decline in the standard of living" or "there is an increase in the natural environment". But although we may be able to predict the direction of these changes, we may never know their magnitude [22].

An indicator represents some aspect of development such as health, equality, and industrialisation. It may be a direct measure of an economic or social variable, gross national product (GNP) its components and growth for example, which is a determination of the state of the economy. Or it may be an indirect measure, such as standard of living. Probably the most publicised early definition of social indicators was given in a U.S. Department of Health, Education, and Welfare (HEW) document, "Toward a Social

Report". It defines a social indicator as a statistic of direct normative interest, which facilitates concise, comprehensive and balanced judgements about the condition of major aspects of a society [23].

In order to select the best indicators:

1) The indicator itself, or the information it is calculated from, should be already available or to be made available easily and cheaply. This is particularly important for third-world countries, where the resources to collect and process statistical information are strictly limited.
2) The indicator should be relatively easy to understand. Indicators, which are the outcome of many complex mathematical adjustments, are liable to be much more difficult to understand than those which appear as the straightforward reporting of a fact.
3) The indicator, if it is to work at all, must be about something measurable. The loss of community and many other things is not itself directly measurable and therefore, however important it may be, it is not an indicator.
4) Perhaps most obvious of all, an indicator should measure something believed to be important or significant in its own right, or should reflect something important beyond what the indicator is itself a measurement of. For example, life expectancy figures might be used to indicate the general state of health of the population. This is really what makes something an indicator, rather than just a statistic.
5) It is useful if the indicator is based on information which can be used to compare different geographical areas or social groups, so that a picture of a distribution and not just totals and averages can be built up.
6) International comparability is desirable, though difficult to achieve because of differences in environmental circumstances and social institutions [24].

Having seen that economic variables, specifically GNP, and its growth are the main measurement of development efforts, there has been a growing interest in the importance of social indicators as complementary measures of development.

Streeten [25], emphasises the need to enquire into the social variables of a developing country. This allows for factors such as poverty and income distribution to be taken into account in economic decisions. Also, this emphasis allows social indicators to be included in the analysis. It is interesting to see the relevance of social indicators in economic analysis, so that when a social indicator is found to explain technology integration, it is immediately related to economic decisions.

Drewnowski [26] in his 1966 foundation paper said that his concerns with indicators were not with all of them, but only with those that are most significant for the process of development. At the outset he points out that there would always have to be both social and economic indicators [27].

The literature on development indicators makes a sharp distinction between social and economic indicators: the former refer to health and demographic states, nutrition, education, housing and communications; the latter include transport and services, agriculture, industry, and trade [28].

4.10 The Selection of Explanatory Variables

Having stressed the relevance of economic and social indicators for the present analysis, it is now intended to describe the variables included in the model.

The initial total number of variables considered was 23. Because of multicollinearity - this concept will be discussed later - between some variables and also through merging two variables (revolution/civil war and war between countries) into a single variable, 18 variables have been included in the analysis. A full list of the data for 34 countries is provided in Appendix A, Table 5. Also, lists of kind of religion and natural disasters/political factors with details, are shown in Appendix A, Tables 6 and 7, respectively.

The data sources for the variables of gross domestic investment (GDI), gross national saving (GNS), manufacturing production, labour force in industry, transport and communications, exports and imports of manufactured goods, population, and gross national product per capita are the World Tables (World Bank) [29]. For the variables adult illiteracy ratio, energy consumption per capita, and labour force in industry the source is the World Development Report (World Bank) [30]. For the variables total educational expenditure, school enrolment ratios for first and second level and adult illiteracy ratio the source is the Statistical Yearbook [31,32]. For the variable gross industrial product (GIP)

National Accounts Statistics and the Statistical Yearbook [12,13] are used. For the variables natural disasters (drought/famine/floods/earthquake) and political factors (revolution/civil war/war between countries) the following references have been used [33,34,35,36]. For the variable of kind of religion (Christian, Muslim, Buddhism and Indigenous Beliefs) they are [37,38,39,40]. For the variables number of scientists and engineers engaged in R&D and expenditure for R&D they are [41,42,43,45,46].

As it has been mentioned before, for the variables such as number of scientists in R&D, expenditure for R&D, and adult illiteracy ratios there was not enough data provided for all years in the whole period of 1983-1992 so an average of the available years is taken. Also, because of the impact of multicollinearity between variables, three of the variables, total educational expenditure, energy consumption per capita and adult illiteracy ratio were dropped from the model. Finally, the variables revolution/civil war and war between countries have been merged as a single variable. So, in total eighteen variables have been used in the analysis. See Appendix A, Table 3, List of Variables & Units.

4.11 Classification of the Indicators Included in the Model

An indictor is a single variable used in conjunction with one or more other variables to form a composite measure (a method of combining several variables which measure the same concept into a single variable in an attempt to increase the reliability of the measurement through multivariate measurement) [47].

The indicators are defined and classified by the World Bank [48]. They fall into two groups, economic and social indicators.

4.11.1 Economic Indicators

The variables are taken as percentage (mostly as a percentage of GDP). This is because they would allow for a comparative study. If, for instance, the variable is gross national saving, its interpretation for analysis is meaningless, as it does not represent the proportion corresponding to the economy but only a value.

The variable GNP per capita is used as the measure. In this case it is standardised and could be used to compare the size of different economies.

The economic variables included in the model are:

1) Gross Domestic Investment (GDI) as percentage of GDP:

This is the sum of gross domestic fixed investment and the change in stocks. Fixed investment comprises all outlays (purchases and own-account production) by industries and producers of government services. Also included are the additions of new and imported durable goods to their stocks of fixed assets. For producers of private non-profit services it is reduced by the proceeds of net sales (sales less purchases) of similar second-hand and scrapped goods. Excluded is the outlay of producers of government services on durable goods primarily for military purposes, which is classified by the system of national accounts as current consumption.

2) Gross National Saving (GNS) as percentage of GDP:

Gross domestic saving plus net factor income and net current transfers from abroad. Gross domestic saving is GDP minus total consumption.

3) Gross Industrial Product (GIP) as a percentage of GDP:

This is the sum of the output of the five industrial branches already mentioned in 4.2.

4) Manufacturing Production as a percentage of GDP:

This comprises commodities in the Standard International Trade Classification (SITC), chemicals and related products, basic manufactures, machinery and transport equipment, other manufactured articles and goods not elsewhere classified. It excludes non-ferrous metals.

5) Energy Consumption per capita in kg of oil equivalent:

This refers to domestic primary energy use before transformation to other end-use energy sources such as electricity and refined petroleum products. The use of firewood, dried animal manure, and other traditional fuels is not included. All forms of commercial energy, primary energy, and primary electricity are converted into oil equivalent. It is divided by the population to obtain the per capita energy consumption [49].

6) Transport and Communications as a percentage of GDP:

This includes ports and logistics (port concessioning, privatisation and financing, inland water transport), railways, roads and highways (construction and maintenance, planning of roads, paved roads, road financing and road funds, road transport), rural transport (rural construction, rural transport services, design and appraisal of rural transport infrastructure), urban transport (motorization, environment and energy impacts, public transport, transportation planning, urban development sector), and communications (telephone, newspaper, television) [6,49].

7&8) Exports/Imports of Manufactured Goods as a percentage of Total Exports/Imports:

This represents all transactions involving a change of ownership of goods and services between residents of a country and the rest of the world. It includes merchandise, non-factor services (shipment, travel, passenger and other transport services), and factor services (services of labour and capital).

9) Gross National Product (GNP) per capita in US dollars:

Gross Domestic Product (GDP) at market prices plus net factor income from abroad at current prices (the net compensation of employees, with less than one year of residence in the host country and the net property and entrepreneurial income components of the SNA). Finally, GNP in US dollars is divided by the mid-year population to obtain the per capita GNP in current US dollars.

4.11.2 Social Indicators

Social indicators have been used for statistics that are relevant for the analysis of the situation in a particular social field or for society as a whole, similarly as statistics for economic analysis are referred to as economic indicators. In some ways social and economic systems overlap because economic processes are linked to their social and societal environment. We can say that some indicators belong mainly to the social sphere (e.g. school performance and sporting performance), while others (e.g. exchange rate and productivity), are mainly economic phenomena. We can say that economic indicators deal mainly with tangible items and money while social indicators are more concerned with people [50].

The social indicators included in the model are:

10) Total Educational Expenditure as a percentage of GNP:

It is accounted for by public spending on public education plus subsidies to private education at the primary, secondary, and tertiary levels. It may exclude spending by religious schools, which plays a significant role in many developing countries.

11) School enrolment ratios for first & second level as a percentage of total pupils:

This is the number of children of official school age (as defined by the education system) enrolled in primary or secondary school, expressed as a percentage of the number of children of official school age for those levels in the population.

12) Adult Illiteracy ratio as percentage of total population aged 15 and above:

This is the percentage of persons aged 15 and above who cannot, with understanding, read and write a short, simple statement about their everyday life. Literacy is difficult to define and to measure. The definition here is based on the concept of functional literacy: a person's ability to use reading and writing skills effectively in the context of his or her society. Measuring literacy using such a definition requires a census or sample survey measurements under controlled conditions [51].

13) Labour Force in Industry as percentage of total labour force:

This shows the share of the labour force engaged in industrial activities. It includes people working in the mining, manufacturing, construction, and electricity, water, and gas industries.

14) Number of Scientists & Engineers Engaged in Research & Development (R&D) per million people:

This is the number of people trained to work in any field of science who are engaged in professional R&D activity (including administrators), per million people. Most such jobs require completion of tertiary education.

15) Expenditure for R&D as percentage of GNP:

This covers current and capital expenditures (including overheads) on creative, systematic activity intended to increase the stock of knowledge and on the use of this knowledge to devise new applications. This includes fundamental and applied research and experimental development work leading to new devices, products, or processes [51,52].

16) Natural Disasters:

We have categorised Drought, famine, floods and earthquakes as natural disasters. Each country which has experienced at least one of these phenomena during the period under study - a major one - has been chosen as natural disaster [33,34,35,36]. It is included in the model as a dummy variable.

17, 18, 19) Kind of Religion:

Religions included are Christian (Roman Catholic & Protestant), Muslim, Buddhism, and Indigenous Beliefs. We have taken the majority of the country's people in which the religion is dominant [37,38,39,40]. They have been included as dummy variables.

20) Population in millions of people:

This is a basic profile of the demography of a country. Population estimates for mid-year (which have been taken as an average over the whole period of 1983-1992) are from a variety of sources, including the U.N. Population Division, national statistical offices, and World Bank country departments. The World Bank uses the de facto definition of a country's population, which counts all residents regardless of legal status or citizenship [14].

21, 22 & 23) Revolution /Civil War /War Between Countries

If one of these events has happened during the period under study in the form of at least one major or considerable phenomena it has been included in the model using a dummy variable [33,34,36].

4.12 Countries Not Included in the Analysis

Developing countries occupy more than two-thirds of the earth's land surface. They differ markedly in terms of size, structure and stage of development. Economists and others have the advantage of using the World Development Indicators compiled by the World Bank. These provide data on the economic, social and natural resources base in developing countries [5].

For operational and analytical purposes, the World Bank's main criterion for classifying economies is GNP per capita. Every economy is classified as low-income, middle-income (lower-middle and upper-middle), and high-income [43].

Low-income and middle-income economies are sometimes referred to as developing economies. It is not implied that all economies in the group are experiencing similar development. Classification by income does not necessarily reflect development status. Economies are divided among income groups according to 1988 GNP per capita. We have chosen the year 1988 because it is a mid - year of our data period, which is 1983-1992. The groups are:

Low-income economies: $500 or less (GNP/capita)

Lower-middle-income economies: $500-$2200

Upper-middle-income economies: $2200-$6000

High-income economies: $6000 or more

High-income economies are also called the industrial countries and they are mostly members of the Organisation for Economic Co-operation and Development (OECD) [44].

Some countries are amongst the oil exporting countries. They are characterised by huge surpluses that can finance not only the imports of capital goods but also the imports of manpower required. Oil production represents the most dominant part of these economies. They are excluded from the analysis. Although there are some oil-producer countries included in the analysis, they are not rich enough and they have been classified amongst the low and lower-middle income, such as Ecuador, Gabon, and Iran.

Some countries are characterised by the fact that they produce part of their own machinery and equipment and also export them to developed countries. They are not so dependent on foreign technology as are most of the other developing countries. Significant examples are the success of the countries of Southeast Asia, in exporting manufactures to the developed world that suggests this strategy may be of more general applicability. To divide exports of manufactures into high, medium and low R&D, it is interesting to note the growth in high R&D exports from some developing countries since 1970 [5].

For instance, Taiwan's total exports grew at an annual rate of over 20% while exports from South Korea grew even faster. In both cases, this export growth was led by manufactured goods, which contributed over 80% of both nations' foreign-exchange earnings [53]. So, these kinds of countries such as South Korea, Taiwan, Hong Kong and Singapore are also excluded from the analysis. Communist countries are also excluded from analysis. They mostly import and export from more advanced communist countries. The process of their technological transfer is therefore different from the other developing countries.

4.13 Countries Included in the Analysis

Apart from the excluded countries already described, most of the remaining countries seem to be suitable for analysis. However, many developing countries had insufficient data and hence, had to be discarded. These countries included Afghanistan, Benin, Burundi, Chad, Ethiopia, Gambia, Guinea, Haiti, Lesotho, Malawi, Maldives, Mali, Nepal, Niger and Zaire. As mentioned before, some oil producer countries are included because of their capital deficit since they have the same characteristics of the oil importing developing countries such as, Nigeria and Iran.

It is not possible to try to generalise too much about the 144 member countries of the UN that constitute the Third World. While almost all are poor in money terms, they are diverse in size of the country (geographic, population and income level), culture, economic conditions and social and political structures. Thus, for example, low-income countries include India with over 810 million people and 17 states as well as Grenada with less than 100,000 people, fewer than most large towns in the United States. Large size causes complex problems of national cohesion and administration while offering the benefits of relatively large markets and a wide range of resources. In contrast, for many small countries the situation is reversed, limited markets, shortages of skills, shortage of resources and weak bargaining power.

Despite the diversity of countries and classification schemes, however, most Third World nations share a set of common and well-defined goals. These include the reduction of poverty, inequality and unemployment, the provision of minimum levels of education, health, housing and food to every citizen. They have growing diversity in the distribution of income, low levels of agricultural productivity, inappropriate technologies, growing imbalances between urban and rural levels of living and socio-economic opportunities and political goals [54].

The number of countries included in the analysis on which data was almost available is thirty-four. A list of countries is provided in Appendix A, Table 4.

4.14 Methodology/Some Definitions

Dependent variable: in regression terminology, the variable being predicted or explained is called the dependent variable.

Explanatory variable: the variable being used to predict or explain the value of the dependent variable is called the explanatory variable.

Dummy variable: explanatory variable used to account for the effect that different levels of a non-metric variable have in predicting the dependent variable. To account for 'L' levels of a non-metric explanatory variable, 'L-1' dummy variables are needed. For example, gender is measured as male or female and could be represented by two dummy variables, x_1 and x_2. When the respondent is male, $x_1 = 1$ and $x_2 = 0$. Likewise, when the respondent is female, $x_1 = 0$ and $x_2 = 1$. However, when $x_1 = 1$, we know that x_2 must equal 0. Thus we need only one variable, either x_1 or x_2, to represent gender. Thus the number of dummy variables is one less than the number of levels of the non-metric variable.

Multiple regression analysis: regression analysis is by far the most widely used and versatile dependence technique, widely used in such subjects as economics and business (decision making). Regression analysis is a powerful analytical tool designed to explore all types of dependence relationships. Multiple regression analysis is a general statistical technique used to analyse the relationship between a single dependent variable and two or more explanatory variables.

The objective of multiple regression analysis is to predict the changes in the dependent variable in response to changes in the explanatory variables [47,55].

4.15 Formulation of the Model

This part is concerned with the analytical framework which is the functional relationship existing between the "technology integration" as the dependent variable and its economic and social variables as the explanatory variables. The multiple regression model is the equation that describes how the dependent variable, y, is related to the explanatory variables, x_i, and an error term, ε, and has the following form:

$$y = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \cdots \beta_p x_p + \varepsilon \qquad (5)$$

in which, 'y' is dependent variable and 'p' denotes the number of explanatory variables. x_1, x_2, x_3, ..., x_p are explanatory variables, β_0, β_1, β_2, ..., β_p are the parameters, and 'ε' is a random variable (error term) [56]. A full examination of this model will be discussed in detail in chapter 5 (section 5.6).

4.16 Objectives of the Model

Having defined one objective of the present study as the identification of a metric for the integration of technology, it is now necessary to outline the objectives of the proposed multiple regression model.

As mentioned before, most of the work done on technological transfer is theoretical; this is mainly due to the complexity and the special nature of the problem. Different countries are ruled by different cultures, different traditions and, most importantly, by different political complexities and economic environments within which the transfer of technology operates. Therefore, the need to test the theoretical literature may lead one to question the main indicators of technological transfer.

A summary of the main objectives is as follows:

1. This model is aimed at determining the variables that have the largest influence on the integration of technology in developing countries. Using it provides an equation which relates the dependent variable with these influential explanatory variables.
2. Once the significant indicators are identified and the model estimated, the researcher, the policy-maker or the economist can make an attempt or predicting the rate of technology integration for other developing countries not included in the analysis because of insufficient data, or for a different period of time.
3. The identification of the relationships between the variables may be used for decision making. For example, if educational expenditure appears to be a relevant indicator then more emphasis on this aspect can be given by policy-makers. Working with the model, the policy-maker or the analyst will perhaps have confirmation that an improvement in educational expenditure to the population will have a direct effect on the integration of technology.

4.17 Summary and Conclusions

This chapter dealt with the identification of a metric for the measurement of technology integration. It is defined as the ratio of the growth of gross industrial product to imported technology. This ratio will then be regressed on a number of economic and social variables in order to identify those which affect significantly the rate of technology integration.

The selection of variables, their definition, calculations, and the selection of the sample of countries included and non-included have been described.

Data sources were indicated and the Minitab Statistical Package will be employed to carry out the necessary calculations required.

The period which the study covers is ten years, 1983-1992. At the time of data collection there were significant gaps in data availability for more recent years.

The main reason for taking the approach to the problem described above is an awareness that the effectiveness of technology transfer is highly influenced by the social and economic conditions of recipient countries. By using the available data it is therefore intended to explore these conditions in order to gain more empirical knowledge and some further insights in the area.

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CHAPTER 5: A Structured Approach to Multivariate Model-Building

5.1 Introduction

As we discuss the numerous multivariate techniques available to the researcher and the great number of issues involved in their application, it becomes apparent that the successful completion of a multivariate analysis involves more than just the selection of the correct method. Issues ranging from problem definition to a critical diagnosis of the results must be addressed. To aid the researcher or user in applying multivariate methods, a six-step of approach to multivariate analysis is presented. The intent is not to provide a rigid set of procedures to follow but, instead, to provide a series of guidelines that emphasises a model-building approach.

A model-building approach focuses the analysis on a well-defined research plan, starting with a conceptual model detailing the relationships to be examined. Once defined in conceptual terms, the empirical issues can be addressed, including the selection of the specific multivariate technique and the implementation issues.

After significant results have been obtained, their interpretation becomes the focus, with special attention directed toward the variate. The variate is a linear combination of variables formed in the multivariate technique by deriving empirical weights applied to a set of variables specified by the researcher. Finally, the diagnostic tests ensure that the model is not only valid for the sample data but that it is as generalisable as possible.

This six-step model-building process provides a framework for developing, interpreting, and validating any multivariate analysis. Each researcher must develop criteria for "success" or "failure" at each stage, but the discussions of each technique provide guidelines whenever available. Emphasis on a model-building approach, rather than just the specifics of each technique, should provide a broader base of model development, estimation, and interpretation that will improve the multivariate analyses of practitioner and academic alike. Examples of multivariate techniques are multiple regression analysis, multiple analysis of variance, factor analysis, and cluster analysis.

The following discussion briefly describes each step in this approach [1].

5.2 Model-Building Stage 1: Define the Research Problem, Objectives, and Multivariate Technique to Be Used

The starting point for any multivariate analysis is to define the research problem and analysis objectives in conceptual terms before specifying any variables or measures. The role of conceptual model development, or theory, cannot be overstated. The researcher must first view the problem in conceptual terms by defining the concepts and identifying the fundamental relationships to be investigated.

A conceptual model need not be complex and detailed, instead, it can be just a simple representation of the relationships to be studied. If a dependence relationship is proposed as a research objective, the researcher needs to specify the dependent and explanatory variables. The researcher first identifies the ideas or topics of interest rather than focusing on the specific measures to be used. This minimises the chance that relevant variables will be omitted in the effort to develop measures and to define the specifics of the research design.

With the objectives and conceptual model specified, the researcher has only to choose the appropriate multivariate technique based on the measurement characteristics of the dependent and explanatory variables. The variables may be specified prior to the study in its design or be defined after the data have been collected when specific analyses are defined.

5.2.1 Model-Building Stage 2: Develop the Analysis Plan

Attention now turns to the implementation issues. For each technique, the researcher must develop an analysis plan that addresses the set of issues particular to its purpose and design. The issues include general considerations such as minimum of desired sample sizes and allowable or required types of variables (metric versus non-metric), and estimation methods, as well as specific issues such as the type of association measures used in multidimensional scaling. In each instance, these issues resolve specific details and finalise the model formulation and requirements for data collection.

5.2.2 Model-Building Stage 3: Evaluate the Assumptions Underlying the Multivariate Technique

All multivariate techniques have underlying assumptions, both statistical and conceptual, that substantially impact their ability to represent multivariate relationships. For the techniques based on statistical inference, the assumptions of multivariate normality, linearity, and independence of the error terms must be met. Each technique also has a series of conceptual assumptions dealing with such issues as model formulation and the types of relationships represented. Before any model estimation is attempted, the researcher must ensure that both statistical and conceptual assumptions are met.

5.2.3 Model-Building Stage 4: Estimate the Multivariate Model and Assess Overall Model Fit

The researcher may choose among options to meet specific characteristics of the data (e.g., use of covariates in MANOVA) or to maximise the fit to the data (e.g., rotation of factors). After the model is estimated, the overall model fit is evaluated to ascertain whether it achieves acceptable levels on the statistical criteria (e.g., level of significance). It also identifies the proposed relationships and achieves practical significance. Many times, the model will be re-specified in an attempt to achieve better levels of overall fit and/or explanation.

The researcher must also determine if the results are affected by any single or small set of observations, by applying reasonably well to all observations in the sample. Ill-fitting observations may be identified as outliers or influential observations.

5.2.4 Model-Building Stage 5: Interpret the Variate(s)

Interpreting the variate(s) reveals the nature of the multivariate relationship. Interpretation of effects for individual variables like regression weights and factor loadings, is made by examining the estimated coefficients (weights) for each variable in the variate. Moreover, some techniques like principal components also estimate multiple variates that represent underlying dimensions of comparison or association. The interpretation may lead to additional re-specifications of the variables and/or model formulation. The objective is to identify empirical evidence of multivariate relationships in the sample data that can be generalised to the total population.

5.2.5 Model-Building Stage 6: Validate the Multivariate Model

Before accepting the results, the researcher must subject them to the final set of diagnostic analyses that assess the degree of generalisability of the results by the available validation methods. It is directed toward demonstrating the total population. These diagnostic analyses add little to the interpretation of the results but can be viewed as "insurance" that the results are the most descriptive of the data and generalisable to the population.

In summary, the six-step approach partitions into two sections. The first section (stages 1 through 3) deals with the issues addressed while preparing for actual model estimation, i.e., research objectives, research design considerations, and testing for assumptions. The second section (stages 4 through 6) deals with the issues pertaining to model estimation, interpretation, and validation.

5.3 Factor Analysis

The multivariate statistical technique of factor analysis has found increased use during the past decade in many fields specially business-related research. As the number of variables to be considered in multivariate techniques increases, there is an essential need for increased knowledge of the structure and interrelationships (correlations) of the variables. Factor analysis is a technique particularly suitable for analysing the patterns of complex, multidimensional relationships (not possible with univariate and bivariate methods) for a large number of variables (e.g., test scores, test items, questionnaire responses) by defining a set of common underlying dimensions, known as factors encountered by researchers. It determines whether the information can be condensed or summarised or whether data could be reduced. In summarising the data, factor analysis derives underlying dimensions that, when interpreted and understood, describe the data in a much smaller number of concepts than the original individual variables. Data reduction can be achieved by calculating scores for each underlying dimension and substituting them for the original variables.

Factor analysis differs from the dependence techniques, i.e., multiple regression, discriminant analysis, and multivariate analysis of variance, in which one or more variables are explicitly considered the criterion or dependent variables and all others are the predictor or explanatory variables. Factor analysis is an interdependence technique in which all variables are simultaneously considered, each related to all others, and still employing the concept of the variate, the linear composite of variables. In factor analysis, the variates (factors) are formed to maximise their explanation of the entire variable set, not to predict a dependent variable. Thus, each variable is predicted by all others. Conversely, one can look at each factor as a dependent variable that is a function of the entire set of observed (original) variables [2].

5.4 Factor Analysis Decision Process

We centre the discussion of factor analysis on the six-stage model-building paradigm. A discussion of each stage follows.

5.4.1 Model-Building Stage 1: Objectives of Factor Analysis

The starting point in factor analysis, is the research problem. The general purpose of factor analytic techniques is to find a way to summarise the information contained in a number of original variables, into a smaller set of new factors with a minimum loss of information [3]. More specifically, factor analysis can satisfy either of two objectives: (1) identifying structure through data summarisation or (2) data reduction.

5.4.1.1 Identifying Structure Through Data Summarisation

Factor analysis can identify the structure of relationships among either variables or respondents by examining either the correlations between the variables or the correlations between the respondents. For example, suppose we have data on 100 respondents in terms of 10 characteristics. If the objective of the research were to summarise the characteristics, the factor analysis would be applied to a correlation matrix of the variables. This is the most common type of factor analysis, and is referred to as "R factor analysis". R factor analysis analyses a set of variables to identify the dimensions that are latent (not easily observed).

5.4.1.2 Data Reduction

Factor analysis can also identify representative variables from a much larger set of variables for use in subsequent multivariate analyses or create an entirely new set of variables, much smaller in number, to partially or completely replace the original set of variables for inclusion in subsequent techniques. In both instances, the purpose is to retain the nature and character of the original variables, but reduce their number to simplify the subsequent multivariate analysis.

5.4.1.3 Variable Selection

Data reduction and summarisation can be performed either with pre-existing sets of variables or with variables created by new research. When using an existing set of variables, the researcher should still consider the conceptual underpinnings of the variables and use judgement as to the appropriateness of the variables for factor analysis. The use of factor analysis for data reduction becomes particularly critical when comparability over time or in multiple settings is required.

5.4.2 Model-Building Stage 2: Designing a Factor Analysis

The design of a factor analysis involves three basic decisions:

(1) Calculation of the input data (a correlation matrix) to meet the specified objectives of grouping variables or respondents.

(2) The design of the study in terms of number of variables, measurement properties of variables, and the types of allowable variables. Variables for factor analysis are generally assumed to be of metric measurement. In some cases, dummy variables (coded 0-1), although considered non-metric, can be used. The researcher should also attempt to minimise the number of variables included but still maintain a reasonable number of variables per factor.

(3) The sample size necessary, both in absolute terms and as a function of the number of variables in the analysis.

5.4.2.1 Correlations among Variables or Respondents

The first decision in the design of a factor analysis focuses on the approach used in calculating the correlation matrix for factor analysis. The researcher could derive the input data matrix from the computation of correlations between the variables. The researcher could also elect to derive the correlation matrix from the correlations between the individual respondents. In this case, the results would be a factor matrix that would identify similar individuals.

5.4.2.2 Variable Selection and Measurement Issues

Two specific questions must be answered at this point: (1) How are the variables measure? and (2) How many variables should be included? Variables for factor analysis are generally assumed to be of metric measurement. In some cases, dummy variables (coded 0 and 1, and have been defined before), although considered non-metric, can be used. The researcher should also attempt to minimise the number of variables included but still maintain a reasonable number of variables per factor. The strength of factor analysis lies in finding patterns among groups of variables, and it is of little use in identifying factors composed of only a single variable. Finally, when designing a study to be factor analysed, the researcher should, if possible, identify several key variables that closely reflect the hypothesised underlying factors. This will aid in validating the derived factors and assessing whether the results have practical significance.

5.4.2.3 Sample Size

Regarding the sample size question, the researcher would not factor analyse a sample of fewer 30 observations, and preferably the sample size should be 50 or larger. Even some believes of 100 or larger. The researcher should always try to obtain the highest cases-per-variable ratio (3 to1 or 5 to 1) to minimise the chances of "over-fitting" the data. The researcher may do this by employing the most parsimonious set of variables, guided by conceptual and practical considerations. Then, he may obtain an adequate sample size for the number of variables examined.

5.4.3 Model-Building Stage 3: Assumptions in Factor Analysis

The critical assumptions underlying factor analysis are more conceptual than statistical. From a statistical standpoint, only normality is necessary if a statistical test is applied to the significance of the factors, but these tests are rarely used. In fact, some degree of multicollinearity is desirable, because the objective is to identify interrelated sets of variables.

In addition to the statistical bases for the correlations of the data matrix, the researcher must also ensure that the data matrix has sufficient correlations to justify the application of factor analysis. If visual inspection reveals no substantial number of correlations greater than 0.30, then factor analysis is probably inappropriate.

The conceptual assumptions underlying factor analysis relate to the set of variables selected and the sample chosen. A basic assumption of factor analysis is that some underlying structure does exist in the set of selected variables. It is the responsibility of the researcher to ensure that the observed patterns are conceptually valid and appropriate to study with factor analysis, because the technique has no means of determining appropriateness other than the correlations among variables. For example, mixing dependent and explanatory variables in a single factor analysis and then using the derived factors to support dependence relationships is inappropriate.

5.4.4 Model-Building Stage 4: Deriving Factors and Assessing Overall Fit

Once the variables are specified and the correlation matrix is prepared, the researcher is ready to apply factor analysis to identify the underlying structure of relationships. In doing so, decisions must be made concerning (1) the method of extracting the factors (common factor analysis versus components analysis) and (2) the number of factors selected to represent the underlying structure in the data. Selection of the extraction method depends upon the researcher's objective. Component analysis, also known as principal components analysis, is used when the objective is to summarise most of the original information (variance) in a minimum number of factors for prediction purposes. In contrast, common factor analysis is used primarily to identify underlying factors that reflect what the variables share in common. For either method, the researcher must also determine the number of factors to represent the set of original variables. Both conceptual and empirical issues affect this decision.

5.4.4.1 Common Factor Analysis Versus Component Analysis

The researcher can utilise two basic models to obtain factor solutions. They are known as "common factor analysis" and "component analysis". To select the appropriate model, the researcher must first understand the differences between types of variance. Three types of total variance exists, common, specific (unique), and error.

Common variance is defined as that variance in a variable that is shared with all other variables in the analysis. Specific variance is that variance associated with only a specific variable. Error variance is that variance due to unreliability in the data-gathering process, measurement error, or a random component in the measured phenomenon.

Component analysis, is also known as principal component analysis. It considers the total variance and derives factors that contain small proportions of unique variance and in some instances, error variance. However, the first few factors do not contain enough unique or error variance to distort the overall factor structure. Specifically, with component analysis, unities are inserted in the diagonal of the correlation matrix, so that the full variance is brought into the factor matrix. Conversely, with common factor analysis, communalities are inserted in the diagonal. Communalities are estimates of the shared, or common variance among the variables. Factors resulting from common factor analysis are based only on the common variance.

5.4.4.2 Criteria for the Number of Factors to Extract

How do we decide on the number of factors to extract? When a large set of variables is factored, the method first extracts the combinations of variables explaining the greatest amount of variance and then proceeds to combinations that account for smaller and smaller amounts of variance. In deciding when to stop factoring that is, how many factors to extract, the researcher generally begins with some predetermined criterion, such as the percentage of variance or latent roots (eigenvalues) criterion, to arrive at a specific number of factors to extract.

5.4.4.2.1 Latent Root (Eigenvalue) Criterion

The rationale for the eigenvalues criterion is that any individual factor should account for the variance of at least a single variable if it is to be retained for interpretation. Each variable contributes a value of "1" to the total eigenvalue. Thus, only the factors having eigenvalues greater than "1" considered significant; all factors with eigenvalues less than "1" are considered insignificant.

5.4.4.2.2 Percentage of Variance Criterion

The percentage of variance criterion is an approach based on achieving a specified cumulative percentage of total variance extracted by successive factors. The purpose is to ensure practical significance for the derived factors by ensuring that they explain at least a specified amount of variance. In the natural sciences, the factoring procedure usually should not be stopped until the extracted factors account for at least 95% of the variance or until the last factor accounts for only a small portion (less than 5%). In contrast, in the social sciences, where information is often less precise, it is not uncommon to consider a solution that accounts for 60% of the total variance as satisfactory [4].

5.4.4.2.3 Scree Test Criterion

With the component analysis factor model, the later factors extracted contain both common and unique (specific) variance. Common variance is defined as that variance in a variable that is shared with all other variables in the analysis. Specific variance is that variance associated with only a specific variable.

Although all factors contain at least some unique variance, the proportion of unique variance is substantially higher in later than in earlier factors. The "scree test" is used to identify the optimum number of factors that can be extracted before the amount of unique variance begins to dominate the common variance structure. The "scree test" is derived by plotting the latent roots (eigenvalues) against the number of factors in their order of extraction, and the shape of the resulting curve is used to evaluate the "cut-off point". Starting with the first factor, the plot slopes steeply downward initially and then slowly becomes an approximately horizontal line. The point at which the curve first begins to straighten out "cut-off point" is considered to indicate the maximum number of factors to extract. Beyond that point, too large a proportion of unique variance would be included thus, these factors would not be acceptable. As a general rule, the "scree test" results in at least one and sometimes two or three more factors being considered for inclusion than does the latent root criterion [5].

5.4.4.2.4 Heterogeneity of the Respondents

Shared variance among variables is the basis for both common and component factor models. An underlying assumption is that shared variance extends across the entire sample. If the sample is heterogeneous with regard to at least one sunset of the variables, then the first factors will represent those variables that are more homogenous across the entire sample. Variables that are better discriminators between the subgroups of the sample will load on later factors, many times those not selected by the criteria discussed above [6].

5.4.5 Model-Building Stage 5: Interpreting the Factor

Three steps are involved in the interpretation of the factors and the selection of the final factor solution. First, the initial unrotated "factor matrix" is computed to assist in obtaining a preliminary indication of the number of factors to extract. The factor matrix contains factor loadings for each variable on each factor. Factor loadings are the correlation of each variable and the factor. Loadings indicate the degree of correspondence between the variable and the factor, with higher loadings making the variable representative of the factor.

In computing the unrotated factor matrix, the researcher is simply interested in the best linear combination of variables. Best in the sense that the particular combination of original variables accounts for more of the variance in the data as a whole than any other linear combination of variables. Therefore, the first factor may be viewed as the single best summary of linear relationships exhibited in the data that accounts for the largest amount of variance. The second factor is defined as the second-best linear combination of the variables that accounts for the most residual variance after the effect of the first factor has been removed from the data. Subsequent factors are defined similarly, until all the variance in the data is exhausted.

Unrotated factor solutions achieve the objective of data reduction, but it will not provide information that offers the most adequate interpretation of the variables under examination. The unrotated factor solution may not provide a meaningful pattern of variable loadings. Generally, rotation will be desirable because it simplifies the factor structure, and it is usually difficult to determine whether unrotated factors will be meaningful. Therefore, the second step employs a rotational method to achieve simpler and theoretically more meaningful factor solutions.

In the third step, the researcher assesses the need to re-specify the factor model owing to (1) the deletion of a variable(s) from the analysis, (2) the desire to employ a different rotational method for interpretation, (3) the need to extract a different number of factors, or (4) the desire to change from one extraction method to another.

5.4.5.1 Rotation of Factors

An important tool in interpreting factors is factor rotation. The reference axes of the factors are turned about the origin until some other position has been reached. The simplest case of rotation is an orthogonal rotation, in which the axes are maintained at 90 degrees.

Most researchers agree that most direct unrotated solutions are not sufficient; that is, in most cases rotation will improve the interpretation by reducing some of the ambiguities that often accompany the preliminary analysis. The ultimate goal of any rotation is to obtain some theoretically meaningful factors and, if possible, the simplest factor structure.

5.4.5.1.1 Orthogonal Rotation Methods

In practice, the objective of all methods of rotation is to simplify the rows and columns of the factor matrix to facilitate interpretation. In a factor matrix, columns represent factors, with each row corresponding to a variable's loading across the factors. By simplifying the rows, we mean making as many values in each row as close to zero as possible (i.e., maximising a variable's loading on a single factor). By simplifying the columns, we mean making as many values in each column as close to zero as possible (i.e., making the number of "high" loadings as few as possible). Three major orthogonal approaches have been developed, Quartimax, Varimax, and Equimax. Among these three methods the Varimax method has proved very successful as an analytic aproach to obtaining an orthogonal rotation of factors.

5.4.5.1.2 Varimax Method

The "varimax" rotational approach centres on simplifying the columns of the factor matrix. That is, the "varimax" method maximises the sum of variances of required loadings of the factor matrix. In this method, there tend to be some high loadings (i.e., close to −1 or +1) and some loadings near 0 in each column of the matrix. The logic is that interpretation is easiest when the variable-factor correlations are (1) close to either +1 or −1, thus indicating a clear positive or negative association between the variable and the factor; or (2) close to 0, indicating a clear lack of association.

5.4.5.2 Criteria for the Significance of Factor Loadings

In interpreting factors, a decision must be made regarding which factor loadings are worth considering. The following discussion details issues regarding practical and statistical significance, as well as the number of variable that affect the interpretation of factor loadings.

5.4.5.2.1 Ensuring Practical Significance

The first suggestion is not based on any mathematical proposition but relates more to practical significance.

In short, factor loadings greater than ±0.30 are considered to meet the minimal level; loadings of ±0.40 are considered more important; and if the loadings are ±0.50 or greater, they are considered practically significant. Thus the larger the absolute size of the factor loading, the more important the loading in interpreting the factor matrix. Because factor loading is the correlation of the variable and the factor, the squared loading is the amount of the variable's total variance accounted for by the factor. Thus, a ±0.30 loading translates to approximately 10% explanation, and a ±0.50 loading denotes that 25% of the variance is accounted for by the factor. The loading must exceed 0.70 for the factor to account for 50% of the variance. The researcher should realise that extremely high loadings (±0.80 and above) are not typical and that the practical significance of the loadings is an important criterion.

5.4.5.2.2 Assessing Statistical Significance

As previously noted, a factor loading represents the correlation between an original variable and its factor. In determining a significance level for the interpretation of loadings, an approach similar to determining the statistical significance of correlation coefficients could be used. However, research has demonstrated that factor loadings have substantially larger standard errors than typical correlations.

5.4.5.2.3 Adjustments Based on the Number of Variables

A disadvantage of both of the prior approaches is that the number of variables being analysed and the specific factor being examined are not considered. It has been shown that as the researcher moves from the first factor to later factors, the acceptable level for a loading to be judged significant should increase. The number of variables being analysed is also important in deciding which loadings are significant. As the number of variables increases, the acceptable level for considering a loading significant decreases.

5.4.5.3 Interpreting a Factor Matrix

Interpreting the complex interrelationships represented in a factor matrix is no simple matter. By following the procedure outlined in the following paragraphs, however, one can considerably simplify the factor interpretation procedure.

5.4.5.3.1 Examine the Factor Matrix of Loadings

Each column of numbers in the factor matrix represents a separate factor. The columns of numbers are the factor loadings for each variable on each factor. For identification purposes, the computer printout usually identifies the factors from left to right by the numbers 1, 2, 3, 4, and so forth. It also identifies the variables by number from top to bottom.

5.4.5.3.2 Identify the Highest Loading for Each Variable

The interpretation should start with the first variable on the first factor and move horizontally from left to right, looking for the highest loading for that variable on any factor. When the highest loading (largest absolute factor loading) is identified, it should be underlined if significant. Attention then focuses on the second variable and, again moving from left to right horizontally, looking for the highest loading for that variable on any factor and underlining it. This procedure should be continued for each variable until all variables have been underlined once for their highest loading on a factor. Recall that for the sample sizes of less than 100, the lowest factor loading to be considered significant would in most instances be ± 0.30.

When each variable has only one loading on one factor, that is considered significant and the interpretation of the meaning of each factor is simplified considerably. In practice, however, many variables may have several moderate-size loadings, all of which are significant, and the job of interpreting the factors is much more difficult. Most factor solutions do not result in a simple structure solution, that is, a single high loading for each variable on only one factor. Thus, the researcher will, after underlining the highest loading for a variable, continue to evaluate the factor matrix by underlining all significant loadings for a variable on all the factors.

Ultimately, the objective is to minimise the number of significant loadings on each row of the factor matrix (that is, make each variable associate with only one factor). In doing this, the researcher should proceed to rotate the factor matrix to redistribute the variance from the earlier factors to the later factors. Rotation should result in a simpler and theoretically more meaningful factor pattern.

5.4.5.3.3 Assess Communalities of the Variables

The communalities for each variable are provided, representing the amount of variance accounted for by the factor solution for each variable. The researcher should view each variable's communality to assess whether it meets acceptable levels of explanation. For example, the researcher would identify all variables with communalities less than 0.50 as not having sufficient explanation.

Variables with higher loadings are considered more important and have greater influence on the name or label selected to represent a factor. Thus the researcher will examine all the underlined variables for a particular factor and, placing greater emphasis on those variables with higher loadings, will attempt to assign a name or label to a factor that accurately reflects the variables loading on that factor. The signs are interpreted just as with any other correlation coefficients. On each factor, like signs mean the variables are positively related, and opposite signs mean the variables are negatively related [7].

5.4.6 Model-Building Stage 6: Validation of Factor Analysis

This stage involves with the degree of generalizability of the results to the population and the potential influence of respondents on the overall results.

One aspect of generalizability is the stability of the factor model results. Factor stability is primarily dependent on the sample size and on the number of cases per variable. The researcher is always encouraged to obtain the largest sample possible to increase the case-to-variables ratio. If sample size permits, the researcher may wish to randomly split the sample into two subsets and estimate factor models for each subset. Comparison of the two resulting factor matrices will provide an assessment of the robustness of the solution across the sample.

Another issue of importance to the validation of factor analysis is the detection of influential observations. The researcher is encouraged to estimate the model with and without observations identified as outliers to assess their impact on the results. Methods have been proposed for identifying influential observations specific to factor analysis [8], but complexity has limited application of these methods.

5.5 Multiple Regression Analysis

Multiple regression analysis is a statistical technique that can be used to analyse the relationship between a single dependent (criterion) variable and several explanatory (predictor) variables. The objective of multiple regression analysis is to use the explanatory variables whose values are known to predict the single dependent value selected by the researcher. Each explanatory variable is weighted by the regression analysis procedure to ensure maximal prediction from the set of explanatory variables. The set of weighted explanatory variables forms the regression variate, a linear combination of the explanatory variables that best predicts the dependent variable. The regression variate is also referred to as the regression equation or regression model, is the most widely known example of a variate among the multivariate techniques.

Multiple regression analysis is a dependence technique thus, to use it, we must be able to divide the variables into dependent and explanatory variables.

The objective of regression analysis is to predict a single dependent variable from the knowledge of one or more explanatory variables [9].

5.6 Multiple Regression Model and Multiple Regression Equation

This part is concerned with the analytical framework which is the functional relationship existing between the "technology integration" as dependent variable and its economic and social variables as explanatory variables. The multiple regression model is the equation that describes how the dependent variable 'y' is related to the explanatory variables and an error term and has the following form:

$$y = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \cdots + \beta_p x_p + \varepsilon \qquad (1)$$

In which, 'y' is dependent variable, 'p' denotes the number of explanatory variables, x_1, x_2, x_3, ..., x_p are explanatory variables, β_0, β_1, β_2, ..., β_p are the parameters, and 'ε' is a random variable (error term).

A close examination of this model reveals that 'y' is a linear function of x_1, x_2, ..., x_p (the $\beta_0 + \beta_1 x_1 + \beta_2 x_2 + \cdots + \beta_p x_p$ part) plus an error term 'ε'. The error term accounts for the variability in 'y' that cannot be explained by the linear effect of the 'p' explanatory variables.

One of the assumptions for the multiple regression model and 'ε' is that the mean or expected value of 'ε' is zero. A consequence of this assumption is that the mean or expected value of 'y', denoted by E(y), is equal to $\beta_0 + \beta_1 x_1 + \beta_2 x_2 + \cdots + \beta_p x_p$. The equation that describes how the mean value of 'y' is related to x_1, x_2, ..., x_p, is of the form:

$$E(y) = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \cdots + \beta_p x_p \qquad (2)$$

Thus is called the multiple regression equation.

If the values of β_0, β_1, β_2, ..., β_p were known, equation (2) could be used to compute the mean value of 'y' at given values of x_1, x_2, ..., x_p. Unfortunately, these parameter values will not, in general, be known and must be estimated from sample data. We denote by b_0, b_1, b_2, ..., b_p the point estimators of the parameters β_0, β_1, β_2, ..., β_p. These sample statistics provide the following estimated multiple regression equation:

$$\hat{y} = b_0 + b_1 x_1 + b_2 x_2 + \cdots + b_p x_p \qquad (3)$$

where b_0, b_1, b_2, ..., b_p are the estimates of β_0, β_1, β_2, ..., β_p and "$\hat{y}$" is estimated value of the dependent variable.

Model building is the process of developing an estimated regression equation that describes the relationship between a dependent variable and one or more explanatory variables. The major issues in model building are finding the proper functional form of the relationship and selecting the explanatory variables to be included in the model [10].

5.7 Interpreting the Regression Coefficients

When considering the equation:

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \varepsilon$$

what for example does β_2 represent? Very simply, it reflects the change in Y that can be expected to accompany a change of one unit in X_2, provided all other variables (namely, X_1 and X_3) are held constant. The primary problem is that a change in one of the predictor variables (such as X_2) always (or almost always) is accompanied by a change in one of the other predictors (say, X_1) in the sample observations. Consequently, variables X_1 and X_2 are related in some manner, such as $X_1 = 1 + 5X_2$. In other words, a situation in which X_2, for instance, changed and the others remained constant would not be observed in the sample data.

In this case (typically not observed in business applications) where the predictor variables are totally unrelated, a unit change in X_2, for example, can be expected to be accompanied by a change of β_2 in the dependent variable. In general, it is not safe to assume that the predictor variables are unrelated. As a result, the b's usually do not reflect the true "partial effects" of the predictor variables, and we should avoid such conclusions [11].

Generally, b_i represents an estimate of the change in "y" corresponding to a one-unit change in x_i when all other explanatory variables are held constant.

5.8 The Least Squares Method

This method is used to develop the estimated multiple regression equation that best approximates the straight-line relationship between the dependent and explanatory variables. The least squares criterion is expressed as follows:

$\text{Min} \sum(y_i - \hat{y}_i)^2$ (4)

Where:

y_i = observed value of the dependent variable for the ith observation

$\hat{y}_i$ = estimated value of the dependent variable for the ith observation

The estimated values of the dependent variable are computed by using the estimated multiple regression equation,

$\hat{y} = b_0 + b_1x_1 + b_2x_2 + \cdots + b_px_p$ (5)

As (4) shows, the least squares method uses sample data to provide the values of b_0, b_1, b_2, ..., b_p that make the sum of squared residuals, the deviations between the observed values of the dependent variable (y_i) and the estimated values of the dependent variable ($\hat{y}_i$), a minimum.

In multiple regression, the presentation of the formulas for the regression coefficients b_0, b_1, b_2, ..., b_p involves the use of matrix algebra [12].

5.9 The Multiple Coefficient of Determination and Adjusted Multiple Coefficient of Determination

The total sum of squares (TSS) can be partitioned into two components: the sum of squares due to regression (SSR) and the sum of squares due to error (SSE). The relationship among TSS, SSR, and SSE is: TSS = SSR + SSE

$TSS = \sum(y_i - \bar{y})^2$

$SSR = \sum(\hat{y}_i - \bar{y})^2$

$SSE = \sum(y_i - \hat{y}_i)^2$

where

$\bar{y}$ = average of all observations

y_i = value of individual observation i

$\hat{y}_i$ = predicted value of observation i

The term "multiple coefficient of determination" indicates that we are measuring the goodness of fit for the estimated multiple regression equation. The multiple coefficient of determination, denoted by "R^2", is computed as: $R^2 = SSR/TSS$.
When "R^2" multiplied by 100, it can be interpreted as the percentage of variation in "y" that can be explained by the estimated regression equation. In general, "R^2" always increases (or at least never decreases) as explanatory variables are added to the model. Many analysts prefer "adjusting R^2" for the number of explanatory variables to avoid overestimating the impact of adding an explanatory variable on the amount of variability explained by the estimated regression equation. Adjusted "R^2" is an approximately unbiased estimate of the population R-sq, and is calculated by the formula:

$$R^2\,(adj) = 1 - \frac{SSE/(n-p)}{TSS/(n-1)}$$

Then it is converted to a percentage. Here, "p" is the number of coefficients fitted in the regression equation.

5.10 A Decision Process for Multiple Regression Analysis Model-Building

In the following sections, the six-stage model-building process will be used as a framework for discussing the factors that impact the creation, estimation, and interpretation of a regression analysis.

5.10.1 Model-Building Stage 1: Objectives of Multiple Regression

Multiple regression analysis, a form of general linear model, is a multivariate statistical technique used to examine the relationship between a single dependent variable and a set of explanatory variables. The starting point, as with all multivariate statistical techniques, is the research problem. In selecting suitable applications of multiple regression, the researcher must consider three primary issues: (1) the appropriateness of the research problem, (2) specification of a statistical relationship, and (3) selection of the dependent and explanatory variables.

5.10.1.1 Research Problems Appropriate for Multiple Regression

Multiple regression is the most used widely multivariate technique. The ever-widening applications of multiple regression fall into two broad classes of research problems: prediction and explanation.

One fundamental purpose of multiple regression is to predict the dependent variable with a set of explanatory variables. In doing so, multiple regression fulfils one of two objectives. The first objective is to maximise the overall predictive power of the explanatory variables as represented in the variate. This linear combination of explanatory variables is formed to be the optimal predictor of the dependent measure.

Multiple regression provides many options in both the form and the specification of the explanatory variables that may modify the variate to increase its predictive power. Prediction is often maximised at the expense of interpretation.

Multiple regression can also meet a second objective of comparing two or more sets of explanatory variables to ascertain the predictive power of each variate.

Multiple regression also provides a means of objectively assessing the degree and character of the relationship between dependent and explanatory variables by forming the variate of explanatory variables. Interpretation of the variate may rely on any of three perspectives: the importance of the explanatory variables, the types of relationships found, or the interrelationships among the explanatory variables.

The most direct interpretation of the regression variate is a determination of the relative importance of each explanatory variable in the prediction of the dependent measure. In all applications, the selection of explanatory variables should be based on their theoretical relationships to the dependent variable. Regression analysis then provides a means of objectively assessing the magnitude and direction (positive or negative) of each explanatory variable's relationship. In addition, multiple regression also affords the researcher a means of assessing the nature of the relationships between the explanatory variables and the dependent variable. The assumed relationship is a linear association based on the correlations among the explanatory variables and the dependent measure.

Finally, multiple regression provides insight into the relationships among explanatory variables in their prediction of the dependent measure. These interrelationships are important for two reasons. First, correlation among the explanatory variables may make some variables redundant in the predictive effort. As such, they are not needed to produce the optimal prediction. The interrelationships among variables can extend not only to their predictive power but also to interrelationships among their estimated effects. This is best seen when the effect of one explanatory variable is contingent on another explanatory variable. Multiple regression provides diagnostic analyses that can determine whether such effects exist based on empirical or theoretical rationale.

5.10.1.2 Specifying a Statistical Relationship

Multiple regression is appropriate when the researcher is interested in a statistical, not a functional, relationship. For example, let us examine the following relationship:

Total cost = Variable cost + Fixed cost

If the variable cost is £2 per unit, the fixed cost is £500, and we produce 100 units, we assume that the total cost will be exactly £700 and that any deviation from £700 is caused by our inability to measure cost since the relationship between costs is fixed. This is called a "functional relationship" because we expect there will be no error in our prediction. But our present project deals with sample data. We assume that our model for integration of technology is only approximate and will not give a perfect prediction. It is defined as a "statistical relationship" because there will always be some random component to the relationship being examined. In a statistical relationship, more than one value of the dependent value will usually be observed for any value of an explanatory variable. The dependent variable is assumed to be a random variable, and for a given explanatory variable we can only hope to estimate the average value of the dependent variable associated with it.

5.10.1.3 Selection of Dependent and Explanatory Variables

The ultimate success of any multivariate technique, including multiple regression, starts with the selection of the variables to be used in the analysis. The selection of both types of variables, dependent and explanatory, should be based principally on conceptual or theoretical grounds. The researcher must be aware of the "measurement error", especially in the dependent variable. If the variable used as the dependent measure has substantial measurement error, then even the best explanatory variables may be unable to achieve acceptable levels of predictive accuracy.

The most problematic issue in explanatory variable selection is specification error, which concerns the inclusion of irrelevant variables or the omission of relevant variables from the set of explanatory variables. Although the inclusion of irrelevant variables does not bias the results for the other explanatory variables, it does have some impact on them. First, it reduces model parsimony, which may be critical in the interpretation of the results. Second, the additional variables may replace the effects of more useful variables. Finally, the additional variables may make the testing of statistical significance of the explanatory variables less precise and reduce the statistical and practical significance of the analysis.

Given the problems associated with adding irrelevant variables, should the researcher be concerned with excluding relevant variables? The answer is definitely yes, because the exclusion of relevant variables can seriously bias the results and negatively any interpretation of them. In the simplest case, the omitted variables are uncorrelated with the included variables. The only effect is to reduce the overall predictive accuracy of the analysis but when correlation exists between the included and omitted variables, the effects of included variables become biased to the extent that they are correlated with the omitted variables. The greater the correlation, the greater the bias. The estimated effects for the included variables now represent not only their actual effects but also the effects that the included variables share with the omitted variables. This can lead to serious problems in model interpretation and the assessment of statistical and managerial significance.

5.10.2 Model-Building Stage 2: Research Design of a Multiple Regression Analysis

In the design of a multiple regression analysis, the researcher must consider issues such as sample size, the nature of the explanatory variables, and the possible creation of new variables to represent special relationships between the dependent and explanatory variables.

5.10.2.1 Sample Size

The effects of sample size are seen most directly in the statistical power of the significance testing of the result. The size of the sample has a direct impact on the appropriateness and the statistical power of multiple regression. Small samples, usually characterised as having fewer than 20 observations, are appropriate for analysis only by simple regression. Likewise, very large samples of more than 1000 observations make the statistical significance tests overly sensitive, often indicating that almost any relationship is statistically significant. Power in multiple regression refers to the probability of detecting as statistically significant a specific level of coefficient of determination, "R^2". R^2 measures the proportion of the variance of the dependent variable about its mean that is explained by the explanatory variables. The coefficient can vary between 0 and 1. If the regression model is properly applied and estimated, the researcher can assume that the higher the value of "R^2", the greater the explanatory power of the regression equation, and therefore the better the prediction of the dependent variable.

As extra variables are added, "R^2" will always increase (at least never decrease). Thus, by including all explanatory variables, we will never find a higher "R^2", but we may find that a smaller number of explanatory variables result in an almost identical value. Therefore, to compare between models with different numbers of explanatory variables, we use the "adjusted R^2". As we have pointed out in section 5.9, adj-R^2 is a modified measure of the R^2 that takes into account the number of explanatory variables included in the regression equation and the sample size. Although the addition of explanatory variables will always cause the R^2 to rise (at least never decrease), the adjusted coefficient of determination may fall if the added explanatory variables have little explanatory power and/or if the degrees of freedom become too small. This statistic is particularly useful in comparing across regression equations involving different numbers of explanatory variables or different sample sizes because it makes allowance for the specific number of explanatory variables and the sample size upon which each model is based.

5.10.2.2 Dummy Variables

One common situation faced by researchers is the presence of non-metric explanatory variables. The concept of dichotomous variables, known as "dummy variables", can act as replacement explanatory variables. Each dummy variable represents one category of a non-metric explanatory variable, and any non-metric variable with "k" categories can be represented as "k-1" dummy variables.

The most common dummy variable is one used for "indicator coding", in which the category is represented by either 1 or 0. The regression coefficients for the dummy variables represent differences between means for each group of respondents. It is formed by a dummy variable from the "reference category" (i.e., the omitted group that received all zeros) on the dependent variable. These group differences can be assessed directly, as the coefficients are in the same units as the dependent variable.

5.10.3 Model-Building Stage 3: Assumptions in Multiple Regression Analysis

We have shown how improvements in prediction of the dependent variable are possible by adding explanatory variables. But to do so we must make several assumptions about the relationships between the dependent and explanatory variables that affect the statistical procedure (least squares) used for multiple regression. In the following sections we discuss testing for the assumptions and corrective actions to take if violations occur.

5.10.3.1 Assessing Individual (Dependent and Explanatory) Variables Versus the Variate

The assumptions underlying multiple regression analysis apply both to the individual variables (dependent and explanatory) and to the relationship as a whole. The consequences of the explanatory variables being too correlated with each other will be discussed later, i.e., in section "assessing multicollinearity ".

This section focuses on examining the variate and its relationship with the dependent variable for meeting the assumptions of multiple regression. These analyses actually must be performed after the regression model has been estimated in stage four. Thus, testing for assumptions must occur not only in the initial phases of the regression, but also after the model has been estimated.

The basic issue is whether, in the course of calculating the regression coefficients and predicting the dependent variable, the assumptions of regression analysis have been met. Are the errors in prediction a result of an actual absence of a relationship among the variables, or are they caused by some characteristics of the data not accommodated by the regression model? The assumptions to be examined are as follows:

- Linearity of the phenomenon measured

. Constant variance of the error terms

. Independence of the error terms

. Normality of the error term distribution

In multiple regression, The principal measure of prediction error for the variate is "residual". The residual for observation "i" is defined as "y_i - $\hat{y}_i$", where "y_i" and "$\hat{y}_i$" are the observed and the estimated values of the dependent variable for observation "i", respectively [10,11]. Plotting the residuals versus the explanatory variables is a basic method of identifying assumption violations for the overall relationship. When examining residuals, some form of standardisation is recommended, as it makes the residuals directly comparable. The general formula for the standardised residuals are calculated by dividing each residual by its standard deviation. Thus, standardised residuals have a mean of 0 and standard deviation of 1. Standardised residuals that are based on a revised standard error of the estimate obtained by deleting observation "i" from the data set and then performing the regression analysis and computations. The most commonly used form of standardised residual is the studentised residual, whose values correspond to "t" values. This correspondence makes it quite easy to assess the statistical significance of particularly large residuals.

The computation of residual, standard deviation of residual, and hence the standardised residual in multiple regression analysis can be obtained as part of the output from the Minitab statistical software package. Table 1, Appendix B lists the residuals and the standardised residuals for our data set.

The residuals and standardised residuals can be used to test the following assumptions (validating model assumptions) about the regression model's error term "ε".

1. $E(\varepsilon) = 0$.
2. The variance of "ε" is the same for all values of "x".
3. The values of "ε" are independent.
4. "ε" is normally distributed.

To determine whether these assumptions are valid, our preference initially is to plot the standardised residuals against the predicted (fitted) values. If the first three assumptions about "ε" are satisfied and the assumed regression model is an adequate representation of the relationship among the variables, the residual plot should give an overall impression of

a horizontal band of points. If not, the variance of "ε" is not constant or the assumed regression model is not an adequate representation of the relationship between the variables we would conclude that for instance, there exists a curvilinear regression model.
The standard residuals and the predicted (fitted) values of "y" were used in Figure 1, Appendix B.

5.10.3.2 Linearity of the Phenomenon

The linearity of the relationship between dependent and explanatory variables represents the degree to which the change in the dependent variable is associated with the explanatory variable. The regression coefficient is constant across the range of values for the explanatory variable. The concept of correlation is based on a linear relationship, thus making it a critical issue in regression analysis.
In multiple regression with more than one explanatory variable, an examination of the residuals shows the combined effects of all explanatory variables, but we cannot examine any explanatory variable separately in a residual plot. To do so, we use what are called "partial regression plots", which show the relationship of a single explanatory variable to the dependent variable. They differ from the residual plots because the line running through the centre of the points, which is horizontal in the residual plots, will now slope up or down depending on whether the regression coefficient for that explanatory variable is positive or negative.

5.10.3.3 Constant Variance of the Error Term

The presence of unequal variances (heteroscedasticity) is one of the most common assumption violations. Diagnosis is made with residual plots or simple statistical tests. Plotting the residuals against the explanatory variables values and comparing them to the null plot, the plot obtained when all assumptions are met. The null plot shows the residuals falling randomly, with relatively equal dispersion about zero and no strong tendency to be either greater or less than zero. It shows a consistent pattern if the variance is not constant. Perhaps the most common pattern is triangle-shaped in either direction and this is an indication of non-constant variance known as heteroscedasticity.

If heteroscedasticity is present, two remedies are available. If the violation can be attributed to a single explanatory variable, the procedure of weighted least squares can be employed. More direct and easier, however, are a number of variance-stabilising transformations that allow the transformed variables to be used directly in our regression model.

Most problems with unequal variances stem from one of two sources. The first source is the type of variables included in model. For example, as a variable increases in value (e.g., units ranging from near zero to millions), there is a naturally wider range of possible answers for the larger values. The second source results from a skewed distribution that creates heteroscedasticity.

The effect of heteroscedasticity is also often related to sample size, especially when examining the variance dispersion across groups. For example, in ANOVA or MANOVA, the impact of heteroscedasticity on the statistical test depends on the sample sizes associated with the groups of smaller and larger variances. In multiple regression analysis, similar effects would occur in highly skewed distributions where there were disproportionate numbers of respondents in certain ranges of the explanatory variable.

5.10.3.4 Independence of the Error Term

We assume in regression model that each predicted value is independent. By this, we mean that the predicted value is not related to any other prediction, that is, they are not sequenced by any variable. We can best identify such an occurrence by plotting the residuals against any possible sequencing variable. If the residuals are independent, the pattern should appear random and similar to the null plot of residuals. Violations will be identified by a consistent pattern in the residuals.

5.10.3.5 Normality of the Error Term Distribution

Perhaps the most frequently encountered assumption violation is non-normality of the error term. The simplest diagnostic is a histogram of residuals, with a visual check for a distribution approximating the normal distribution. There is a useful method for determining the validity of the assumption that the error term has a normal distribution. It is called "normal probability plots". They differ from residual plots in that the standardised residuals are compared with the standard normal distribution. The standard normal distribution makes a straight diagonal line, and the plotted residuals are compared with the diagonal. If a distribution is normal, the residual line closely follows the diagonal.

If we were to develop a plot with the normal scores on the horizontal axis and the corresponding standardised residuals on the vertical axis, the plotted points should cluster closely around a 45-degree line passing through the origin if the standardised residuals are approximately normally distributed. For "n" random observations, it is mathematically possible to establish what the "ideal" values would be if they came from a standard normal distribution. Such numbers are called "normal scores". In general, the normal scores for a sample of size "n" are "n" numbers along the horizontal axis that divide the total area under the standard normal curve into (n + 1) equal areas. For example, for n = 5 the normal scores may be described as the standard normal percentiles corresponding to the fractions 1/6, 2/6, 3/6, 4/6, and 5/6, or –0.97, -0.43, 0, +0.43, and +0.97 [13].

5.10.4 Model-Building Stage 4: Estimating the Regression Model and Assessing Overall Model Fit

The researcher is now ready to estimate the regression model and assess the overall predictive accuracy of the explanatory variables. In this stage, the researcher must accomplish three basic tasks: (1) select a method for specifying the regression model to be estimated, (2) assess the statistical significance of the overall model in predicting the dependent variable, and (3) determine whether any of the observations exert an undue influence on the results.

5.10.4.1 General Approaches to Variable Selection

In most instances of multiple regression, the researcher has a number of possible explanatory variables from which to choose for inclusion in the regression equation. Sometimes the set of explanatory variables may be closely specified and the regression model is essentially used in a confirmatory approach. In other instances, the researcher may wish to pick and choose among the set of explanatory variables. There are several approaches to assist the researcher in finding the "best" regression model including, "sequential search methods" and "combinatorial processes".

5.10.4.1.1 Confirmatory Specification

The simplest approach for specifying the regression model is to employ a confirmatory perspective wherein the researcher completely specifies the set of explanatory variables to be included and the variable selection is totally under their control.

5.10.4.1.2 Sequential Search Methods

These methods have in common the general approach of estimating the regression equation with a set of variables and then selectively adding or deleting variables until some overall criterion measure is achieved. This approach provides an objective method for selecting variables that maximises the prediction with the smallest number of variables employed. "Stepwise estimation" is one of the types of sequential approach.

5.10.4.1.3 Stepwise Estimation

Stepwise estimation (forward selection and backward elimination are kinds of stepwise regression) is one of the two computer-based methods for selecting the explanatory variables in a regression model (the other method that is among the combinatorial approach, is best-subsets regression which will be discussed next).

It is perhaps the most popular sequential approach to variable selection. This approach allows the researcher to examine the contribution of each explanatory variable to the regression model. Each variable is considered for inclusion prior to developing the equation. The explanatory variable with the greatest contribution is added first. Explanatory variables are then selected for inclusion based on their incremental contribution over the variable(s) already in the equation. The specific issues at each stage are as follows:

1) Start with the simple regression model in which only the one explanatory variable that is the most highly correlated with the dependent variable is used. The equation would be $Y = b_0 + b_1X_1$.
2) Examine the "partial correlation coefficients" to find an additional explanatory variable that explains the largest statistically significant portion of the error remaining from the first regression equation.
3) Re-compute the regression equation using the two explanatory variables, and examine the "partial F value" for the original variable in the model to see whether it still makes a

significant contribution, given the presence of the new explanatory variable. If it does not, eliminate the variable. If the original variable still makes a significant contribution, the equation would be $Y = b_0 + b_1X_1 + b_2X_2$. Suppose, for instance, that we are considering adding X_3 to a model involving X_1 or deleting X_3 from a model involving X_1 and X_3. In this case:

$$F = \frac{\dfrac{SSE(X_1) - SSE(X_1, X_3)}{1}}{\dfrac{SSE(X_1, X_3)}{n-k-1}}$$

where the numerator degrees of freedom is equal to the number of variables added to the model, and the denominator degrees of freedom is equal to "n-k-1". This F statistic can be used as a criterion for determining whether the presence of X_3 in the model causes a significant reduction in the error sum of squares. The value of this "F" statistic is the criterion to determine whether a variable should be added to or deleted from the regression model at each step.

4) Continue this procedure by examining all explanatory variables not in the model to determine whether one should be included in the equation. If a new explanatory variable is included, examine all explanatory variables previously in the model to judge whether they should be kept. A potential bias in the stepwise procedure results from considering only one variable for selection at a time.

To see how a step of the procedure is performed, suppose that after four steps the following four explanatory variables have been selected: school enrolment ratios, transport and communications, kind of religion (Christian), and Gross National Saving (GNS). At the next step, the procedure first determines whether any of the variables already in the model should be deleted. It does so by first determining which of the four variables is the least significant addition in moving from a three- to four-explanatory-variable model. An F statistic is computed for each of the four variables. The F statistic for school enrolment ratios enables us to test whether adding school enrolment ratios to a model that already includes transport and communications, kind of religion (Christian), and GNS leads to a significant reduction in sum of squares due to error (SSE). If not, the stepwise procedure will consider dropping school enrolment ratios from the model. Before doing so, however, a similar F statistic will be computed for transport and communications, kind of the religion (Christian), and GNS. The variable with the smallest F statistic makes the least significant addition in moving from a three- to four-explanatory-variable regression model and becomes a candidate for deletion. If any variable is to be deleted, that will be the one. We will denote by FMIN, the smallest of the F statistics for all variables in the regression model at the beginning of a new step. If the value of FMIN is too small to be significant, the corresponding variable is deleted from the model. If FMIN is large enough to be significant, none of the variables are deleted from the model (none of the other variables can have smaller F statistics).

The use of a computer-based stepwise regression procedure must specify a cut-off value for the F statistic so that the method can determine when FMIN is large enough to be significant. With the Minitab package (in this research we have used the one with release 11, year 1996), the smallest significant F value is donated by FREMOVE. If the user does not specify a value for FREMOVE, it is automatically set equal to four by Minitab. Whenever FMIN $<$ FREMOVE, the stepwise procedure of Minitab will delete the corresponding variable from the model. If FMIN $\geq$ FREMOVE, no variable is deleted at that step of the procedure.

If no variable can be removed from the model, the stepwise procedure next checks to see whether adding a variable can improve the model. For each variable "not in the model", an F statistic is computed. The largest of these F statistics corresponds to the variable that will cause the largest reduction in SSE. That variable then becomes a candidate for inclusion in the model. We will denote the largest F statistic for variables not currently in the model by FMAX. Again, a cut-off value for the F statistic must be used to determine whether FMAX is large enough for the corresponding variable to make a significant improvement in the model.

The cut-off value for determining when to add a variable is denoted by FENTER in the Minitab computer package. If the user does not specify a cut-off value for FENTER, Minitab will automatically set FENTER equal to four. If FMAX > FENTER, the corresponding variable is added to the model and the stepwise regression procedure goes on to the next step. The procedure stops when no variables can be deleted and no variables can be added.

In summary, at each step of the stepwise regression procedure, the first consideration is to see whether any variable can be removed. If none of the variables can be removed, the procedure checks to see whether any variables can be added. Because of the nature of the stepwise procedure, a variable can enter the model at one step, be deleted at a subsequent step, and then re-enter the model at a later step. The procedure stops when FMIN ≥ FREMOVE (no variables can be deleted) and FMAX ≤ FENTER (no variables can be added).

Forward addition and backward elimination procedures are largely trial-and-error processes for finding the best regression estimates. The forward addition model is similar to the stepwise procedure described above, whereas the backward elimination procedure computes a regression equation with all the explanatory variables, and then deletes explanatory variables that do not contribute significantly. The primary distinction of the stepwise approach from the forward addition and backward elimination procedures is its ability to add or delete variables at each stage. Once a variable is added or deleted in the forward addition or backward elimination schemes, there is no chance of reversing the action at a later stage [14].

5.10.4.1.4 Combinatorial Approach

The combinatorial approach is primarily a generalised search process across all possible combinations of explanatory variables. The best-known procedure is "all-possible-subsets-regression", which is exactly as the name suggests. All possible combinations of the explanatory variables are examined, and the best-fitting set of variables is identified.

5.10.4.1.5 Best-Subsets Regression

Stepwise regression, forward selection, and backward elimination are approaches to choosing the regression model by adding or deleting explanatory variables one at a time. There is no guarantee that the best model for a given number of variables will be found. Hence, these one-variable-at–a-time methods are properly viewed as heuristics for selecting a good regression model.

Some software packages (has been used here) have a procedure called best-subsets regression that enables the user to find, given a specified number of explanatory variables, the best regression model.

All other things being equal, a simpler model with fewer variables is usually preferred. In other words, the general method is to select the smallest subset that fulfils certain statistical criteria [15]. The motivation for variable selection is based on the fact that the subset model may actually estimate the regression coefficients and predict future responses with smaller variance than the full model using all predictors.

The value of four statistics are calculated for each model: R-squared, adjusted R-squared, C_p, and s.

"s" is an estimate of sigma, the standard deviation of the observations about the regression line. Adjusted R-squared and R-squared, have been defined in detail in the previous sections.

The criterion used in determining which estimated regression equations are best for any number of predictors is assessed according to some criterion. The three criteria most used are:

1) The value of "R^2" or "adj-R^2" achieved by the least squares fit.

2) The value of s^2, the residual mean square.

3) The Mallows' C_p statistic.

In fact, all these are related to one another. The choice of which equation is best to use, is made by assessing the patterns observed. If, for example, the "adj-R^2" criterion is used, the best subset then is the one with maximum adj-R^2 [16].

As Kennard [17] has pointed out, C_p is approximately closely related to the adjusted R^2 statistic and it is also related to the R^2 statistic.

Hocking and Leslie [18] used the Mallows' C_p statistic [19] as a basic criterion for comparing regression subsets. Their article reviews the method and gives examples. They discuss the validity of the criteria used for the selection of variables and similarities existing between them.

In the present analysis, the Mallows' C_p statistic, which is based on selecting variables that improve the predictive power of the model is used because this is the one most commonly used and preferred by other researchers.

The C_p statistic which is Mallows' C_p criterion, is given by the formula:

$C_p = (SSE_p/MSE_m) + (2p - n)$

where "n" is the number of observations, SSE_p is SSE for the best model with "p" parameters (including the intercept, if it is in the equation), and $MSE_m = s^2$, is the mean square error for the model with all "m" predictors.

If the subset model contains all the important predictors it may be shown that, on average, $C_p = p$. On the other hand, if the subset model is missing important predictors, C_p will tend to be larger than p. Two subset models may be compared by comparing their values of C_p. Mallows suggests that good models have $C_p = p$.

Once a small number of models has been singled out, they are studied carefully with respect to outliers, influential observations, normality of the errors, and constancy of the standard deviation of the errors before choosing a final model for use.

In general, models with fewer predictors and with C_p near p will be the better models.

A small value of C_p indicates that the model is relatively precise (has small variance) in estimating the true regression coefficients and predicting future responses. The subset for which the residual sum of squares is a minimum and hence, subsets with minimal C_p are considered best. This precision will not improve much by adding more predictors. Models with considerable lack of fit have values of C_p larger than p [20].

5.10.4.2 Testing the Regression Variate for Meeting the Regression Assumptions

Once the explanatory variables have been selected and the regression coefficients estimated, the researcher must now assess the estimated model for meeting the assumptions underlying multiple regression. As discussed in stage 3, the individual variables and regression variate must meet the assumptions of linearity, constant variance, independence, and normality.

5.10.4.3 Examining the Statistical Significance of the Model

If we were to take repeated data samples of our observations, we would seldom get exactly the same values as we have done before. Usually, we take only one sample and base our predictive model on it. With only one sample and regression model, we need to test the hypothesis that our predictive model can represent the population of all observations. A test of the explained variation (coefficient of determination) will be discussed.

5.10.4.3.1 Significance of the Overall Model: The Coefficient of Determination

To test the hypothesis that the amount of variation explained by the regression model is more than the variation explained by the average value of the dependent variable (i.e., that R^2 is significantly greater than zero), the F ratio is used.

5.10.4.3.2 F Test

Recall that the multiple regression model is:

$y = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \cdots \beta_p x_p + \varepsilon$

The hypotheses for the F test involves the parameters of the multiple regression models.

H_0: $\beta_1 = \beta_2 = \cdots = \beta_p = 0$

H_a: one or more of the parameters is not equal to zero

If H_0 is rejected, we have sufficient statistical evidence to conclude that one or more of the parameters are not equal to zero and that the overall relationship between 'y' and the set of explanatory variables $x_1, x_2, \ldots, x_p$ is significant. However, if H_0 cannot be rejected, we do not have sufficient evidence to conclude that a significant relationship is present.

Before describing the steps of the F test, we need to review the concept of "mean square". A "mean square" is a sum of squares divided by its corresponding degrees of freedom. In the multiple regression case, the total sum of squares has "n-1" degrees of freedom, the sum of squares due to regression (SSR) has "p" degrees of freedom, and the sum of squares due to error has "n-p-1" degrees of freedom. Hence, the mean square due to regression (MSR) is "SSR/p" and the mean square due to error (MSE) is SSE/(n-p-1).

Test statistic: $F = MSR/MSE$

MSR and MSE are the mean squares due to regression and error respectively.

Rejection rule: reject H_0 if $F>F_\alpha$

Where, F_α is based on an F distribution with 'k' degrees of freedom in the numerator and 'n-k-1' degrees of freedom in the denominator.

5.10.4.4 Identifying Influential Observations

Up to now, we have focused on identifying general patterns within the entire set of observations. Here we shift our attention to individual observations, with the objective of finding the observations that lie outside the general patterns of the data set or that strongly influence the regression results. We should remember that these observations are not necessarily "bad" in the sense that they must be omitted. In many instances they represent the distinctive elements of the data set. An influential observation is an observation that has a disproportionate influence on regression estimates. This influence may be based on extreme values of the dependent and/or explanatory variables. Influential observations potentially include outliers (observations that have large residual values) and leverage points (observations that are distinct from the remaining observations based on their explanatory variable values). Their impact is particularly noticeable in the estimated coefficients for one or more explanatory variables. Also, not all outliers and leverage points are necessarily influential observations.

Outliers and leverage points are based on one of four conditions:

1) An error in observations or data entry
2) A valid but exceptional observation that is explainable by an extraordinary situation
3) An exceptional observation with no likely explanation
4) An ordinary observation in its individual characteristics but exceptional in its combination of characteristics

Courses of action can be recommended for dealing with influentials from each condition. For an error in observation (condition 1), correct the data or delete the case. With the valid but exceptional observation (condition 2), deletion of the case is warranted unless variables reflecting the extraordinary situation are included in the regression equation. The unexplained observation (condition 3) presents a special problem because there is no reason for deleting the case, but its inclusion cannot be justified either. Finally, the observation that is ordinary on each variable separately yet exceptional in its combination of characteristics (condition 4) indicates modifications to the conceptual basis of the regression model and should be retained. The objective is to ensure the most representative model for the sample data so that it will best reflect the population from which it was drawn.

5.10.5 Model-Building Stage 5: Interpreting the Regression Variate

In this stage the researcher's task is to interpret the regression variate by evaluating the estimated regression coefficients for their explanation of the dependent variable. In this case, multicollinearity (which will be discussed later) may substantially affect the variables ultimately included in the regression variate. Thus, in addition to assessing the estimated coefficients, the researcher must also evaluate the potential impact of omitted variables.

5.10.5.1 Using the Regression Coefficients

The estimated regression coefficients are used to calculate the predicted values for each observation and to express the expected change in the dependent variable for each unit change in the explanatory variables. Many times we also wish to engage in explanation, assessing the impact of each explanatory variable in predicting the dependent variable.

5.10.5.2 Assessing Multicollinearity

A key issue in interpreting the regression variate is the correlation among the explanatory variables, since one assumption of the regression model is that the explanatory variables are independent of each other. This is a data problem, not a problem of model specification. The ideal situation for a researcher would be to have a number of explanatory variables highly correlated with the dependent variable, but with little correlation among themselves. Thus, the researcher's task is to assess the degree of multicollinearity, ie., the degree of dependence amongst the explanatory variables and determine its impact on the results and the necessary remedies if needed.

5.10.5.2.1 The Effects of Multicollinearity

The effects of multicollinearity can be discussed in terms of "explanation" and "estimation". The effects on explanation primarily concern the ability of the regression procedure and the researcher to represent and understand the effects of each explanatory variable in the regression variate. As multicollinearity occurs (even at the relatively low levels of 0.30 or so), the process for separating the effects of individuals becomes more difficult. First, it limits the size of the coefficient of determination and makes it increasingly more difficult to add unique explanatory prediction from additional variables. Second, it makes determining the contribution of each explanatory variable difficult because the effects of the explanatory variables are confounded. Multicollinearity results in larger portions of shared variance and lower levels of unique variance from which the effects of the individual explanatory variables can be determined. For example, assume that two explanatory variables (X_1 and X_2) have correlations of 0.60 and 0.50 with the dependent variable, respectively. Then X_1 would explain 36% (obtained by squaring the correlation of 0.60) of the variance of the dependent variable, and X_2 would explain 25%. If the two explanatory variables are not correlated with each other at all, there is no overlap or sharing of their predictive power. The total explanation would be their sum, or 61%. But as collinearity increases, there is some sharing of predictive power, and the collective predictive power of the explanatory variables decreases.

As multicollinearity increases, the total variance explained decreases. Moreover, the amount of unique variance for the explanatory variables is reduced to levels that make estimation of their individual effects quite problematic.

In addition to the effects on explanation, multicollinearity can have substantive effects on the estimation of the regression coefficients and their statistical significance tests. First, the extreme case of multicollinearity in which two or more variables are perfectly correlated, termed singularity, prevents the estimation of any coefficients. In this instance, the singularity must be removed before the estimation of coefficients can proceed. Even if the multicollinearity is not perfect, high degrees of multicollinearity can result in regression coefficients being incorrectly estimated and even having the wrong signs.

5.10.5.2.2 Identifying Multicollinearity

In any regression analysis, the assessment of multicollinearity should be undertaken in two steps: (1) identification of the extent of collinearity and (2) assessment of the degree to which the estimated coefficients are affected.

The simplest way of identifying collinearity is an examination of the correlation matrix for the explanatory variables. The presence of high correlations (generally 0.90 and above) is the first indication of substantial collinearity. Collinearity also may be due to the combined effect of two or more other explanatory variables.

One of the more common measure of collinearity and multicollinearity is "tolerance". The tolerance of variable "i" is "$1 - R_i^{2*}$", where R_i^{2*} is the coefficient of determination for the prediction of variable "i" by the other explanatory variables.

5.10.5.2.3 Remedies for Muticollinearity

The remedies for multicollinearity range from modification of the regression variate to the use of specialised estimation procedures. The researcher has a number of options, such that:

1) Omit one or more highly correlated explanatory variables and identify other explanatory variables to help the prediction.
2) Use the model with the highly correlated explanatory variables for prediction only (i.e., make no attempt to interpret the regression coefficients).
3) Use the simple correlations between each explanatory variable and the dependent variable to understand the explanatory-dependent variable relationship.

Each of these options requires that the researcher make a judgement on the variables included in the regression variate, which should always be guided by the theoretical background of the study.

5.10.6 Model-Building Stage 6: Validation of the Results

After identifying the best regression model, the final step is to ensure that it represents the general population (generalisability) and is appropriate for the situations in which it will be used. The best guideline is the extent to which the regression model matches an existing theoretical model or set of previously validated results on the same topic. In many instances, however, prior results or theory are not available thus, we discuss empirical approaches to model validation.

5.10.6.1 Additional or Split Samples

The most appropriate empirical validation approach is to test the regression model on a new sample drawn from the general population. A new sample will ensure representativeness and can be used in several ways. For instance, a separate model can be estimated with the new sample and then compared with the original equation on characteristics such as the significant variables included, sign, size, relative importance of variables, and predictive accuracy. The researcher determines the validity of the original model by comparing it to regression models estimated with the new sample.

When there is a restriction for collecting new data, researcher may then divide the sample into two parts and creates the regression model on the sub-samples. Most times there will be differences among results and the researcher may look for the best model. No regression model, unless estimated from the entire population, is the final and absolute model.

5.10.6.2 Comparing Regression Models

When comparing regression models, the most common standard used is "R^2". We discussed earlier that "R^2" provides us with this information, but it has one drawback: as more variables are added, "R^2" will always increases (or at least never decreases). Thus, by including all explanatory variables, we will never find a higher "R^2", but we may find that a smaller number of explanatory variables results in an almost identical value. Therefore, to compare between models with different numbers of explanatory variables, we use the "adjusted R^2".

5.10.6.3 Predicting with the Model

Model predictions can always be made by applying the estimated model to a new set of explanatory variable values and calculating the dependent variable values. However, in doing so, we must consider several factors that can have a serious impact on the quality of the new predictions:

1. When applying the model to a new sample, we must remember that the predictions now have not only the sampling variations from the original sample but also those of the newly drawn sample. Thus we should always calculate the confidence intervals of our predictions in addition to the point estimate to see the expected range of dependent variable values.
2. We must make sure that the conditions and relationships measured at the time the original sample was taken have not changed materially.
3. Finally, we must be aware that the model is only valid for predictions within the range of values of the explanatory variables used in the original sample from which the model was built [21].

5.11 Summary and Conclusions

As we discuss the numerous multivariate techniques available to the researcher, it becomes apparent that the successful completion of a multivariate analysis involves more than just the selection of the correct method. Issues ranging from problem definition to a critical diagnosis of the results have been addressed. To aid the researcher in applying multivariate methods, a six-step of approach to multivariate analysis was presented. The intent is not to provide a rigid set of procedures to follow but, instead, to provide a series of guidelines that emphasises a model-building approach.

A model-building approach focuses the analysis on a well-defined research plan, starting with a conceptual model detailing the relationships to be examined. Once defined in conceptual terms, the empirical issues can be addressed, including the selection of the specific multivariate technique and the implementation issues.

Factor analysis which is a technique particularly suitable for analysing the patterns of complex, multidimensional relationships for a large number of variables, by defining a set of common underlying dimensions, known as factors encountered by researchers, were introduced. Factor analysis determines whether the information can be condensed or summarised or whether data could be reduced.

Multiple regression analysis, another multivariate technique, also introduced. It is a statistical technique that can be used to analyse the relationship between a single dependent variable and several explanatory (predictor) variables. The objective of multiple regression analysis is to use the explanatory variables whose values are known to predict the single dependent value selected by the researcher.

Stepwise regression and best-subsets regression, two important computer-based methods for selecting the explanatory variables in a regression model, were also introduced.

Stepwise regression is perhaps the most popular sequential approach to variable selection. This approach allows the researcher to examine the contribution of each explanatory variable to the regression model. Each variable is considered for inclusion prior to developing the equation. Best-subsets regression is a method of selecting the variables for inclusion in the regression model. It consists all possible combinations of the explanatory variables. The technique would then identify the model(s) with the best predictive accuracy. In the present analysis, the criterion used in best-subsets, in determining which estimated regression equations are best for any number of predictors is the Mallows' C_p statistic. It is based on selecting variables that improve the predictive power of the model is used because this is the one most commonly used and preferred by other researchers.

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CHAPTER 6: Results Analysis and Theoretical Interpretation

6.1 Introduction

As we have pointed out in chapter five, multiple regression analysis, a form of general linear modelling, is a multivariate statistical technique used to examine the relationship between a single dependent variable, technology integration, and a set of explanatory variables.

The purpose of the multiple regression model is to determine the variables that have the largest influence on the integration of technology in the selected developing countries. Once the significant indicators are identified and the parameters are measured, the researcher, the policy-makers, or the economist can use the model to estimate the rate of technology integration for other developing countries not included in the analysis. Also, the estimation of the economic relationships which exist between the variables may be used for decision making. That is, for instance, if education appears to be a relevant indicator then emphasis on this aspect can be made. In other words, working with the model, the policy-maker or the analyst can see that an improvement in education will have a direct effect on the integration of technology.

Factor analysis, including both principal component and common factor analysis, is used to analyse the interrelationships among a large number of variables and to explain these variables in terms of their common underlying dimensions (factors).

In this chapter it is intended to apply the framework for classifying the economic and social variables, which has been theoretically discussed in chapter five, as they relate to the characteristics of countries. Such a framework makes it easier to adopt a systematic approach to the analysis of socio-economic indicators of technological transfer, as it provides greater insight into the similarities of the variables and indicates their hierarchical relationships. The grouping or classification of variables (factor analysis) provides information on their functional similarities, which allows further knowledge on the interrelation (correlation) between the variables. This assists the regression model in the choice of variables, that is, a variable can be selected or rejected by the analyst on the ground of the dimension it explains. For instance, if two selected variables by the regression model are known to explain the same dimension by the use of factor analysis, then one of the variables should be discarded and only one would be used. Therefore, with the grouping variables (factor analysis), essentially as the back-up the results of the regression analysis, as well as their importance, the researcher can test whether the regression model has selected the appropriate variables. Also, the researcher is more aware of the validity and importance of the variables and has a more defined idea of what they represent, and how they relate to each other.

Most important of all, once the variables or indicators are identified by the regression model, the grouping helps locate the indicators that are from the same or a different category from the ones retained. This is of relevance in the sense that the model can be applied for cases in which data on that variable is unknown. This cannot be achieved, for example, by regression analysis. It should therefore, be stressed that the grouping of variables (factor analysis) is a complementary back-up analysis of exploratory ability to the multiple regression analysis model.

In the following we describe the methods used for obtaining the results.

6.2 The Factor Analysis: Results and Interpretation

We are going to use factor analysis on our collected data to identify the separate dimensions of the structure and then determine the extent to which each variable is explained by each dimension.

As we know, the primary database consisting of 34 observations on 18 explanatory variables. The first stage is the objectives of factor analysis. As we mentioned before, factor analysis can identify the structure of a set of variables as well as provide a process for data reduction. There are 153 separate correlations among the 18 explanatory variables. Given "n" distinct objects, the number of selections of "r" objects without regard to the order is called combinations and is given by: ${}^{n}C_r = n! / [r!(n-r)!]$. In here, we have: ${}^{18}C_2 = 18! / [2!(18 - 2)!] = 153$. Similarly, we have 171 correlations (${}^{19}C_2$) together with the single dependent variable, "y". We are examining the data structure to (1) understand if these variables can be "grouped" and (2) reduce the eighteen variables to a smaller number.

The second stage is designing a factor analysis. Understanding the structure of the variables requires R-type factor analysis (R-type factor analysis analyses relationships among variables to identify groups of variables forming eigenvalue factors) and a correlation matrix between variables, not respondents. Thirteen of the eighteen variables are metric and the rest are non-metric.

Metric data are also called quantitative data. These measurements identify or describe subjects or objects not only on the possession of an attribute but also by the amount or degree to which the subject may be characterised by the attribute. Non-metric data are also called qualitative data. These are attributes, characteristics, or categorical properties that identify or describe a subject or object. They differ from metric data by indicating the presence of an attribute, but not the amount.

The third stage is to examine the assumptions in factor analysis. The underlying statistical assumptions impact factor analysis to the extent that they affect the derived correlations. The researcher must also assess the factorability of the correlation matrix. The first step is a visual examination of the correlations, identifying those that are statistically significant. Table 2 in Appendix B, shows the correlation matrix for the variables. Inspection of the correlation matrix reveals that 47 of the 153 correlations (31%) are significant at the 0.01 level.

Stages four through six are component factor analysis. As noted earlier, factor analysis procedures are based on the initial computation of a complete table of intercorrelations among the variables (correlation matrix). This correlation matrix is then transformed through estimation of a factor model to obtain a factor matrix. The loadings of each variable on the factors are then interpreted to identify the underlying structure of the variables, in our case. These steps of factor analysis, contained in stages four through six, are examined first for component analysis. Then, a common factor analysis is performed and comparisons made between the two factor models [1].

Deriving factors and assessing overall fit is in stage four. Table 3 (Appendix B) shows principal component analysis and contains the information regarding the factors and their relative explanatory power as expressed by their eigenvalues. In addition to assessing the importance of each component, we can also use the eigenvalues to assist in selecting the number of factors. If we apply the latent root (eigenvalue) criterion, six components will be retained. The scree plot, Fig. 5, Appendix B, however, indicates that seven factors may be appropriate. In viewing the eigenvalue for the seventh factor, it's value, 0.944, is quite close to 1.0, then it might be considered for inclusion as well. These results illustrate the need for multiple decision criteria in deciding the number of components to be retained.

The six factors retained represent 71% of the variance of the eighteen variables (if the seventh factor has been included, it represents 76% of the variance).

Stage five is interpreting the factors. The results of the last stage is shown in Table 4 (Appendix B) , the unrotated component analysis factor matrix. To begin the analysis, let us explain the numbers included in the table. Eight columns of numbers are shown. The first seven are the results for the seven factors that are extracted (i.e., factor loadings of each variable on each of the factors). The last column, communality (total amount of variance an original variable shares with all other variables included in the analysis), provides summary statistics detailing how well each variable is explained by the seven components, which are discussed in the next section. The first row of numbers at the bottom of each column is the column sum of squared factor loadings (variances or eigenvalues) and indicates the relative importance of each factor in accounting for the variance associated with the set of variables being analysed. Note that the variances for the seven factors are 3.76, 2.81, 2.07, 1.58, 1.39, 1.12, and 0.94, respectively. As expected, the factor solution has extracted the factors in the order of their importance, with factor 1 accounting for the most variance and the other factors less, respectively. At the far last column is the number 13.70, which represents the total explained sum of squares. The total sum of squared factors represents the total amount of variance extracted by the factor solution.

The total amount of variance explained by the factor solution (13.70) can be compared to the total variation in the set of variables as represented by the "% var" (percentage of trace) of the factor matrix, which is 76.1%. The trace is the total variance to be explained and is equal to the sum of the variances of the variable set. In components analysis, the trace is equal to the number of variables, as each variable has a possible eigenvalue of 1.0.

The percentages of variance explained by each of the seven factors is shown as the last row of values of Table 4 (Appendix B). The percentage of variance is obtained by dividing each factor's sum of squares by the variance for the set of variables being analysed. For example, dividing the sum of squares of 3.7606 for factor 1 by the variance of 18.0 (sum of eigenvalues or number of variables, as each variable has a possible eigenvalue of 1.0), results in the percentage of variance of 20.9% for factor 1. By adding the percentages of variance for each of the seven factors, we obtain the total percentage of variance extracted for the factor solution, which can be used as an index to determine how well a particular factor solution accounts for what all the variables together represent. If the variables are all very different from one another, this index will be low. If the variables fall into one or more highly redundant or related groups, and if the extracted factors account for all the groups, the index will approach 100 percent. The index for the present solution shows that 76.1 percent of the total variance is represented by the information contained in the factor matrix of the seven-factor solution. Therefore, the index for this solution is high, and the variables are in fact highly related to one another.

The square of a correlation coefficient can be interpreted as a proportion of explained variance [2]. The loading of X_1 on the first factor is 0.156. The square $(0.156)^2 = 0.0243$ means that 2.43% of the variance of variable X_1 is explained by the first factor. Second factor adds $(0.354)^2 = 0.1253$, 12.53%, and the others add, 30.91%, 23.14%, 3.0%, 0.10%, and 3.7% respectively. The sum is 75.81% (with only seven factors). It means 75.81% of the dispersion of X_1 can be explained on seven factors. The total sum for all of the factors is 100%. Looking at rows, we can give a similar explanation for X_2, X_3, and so forth.

We can also look at the columns of the matrix. The sum of squared loadings of a factor column, is the sum of the variance proportions of each of the eighteen variables that are explained by that factor. This sum is equal to the eigenvalue of the factor. For example, this sum for the first factor is: $(0.156)^2 + (0.718)^2 + \cdots + (-0.420)^2 = 3.7606$.

A similar explanation can be given for factor 2, factor 3, and so forth.

The row sum of squared factor loadings is shown at the far last column of Table 4 (Appendix B).

These figures, referred to in the table as communalities, show the amount of variance in a variable that is accounted for by the seven factors taken together. The size of the communality is a useful index for assessing how much variance in a particular variable is accounted for by the factor solution. Large communalities indicate that a large amount of the variance in a variable has been extracted by the factor solution. For instance, the communality figure of 0.758 for variable X_1 indicates that it has less in common with the other variables included in the analysis than does variable X_2, which has a communality of 0.863.

Having defined the various elements of the unrotated factor matrix, let us examine the factor loading patterns. As anticipated, the first factor accounts for the largest amount of variance and is a general factor, with most variables having high loadings.

In this first factor, we notice two groups of the variables have a positive tendency with each other. In one group, GNS, GIP, labour force in industry, GNP per capita, and imports of manufactured goods are stated, that they are amongst the economic indicators. School enrolment ratios for first and second level, number of scientists and engineers engaged in R&D, and expenditure for R&D, are located in the second group, which constitutes the education section. In other words, this factor seems to be dominated by education variables. All three variables in the second group have positive signs.

For individuals and for countries, education is the key to creating, adapting, and spreading knowledge. Basic education increases people's capacity to learn and to interpret information. But that is just the start. Higher education and technical training are also needed to build, for example, a labour force that can keep up with a constant stream of technological advances. Educated farmers tend to adopt new technologies first, and in so doing provide those who follow with valuable, free information about how best to use the new methods. A recent study investigated the relationship between the proportions of college students majoring in various disciplines in 1970 and subsequent real growth in GDP per capita. The study found a significant positive association between the proportion of engineering majors and later growth. And for the 55 countries with college enrolments of at least 10,000 in 1970, the proportion of college students in engineering was significantly and positively associated with subsequent levels of physical capital investment and with primary schooling. It has confirmed that countries with a more science and engineering involved and with a more technically skilled labour force do have faster growth [3]. So, it could be said that more education has a positive effect on the economic sector.

The loadings on the second factor show two variables: gross domestic investment, and expenditure for R&D are at acceptable level. Two others, gross national saving, and imports of manufactured goods, are considered more important; and another four, Christian and Muslim religions, exports of manufactured goods, and population having high loadings so, are considered practically significant.

The loadings on the third factor also show nine of the variables having good loadings. Based on this factor-loading pattern, interpretation would be difficult. Therefore, we need to proceed to rotate the factor matrix to redistribute the variance from the earlier factors to the later factors. Rotation should result in a simpler and theoretically more meaningful factor pattern.

Having applied the "varimax" procedure the rotated component analysis factor matrix is shown in Table 5, Appendix B. Note that the total amount of variance extracted is the same in the rotated solution as it was in the unrotated one, 76.1%. Two differences are apparent. First, the variance has been redistributed so that the factor-loading pattern and the percentage of variance for each of the factors is different. Specifically, in the "varimax" rotated factor solution, the first factor accounts for 14.3% of the variance, compared to 20.9% in the unrotated solution. Likewise, the second factor accounts for 14.3% versus 15.6% in the unrotated solution and so forth. Thus, the explanatory power has shifted slightly to a more even distribution because of the rotation. Second, the interpretation of the factor matrix has been simplified. Recall that in the unrotated factor solution all variables loaded significantly on the first factor.

In the rotated factor solution, however, four variables - Christian and Muslim religions, imports of manufactured goods, and revolution/war between countries load significantly on factor 1. The other acceptable indicators are population and exports of manufactured goods. Muslim religion, population, and exports of manufactured goods have a positive sign. For Christian religion, and imports of manufactured goods, the loadings are negative. Clearly, imports and exports of manufactured goods are opposed to each other also, for two kinds of religions.

Four variables - school enrolment ratios, labour force in industry, number of scientists engagement in R&D, and GNP per capita - are all significantly positively loaded on the second factor. These relationships could explain that the higher education and educated scientists causes the higher GNP per capita. Also where there is more education, the labour force is more educated and produces higher quality goods which results in more GNP per capita in a country.

Variables, gross national saving and gross industrial product, have loaded significantly on factor 3. Followed by the indicators, gross domestic investment, labour force in industry, and GNP per capita, which are important loadings. All of them are important economic indicators as a group which have gathered in the third factor.

The close relationship between investment and saving is well known in economics. The grouping of these two variables in this factor shows the consistency of the data collected as well as the regular pattern of the sample of countries under study. The close relationship between investment and saving as well as gross industrial product to a certain extent tends to show that, among the countries studied those that have higher gross domestic investment and therefore savings, tend to have relatively greater industrial production. The dimension expressed by this factor is very relevant to the present study. In order to get some insight into these relationships, the notion of investment and saving had to be seen more deeply.

Investment is that part of national income or expenditure devoted to the production of capital goods and services over a given period of time. "Gross" investment refers to the total expenditure on new capital goods, while "net" investment refers to the additional capital goods produced in excess of those that wear out and need to be replaced [4].

Investment is therefore that part of the current output of goods and services devoted to adding to the stock of capital and thus to raising the future potential of a community. It is mainly referred to as capital formation.

The computations of gross domestic investment consist of subtracting the private and general government consumption from the gross domestic product (GDP) and adding the difference between exports and imports, that is [5]:

$$I = GDP - C + X - M$$

Where, I represents the gross domestic investment, C is the private and general government consumption, X is exports, and M is imports. It is well known that investment provides a major force to the process of economic growth.

There is a problem in the measurement of national savings, even if one decides to include savings of domiciled foreign enterprises in the definition of national savings. This arises because the identity: $I - S = X - M$, (where, I is the investment, S is national savings, X and M are exports and imports of goods and services, respectively), does not mean that the import surplus is necessarily equal to the net inflow of capital from abroad. A country may have decided to utilise some of its accumulated foreign exchange reserves to finance domestic investments (or even to enlarge its consumption), and therefore:

$M - X = K_f - A_f$, where K_f is the net inflow of capital from abroad and A_f is the use of foreign assets or reserves owned by the country. For such cases, if one wishes to measure that part of investment financed by domestic effort, the actual savings as recorded in the national income accounts may need to be adjusted by the amount of A_f [6].

According to Bhagwati [7], the developing countries are linked to the developed countries through trade, aid, investment, and migration. The central issue for them is whether these links work to their detriment or advantage. Several ideologies compete for attention on this question. The ideology that has traditionally been dominant is aptly characterised as that of "benign neglect"-links where the rich nations create benefits for the poor nations. While MNCs invest in these countries to make profits, they will increase incomes, diffuse technology, and domestic savings in these countries. The exchange of commodities and services in trade will reflect the principle of division of labour and hence bring gains from trade to these countries. The migration of skilled labour, instead of constituting a troublesome brain drain, will help to remove impediments to progress such as inadequate remuneration of the educated elite.

On the other hand, Streeten [8] shows the repercussions that investment and savings have on economic growth when their level of equilibrium is different. He emphasises the responsibility of government to maintain an aggregate equilibrium between investment and saving in developing countries.

Two variables - manufacturing production, and exports of manufactured goods - are highly loaded on factor 4, followed by the variable, population with a relatively good loading. All three have the same sign. Frederiksen [9] studied the relationship between population and infrastructure, using cross province regressions for the Philippines. He found that there is a strong positive effect of population on infrastructure. It shows that densely populated areas are more likely to specialise in manufacturing and hence have a greater basic infrastructure, because of the close relationship between these two economic branches (manufacturing production and exports of manufactured goods).

Countries that have higher exports of natural products such as cocoa, copper, jute, tobacco, coffee, tea, or rice, have a tendency to export some of their manufactured foods.

It is well recognised among those who are working actively in economic development, that the growth of exports is an essential element of development programmes.

There are very strong theoretical reasons for believing that the pursuit of export-oriented policies, by which is meant policies which do not discriminate between production for the domestic market, and production for export, will lead to greater economic growth. Such policies promote allocative and dynamic efficiency and also self-correcting mechanisms for efficient macro-economic management [10].

We can say that the level of production depends on the population or number of people employed, hours of working, education, training, and the quality of capital equipment [11].

Variables-gross domestic investment and gross national saving from one side and Christian religion, Buddhism religion (factor loadings of these two religions are in opposite signs), and revolution/war between countries from the other side have been loaded on factor 5.

The close relationship between saving and investment has already been discussed in factor 3.

As for the relationship between religion (as dummy variable) and those economic indicators (on factor 5), we can say that for instance, Philippines is a Christian country, Thailand is a Buddhist country, and Indonesia is predominantly a Muslim country. Does this affect in any way the process of transfer of new modern technologies? How conscious of religion are the businessmen in these countries? Chatterji's survey attempted to explore their views on this difficult question [12]. The findings seem to show certain ways of thinking on the part of Southeast Asian businessmen about the relations between material welfare and spiritual nemeses.

The business world in Southeast Asia has several other systems of religious beliefs besides those three mentioned above. Most Westerners are Christians, and there are others for instance, Japanese, Chinese, Indians, and so on. Since, moreover, the business enterprises in Southeast Asia are often joint ventures and the participation ratios of overseas Chinese in these joint ventures are relatively high, the ethnic problems related to overseas Chinese arise along with other anti-foreigner problems. In particular the government policy tries to provide preferential treatments for non-Chinese indigenous ethnic groups. There may be some active opposition towards Westerners or Japanese, which may or may not affect the decisions on adopting new technologies. The findings of the survey seem to show significant differences among the three countries with regard to the mode of decision-making.

Investment is always made with some degree of risk, and how such actions are considered in the context of religious or spiritual circumstances is important for understanding the thinking of entrepreneurs in these countries. The survey findings on these issues seem to show something of the psychology of businessmen. Here again businessmen in Indonesia seem to be influenced by religious factors much more significantly than those in Thailand and the Philippines. From the observations mentioned above it seems safe to presume that religion has a relationship with economic action, although the strength of the relationship varies between countries. For example, Islam in Indonesia has closer relations with economic affairs than Buddhism in Thailand and Catholicism in the Philippines.

Another aspect of religion's influence on economic action concerns the conception of success or failure in business. This may be influenced by the nature of religions or their teachings; whether, for example, the religion is submissive to fate or emphasises nemesis [13].

From table 2 (Appendix B), we notice that the indicator, revolution/war between countries, has a negative relationship with the indicators, gross domestic investment and gross national saving.

Of all the human factors which cause famines - for example in Africa - war is the most conclusive. The countries of Ethiopia, Sudan, Chad, Mozambique, and Angola are among the countries which have suffered chronic famines and mass starvation caused by war. Although Ethiopia is one of the world's poorest nations, its government spends vast sums of money fighting several wars at once. For example, trying to put down the 26-year-old rebellion in Eritrea, the 11-year-old rebellion in Tiger, supporting rebellions in Somalia and southern Sudan, and so on [14]. With these conditions how would these countries have suitable economic situations.

In the Third World, in addition to the lack of indigenous technological capacities, the relative failure of the technology transfer process is due to many causes. Some of these causes derive from the inherent ineffectiveness of the process itself. In this situation, the profit motive of the so-called "donors" is not always in harmony with the basic needs of the recipients. The other causes are due to political, financial, and social factors in the recipient countries [15].

Two dummy variables - natural disasters and population - have the same sign and are strongly loaded on factor 6. The relationship between the population and natural disasters seems clear.

The disasters affecting the areas include those associated with flooding, famine, drought, and earthquakes; many people have been killed every year and everywhere in the world. Conventional analysis of the relationship between humankind and the environment has tended to emphasise nature as a set of determinants, without adequately integrating nature with social and economic systems. In order to understand the relationship between humans and nature, it is more important to discern how human systems themselves place people in relation to each other and to the environment than it is to interpret natural systems. The main concept by which "social causation" is explained is "vulnerability", which is a measure of the degree and type of exposure to risk generated by different societies in relation to hazards.

There are particular characteristics of different groups of people (derived from economic, social and political processes) which mean that with the impact of a particular type of hazard of a given intensity, some avoid disaster and others do not. The processes that make people more or less vulnerable are largely (but not exactly) the same as those that generate differences in wealth, control over resources, and power, both nationally and internationally [16].

It that has been obvious to many victims of disaster for some time that their suffering is not simply the result of an "Act of God". This is now being more widely understood [17]. It is easy to identify war and civil disturbance as relevant economic and political factors. What is more difficult but essential is to identify the processes and conflicts which generate and maintain vulnerability to disaster in the more general sense. This is more difficult to substantiate, because it usually involves analysis of the means by which some people live (and survive hazards better) at the expense of others. While many will condemn wars, and be critical of desertification, famine and pestilence, or population growth, there is more reluctance (especially among those who have power) to accept that the conditions which create vulnerability in some people have as their counterpart a more comfortable life for others [18].

There is a long history of damaging floods in Bangladesh. It appears that within recent records, many people have been killed by the highest flood stages, in 1987 and 1988. It involved the areas with the highest population in Bangladesh [19].

In 1970, a huge earthquake at 7.7 on the Richter scale happened in Peru, which was the worst historic natural disaster of the western hemisphere. The earthquake devastated the North-central coastal and Andean regions of Peru [20].

Both the 1972-1974 and the 1984 famines in Bangladesh, were attributed to inadequate harvests during successive years of drought and/or deviant rains [21].

Finally according to the Table 5 (Appendix B), a single variable transport and communications is loaded very significantly (0.844) on factor 7.

A country's infrastructure constitutes part of its social organisation in a broad sense. It represents the network of institutional and other channels through which the social division of labour can be realised. It confronts the social carriers of technology as possibilities and limitations of operation and forces them to make their technology choices as a response to the possibilities it offers.

The concept of infrastructure consists of four principal dimensions:

1. The physical infrastructure includes systems of transportation and telecommunication and to some extent different kinds of public works. This part of the infrastructure makes possible the movement of goods, labour, and other inputs to the production.
2. Economic infrastructure consists of the channels through which the participants obtain access to financial resources to realise the transactions with other production units and participants (capital market, credit institutions, regulations of investments, subsidies).
3. Social infrastructure consists of systems of health and education particularly seen as a matter of the qualifications of the labour force.
4. Technological infrastructure covers various types of institutions dealing with the generation and diffusion of technology and the education of scientific personnel.

The optimal function of a given technology requires infrastructural equipment of a certain quality and quantity. As a given infrastructure is developed in accordance with commonly used technologies, so carriers of new technologies will necessarily find some limitations in the infrastructural development and this forces them to make choices. The level of development of the infrastructural dimensions, therefore, decisively influences the behaviour of the social carriers of technology.

The carriers of technology can decide to dedicate some of their own resources to compensate for the deficiencies of the given infrastructure, typically through in-house training and education, private road-construction and other private systems of transportation. This strategy will be relevant among other things in relation to projects of technology transfer from developed to less developed countries. It implies a move of technology from well developed to less-developed infrastructural surroundings [22].

No variable loads significantly on more than one factor. It should be apparent that factor interpretation has been simplified considerably by rotating the factor matrix.

Now lets sum up the findings. Substantive interpretation is based on the significant higher loadings. Factors 1 through 6 have four, four, three, two, two and two significant loadings respectively, and factor 7 has only one significant loading. For factor 1, we see two groups of variables. The first are Christian religion and imports of manufactured goods, both of which have negative signs. The two other variables, Muslim religion and revolution/war between countries, have positive signs. Thus the first two vary together, as do the other two. However, the two groups move in directions opposite to each other. Turning to factor 2, we notice that all four variables, school enrolment ratios, labour force in industry, number of scientists engagement in R&D, and GNP per capita, are of the same sign. This suggests that they are quite similar among respondents and do not act in differing directions, as in the first factor. Two of them relate to education and the other two to industry.

In factor 3, we have three variables, gross national saving, gross industrial product, and expenditure for R&D. They are of the same sign. They move in same direction specially, the first two seem logically are related to each other.

In factor 4, the two variables - manufacturing production and exports of manufactured goods - both have the same sign, and again it seems logical that this is the case.

Also, in factors 5 and 6, there are two variables in each and with the same sign - gross domestic investment and Buddhism in factor 5, natural disasters and population in factor 6. In each factor, variables act in the same direction. Finally, the single variable transport and communications, is highly loaded on the factor 7.

Validation of any factor results is essential, particularly when attempting to define underlying structure among the variables. Split samples analysis (from original sample) may be applied.

We have chosen two equal-random-split-samples (from the original sample) and re-estimated the factor models to test for comparability. Tables 6 and 7, Appendix B (split samples 1 & 2), contains the "Varimax" rotations for the seven factor models, along with the communalities. As can be seen, the two "Varimax" rotations are quite comparable in terms of both loadings and communalities for all eighteen perceptions. One notable occurrence is the reversal of signs on some factors in split-sample 1 versus split-sample 2. The interpretations of the relationships among the variables (e.g., as adult illiteracy ratio gets higher, gross industrial product decreases) do not change because they are relative among the loadings in each factor.

With these results we can be more assured that the results are stable within our sample.

6.3 Multiple Regression Analysis: Results and Interpretation

The issues concerning the application and interpretation of regression analysis which have been discussed in the previous chapter. We are going to apply this method on our collected data to determine the variables that have the largest influence on the integration of technology of developing countries which is the objective of the model.

To apply the regression procedure, we have selected "integration of technology" as the dependent variable (y) to be predicted by eighteen explanatory variables (Table 3, Appendix A).

The relationship among the explanatory variables is assumed to be statistical, not functional, because it may have had levels of measurement error.

This survey contains 34 observations (countries) for analysis. Meeting the assumptions of regression analysis is essential to ensure that the results obtained were truly representative of the sample and that we have obtained the best results possible [23]. Scatter-plots of the individual variables did not indicate any non-linear relationships between the dependent variable and the explanatory variables. Tests for "heteroscedasticity" found that none of the variables violate this assumption. Finally, in the tests of normality, two of the variables (exports of manufactured goods and population) were found to violate the statistical tests.

The series of tests for the mentioned assumptions underlying regression analysis indicated that the concerns should enter on the normality of two explanatory variables.

One way to determine whether any of the explanatory variables contributes significantly to the prediction of dependent variable, is the F-test.

Recall that the multiple regression model is:

$y = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \cdots \beta_p x_p + \varepsilon$

The hypotheses for the F test involves the parameters of the multiple regression models.

H_0: $\beta_1 = \beta_2 = \cdots = \beta_p = 0$ (there is no significant relationship between integration of technology, "y", and the eighteen explanatory variables)

H_a: one or more of the parameters is not equal to zero

If H_0 is rejected, we have sufficient statistical evidence to conclude that one or more of the parameters are not equal to zero and that the overall relationship between 'y' and the set of explanatory variables x_1, x_2,..., x_p is significant. However, if H_0 cannot be rejected, we do not have sufficient evidence to conclude that a significant relationship is present.

With respect to the Minitab output for the multiple regression model, Table 8, Appendix B, we see that MSR = 1.4750 and MSE = 0.2620. Using test statistic, we obtain the test statistic, F = 5.63 (this F- value is shown in the analysis of variance part of the Table 8).

With a level of significance $\alpha = 0.05$, according to the table of F distribution with eighteen degrees of freedom in the numerator and fifteen degrees of freedom in the denominator, we get, $F_{0.05} = 2.36$. Since 5.63 > 2.36, we reject H_0: $\beta_1 = \beta_2 = \cdots = \beta_p = 0$ and conclude that a significant relationship is present between integration of technology "y" and the eighteen explanatory variables. The p-value = 0.001 in the last column of the analysis of variance of the Table 8 also indicates that we can reject the null hypothesis since the p-value is less than $\alpha = 0.05$. Also, even with a level of significance $\alpha = 0.01$ and according to the table of F distribution, we obtain, $F_{0.01} = 3.43$. Again 5.63 > 3.43 and we can reject H_0.

The mean square error provides an unbiased estimate of σ^2, the variance of the error term ε. Referring to the Table 8, we see that the estimate of σ^2 is MSE = 0.2620. The square root of MSE is the estimate of the standard deviation of the error term. This standard deviation is called the standard error of the estimate (s). Hence, the square root of MSE is s = 0.5118.

Using Minitab to develop the estimated regression equation on our collected data, we obtained the output shown in Table 8, Appendix B. Also, data for a sample of 34 are reported in Table 5, Appendix A.

The p-value of 0.001 associated with the F test (F = 5.63) indicates that the regression relationship is significant. The t tests on the coefficients in Table 8, Appendix B, show that the variables - Gross Domestic Investment (GDI) (p-value = 0.025), manufacturing production (p-value = 0.092), transport and communications (p-value = 0.000), natural disasters (p-value = 0.053), kind of religion (Buddhism) (p-value = 0.085) and revolution/ civil war/war between countries (p-value = 0.093) - are statistically significant. In addition, R-sq = 87.1% and R-sq(adj) = 71.6% indicate that the estimated regression equation provides a good model for explaining the variability in technology integration.

In Table 8, Appendix B (regression analysis results), we notice that many variables are insignificant so, we should be looking for ways of fitting a smaller model. In doing this, we fit a model which arises by taking all variables in full model where we have already discussed such that their p-values ≤ 0.1. Then it will be comparable with the reduced models we will obtain from stepwise regression and best-subsets regression later on.

The estimated regression model with the six variables already mentioned above (all with p-value ≤ 0.1), is shown in Table 9, Appendix B.

The p-value of 0.000 associated with the F test (F = 13.92) indicates that the regression relationship is significant. The t tests on the coefficients of this table show that the variables Gross Domestic Investment (GDI) (p-value = 0.003), manufacturing production (p-value = 0.000), transport and communications (p-value = 0.000), natural disasters (p-value = 0.008), kind of religion (Buddhism) (p-value = 0.000) and revolution/civil war/war between countries (p-value = 0.001) are statistically significant. In addition, R-sq = 75.6% and R-sq (adj) = 70.1% indicate that the estimated regression equation provides a good model for explaining the variability in technology integration [24,25].

6.3.1 Stepwise Regression

As we discussed, the full model - all eighteen variables has already been rejected since too many variables are insignificant. So, we should be looking for ways of fitting a smaller model that adequately fits the data. The stepwise regression is one of the methods that can be employed to select variables for inclusion in the regression variate. The best-subsets regression procedure provides another model-building technique. This will also be considered before a final decision is made.

As discussed in chapter five in detail, stepwise regression is a method of selecting variables for inclusion in the regression model that starts by selecting the best predictor of the dependent variable. Additional explanatory variables are selected in terms of the incremental explanatory power they can add to the regression model. Explanatory variables are added as long as their partial correlation coefficients are statistically significant. Explanatory variables may also be dropped if their predictive power drops to a non-significant level when another explanatory variable is added to the model.

Table 10 (Appendix B) shows the results obtained by using the Minitab stepwise regression procedure for this research's collected data. When only one variable is being added, the t statistic provides the same criterion as the F statistic (one can show that $F = t^2$). The entries in the T-Value row are the t statistics. The values of FREMOVE and FENTER were both automatically set equal to four. At step 1, there are no variables to consider for deletion. The variable providing the largest value for the F statistic is school enrolment ratios, with $F = t^2 = (2.83)^2 = 8.01$. Since $8.01 > 4$, school enrolment ratios is added to the model. In the next steps, transport and communications, kind of religion (Christian), GNS, and natural disasters are added to the model. After the last step, an F statistic was computed for each of the five variables in the model. The value of the F statistic for school enrolment ratios is too small, so it can be dropped from the model and the stepwise procedure re-applied for the rest of the variables. It is shown in Table11 (Appendix B). The values of the F statistic are $(5.84)^2 = 34.11$, $(5.09)^2 = 25.91$, $(4.37)^2 = 19.10$, and $(-3.17)^2 = 10.05$ for the variables transport and communications, kind of religion (Christian), GNS, and natural disasters , respectively. Thus, FMIN = 10.05, and the corresponding variable is natural disasters. Since, $10.05 > 4$, no variable is dropped from the model.

An F statistic was then computed for each of the other variables not in the model. Since all of these F statistics were less than four, no variables were added to the model. The stepwise procedure stopped at this point; no variables could be deleted and none could be added to improve the model. The estimated regression equation identified by the Minitab stepwise regression procedure is:

$$\hat{y} = -1.30 + 0.0509\, GNS + 0.240\, TC - 0.625\, ND + 0.993\, CH$$

Where, GNS, TC, ND, and CH, are for gross national savings, transport and communications, natural disasters, and Christian religion, respectively. See Table 12 in Appendix B.

When we look back at the results of principal component factor analysis of the correlation matrix (rotated), we notice that for instance, the variable school enrolment ratios for first and second level which has appeared in the first step of stepwise regression, has a high loading on factor 2 (0.690). The second variable, transport and communications, which is included in the second step of the stepwise regression, has the highest loading on factor 7 (0.844). The third variable in the third step of stepwise regression is Christian religion, it has a high loading on factor 1 (- 0.737). The variable gross national saving, has a high loading on factor 3 (- 0.602). The variable natural disasters has also the highest loading of - 0.756 (on factor 6). Therefore, variables, which are most important in regression model, are the ones that appear as constituent parts of the important factors.

Note also in Table 11 (Appendix B) that, with the error sum of squares being reduced at each step, s (square root of MSE) has been reduced from 0.884 with the best one-variable model to 0.555 after the last step. The value of R-sq has been increased from 18.00% to 70.71%.

As part of the analysis, we attempt to identify any observation that is influential (having a disproportionate impact on the regression results). The most basic diagnostic tool involves the residuals and identification of any outliers, that is, observations not predicted well by the regression equation, and thus having large residuals.

The residual plots approximate a horizontal band of points so, they do not indicate any unusual abnormalities (see Figures 1, 2, 3 & 4 in Appendix B). Only one of the standardised residuals is outside ± 2. This standardised residual has the value –2.90167 is related to the country number five, Cameroon (Table 1 & Fig. 1 in Appendix B). With only one residual out of 34 significant, we conclude that the model assumptions 1, 2, and 3 are reasonable.

6.3.2 All-Possible-Subsets-Regression

The theoretical method of all-possible-subsets-regression (best subsets regression) procedure has been introduced in detail in the previous chapter.

Stepwise regression, forward selection, and backward elimination are approaches to choosing the regression model by adding or deleting explanatory variables one at a time. There is no guarantee that the best model for a given number of variables will be found. Hence, we are going to use a method of selecting the variable for inclusion in the regression model that considers all possible combinations of the explanatory variables, which is called all-possible-subsets-regression. For example, if the researcher has specified four potential explanatory variables, this technique would estimate all possible regression models with one, two, three, and four variables. The technique would then identify the model(s) with the best predictive accuracy [26].

To illustrate these selection methods, all-possible-subsets-regression for our data set with eighteen variables on thirty four countries has been used by the Minitab software package. Table 13 (Appendix B) is the computer output obtained by using the best-subsets procedure for our data analysis. Results for each of the two "best" models of each possible size are displayed. The first two lines show the two best one-variable estimated regression equations. In the next second two lines, the two best two-variable equations, and so on. The X's under the predictor variable names indicate that those predictors are included in the corresponding model.

There are five columns in this table (Table 13). The first column, Vars, is the number of variables or predictors in the model. Values of R-squared and adjusted-R-squared, are converted to percents. The c-p statistic, and error sum of squares.

As discussed in chapter five, the criterion we have used in determining which estimated regression equations are best for any number of predictors is the small Mallows' C_p statistic and its closeness to p, number of parameters including the intercept (if it is in the equation) [27,28]. For instance, the variable school enrolment ratios for first and second level, with $C_p = 63$, provides an estimated regression equation using only one explanatory variable. The variables, transport and communications and Christian religion, with $C_p = 39.4$, provides another estimated regression equation using only two explanatory variables, and so on.

Since models with C_p small, near p, and with the least number of predictors are preferred, in this analysis, the model with the following characteristics matches the optimal of the five-predictor-model:

$s = 0.53453$, $C_p = 8.5$, and $p = 5 + 1 = 6$ (the addition of "1" is because of the presence of β_0, the intercept).

According to the Mallows' C_p criterion:

$C_p = (SSE_p/MSE_m) + (2p - n)$

where "n" is the number of observations, SSE_p is SSE for the best model with "p" parameters (including the intercept, if it is in the equation), and $MSE_m = s^2$, is the mean square error for the model with all "m" predictors. So:

$C_p = (8.0003/0.2619) + (2 \times 6 - 34) \cong 8.5$ (Tables 8 & 14, Appendix B)

Any reasonable criterion will help eliminate many poor models and allow us to concentrate on a small number of potentially useful models.

The five explanatory variables in the above selected model are gross domestic investment, manufacturing production, transport and communications, Muslim religion, and Buddhism religion.

The regression equation for this model explaining of R-sq (adj) = 69.1% is:

$y = - 2.47 + 0.0591\ GDI + 0.0731\ MP + 0.264\ TC - 0.987\ MUS - 2.06\ BUD$ (Table 14)

where, GDI is gross domestic investment, MP is manufacturing production, TC is transport and communications, MUS is Muslim religion, and BUD is Buddhism religion.

A full list of Minitab computer output for best-subsets regression and for regression analysis on the five variables extracted from the best-subsets have been shown in Tables 13 and 14 (Appendix B), respectively.

The "t" statistics of – 4.19, 4.26, 4.62, 6.34, - 4.78, and – 5.52 for the constant and the above five coefficients, respectively, are statistically significant. Also, the R-sq (adj) = 69.1% is high.

When we look back at the results of principal component factor analysis of the correlation matrix, we notice that for instance, the variable gross domestic investment, which is one of the five variables has appeared in the best-subsets model, has the highest loading on factor 3 (0.556). The other four variables manufacturing production, transport and communications, Muslim religion, and Buddhism religion, which have appeared in the best-subsets model, have the highest loadings –0.711 on factor 4, 0.555 on factor 6, 0.696 on factor 2, and 0.755 on factor 3, respectively. Therefore, variables, which are most important in best-subsets model, are the ones that appear as constituent parts of the important factors.

Looking back at the results of stepwise regression, the five variables which appear are transport and communications, Christian religion, gross national saving, natural disasters, and school enrolment ratios for first and second level. We notice one of them, transport and communications has appeared as a variable common to both the stepwise regression and best-subsets model. But meanwhile, if we return to the results of best-subsets regression (Table 13), we notice an interesting result. There is another five-predictor-model with s = 0.53720, C_p = 8.8, and p = 5 + 1 = 6. In other words, another model with C_p small, near p, and with the least number of predictors (according to Mallow's criterion). It is the one with C_p = 8.8 (In the model described above C_p = 8.5). Thus this is quite close to the first one. The five explanatory variables in this second model are transport and communications, Christian religion, gross national saving, natural disasters, and gross industrial product.

The regression equation for this model explaining of R-sq (adj) = 68.8% is:

$y = -1.69 + 0.238\ TC + 0.998\ CH + 0.0396\ GNS - 0.555\ ND + 0.0141\ GIP$

where, TC is transport and communications, CH is Christian religion, GNS is gross national saving, ND is natural disasters, and GIP is gross industrial product.

A full list of Minitab computer output for best-subsets regression and for regression analysis on this new five-variable extracted from the best-subsets are shown in Tables 13 and 15 (Appendix B), respectively.

The "t" statistics of – 3.71, 3.03, 1.71, 5.99, - 2.85, and 5.28 for constant and the above five coefficients, respectively, are statistically significant. Also, the R-sq(adj) = 68.8% is high. Hence, with this result not only are four variables - transport and communications, Christian religion, gross national saving, and natural disasters - common to both the stepwise regression and the second best-subsets model, but also there is a similarity between the coefficients of the four common variables. That is, the two sets of coefficients for the two models are + 0.240, + 0.993, + 0.0509, - 0.625 and + 0.238, + 0.998, + 0.0396, - 0.555, respectively.

As we pointed out earlier, we can also compare variables in these two reduced models (the stepwise regression and the second best-subsets regression) with those in the model fitted which used the variables in the regression model based on all 18 variables whose p-values ≤ 0.1. There were six such variables. So, if we compare those six variables with the five variables which have arisen from the results of the stepwise regression, we notice that only two of them, transport and communications and natural disasters are common to the both models. Another two variables, transport and communications and gross domestic investment are also common with both the first and the second best-subsets models.

6.4 Further Validation - Tests Using Cluster Analysis

Cluster analysis is the name for a set of multivariate techniques whose primary purpose is to group objects based on the characteristics they possess. Cluster analysis classifies objects (e.g., respondents, products) so that each object is very similar to others in the cluster with respect to some predetermined selection criterion. The resulting clusters of objects should then exhibit high internal (within-cluster) homogeneity and high external (between-cluster) heterogeneity. Then, if the classification is successful, the objects within clusters will be close together when plotted geometrically, and different clusters will be far apart.

Using cluster analysis on the data from the 34 countries produced two distinct groups. The two groups contained 20 and 14 countries respectively with $n_1 = 20$ and $n_2 = 14$ (Figure 6 & Table 16, Appendix B).

The t-test assesses the statistical significance of the difference between two independent sample means.

A t-test was applied to the two groups to test whether there was a significant difference between the two mean indices of the integration of technology index. Also, t-test has been done as further validating the models (model-building stage 6: validating the models).

The results show that there is not a significant difference in the mean indices of technology integration for the two samples derived from the cluster observations. The p- value of test statistic is 0.31 (Table 17, Appendix B). A detailed on technical description together with the calculation of the t-test statistic and a description of cluster analysis have been discussed in Appendix C.

6.5 Making the Final Choice

The analysis performed on the collected data to this point is a good preparation for choosing a final model. The regression analysis on all eighteen variables showed that many variables were insignificant so, a smaller model was fitted using those variables in the full model with p-values ≤ 0.1. This six-variable-model has as explanatory variables transport and communications, natural disasters, manufacturing production, gross domestic investment, Buddhism religion, and revolution/civil war/war between countries. In addition, R-sq = 75.6% and R-sq (adj) = 70.1%. This six-variable-model was then compared with the two five-variable-models which were obtained from the best-subsets regression. All other things being equal, a simpler model with fewer variables is usually preferred (the principle of parsimony). The R-sq and R-sq (adj) values for all models were quite close to each other. Now, the best stepwise regression results was a four-variable-model (As we discussed, it was originally a five-variable-model with an additional variable, school enrolment ratios, which had a very small t statistic so it was dropped from the model). This has as explanatory variables transport and communications, Christian religion, natural disasters and gross national savings, with R-sq = 70.71% high enough to be significant, which R-sq (adj) = 66.7%. The estimated regression equation identified by the Minitab stepwise regression procedure is:

$\hat{y} = -1.30 + 0.240\ TC + 0.993\ CH - 0.625\ ND + 0.0509\ GNS$

Where, TC, CH, ND, and GNS, are for transport and communications, Christian religion, natural disasters, and gross national savings, respectively. The signs of the coefficients, a priori, are as expected and therefore plausible. Also, there were two four-variable-model in best-subsets regression results. One of them has a minimum $C_p = 10.1$. This four-variable-model has most explanatory variables common to the one obtained using stepwise regression. However, because $p = 4 + 1 = 5$ it is very far away from the value of $C_p = 10.1$ (contrary to Mallow's criterion). So, it can not be acceptable.

Hence, it seems that the four-variable-model, with the explanatory variables transport and communications, Christian religion, natural disasters, and gross national savings derived from the stepwise regression is the preferred model.

6.6 Summary and Conclusions

In this chapter we applied the framework theoretically discussed in chapter five for classifying the economic and social variables relating to the characteristics of countries. Such a framework makes it easier to adopt a systematic approach to the analysis of socio-economic indicators of technological transfer, as it provides greater insight into the similarities of the variables and indicates their hierarchical relationships. The grouping or classification of variables (factor analysis) provides information on their functional similarities, which provides further knowledge on the interrelation (correlation) between the variables. This assists in the choice of variables for the regression model, that is, a variable can be selected or rejected by the analyst on the ground of the dimension it explains. Therefore, with the grouping variables (factor analysis), being used to support the results of the regression analysis, the researcher can test whether the regression model has selected the appropriate variables. Also, the researcher is more aware of the validity and importance of the variables and has a more defined idea of what they represent, and how they relate to each other.

Most important of all, once the variables were identified by the regression model, the grouping helped locate the indicators that are from the same or a different category from the ones retained. This is of relevance in the sense that the model can be applied for cases in which data on a particular variable is unknown. This cannot be achieved, for example, by using regression analysis alone. It should therefore, be stressed that the grouping of variables (factor analysis) provides a complementary explanatory analysis to the multiple regression analysis model.

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CHAPTER 7: Discussion, Conclusions and Recommendations for Further Research

7.1 Introduction

There are many explanations of economic development and therefore of the different development performances of countries. However, none is totally satisfactory because the predictions do not always accord with the facts. And yet there is enough in each of the explanations, when introduced at the right time and place, to suggest that they are important pieces in solving the jigsaw puzzle.

In the 1950s when most of the newly independent developing countries began their search for greater economic growth, most observers of the development scene despaired of seeing much progress. Many of the developing countries had registered no growth at all for thousands of years. Most were experiencing rapid population growth and decreases rather than increases in their per capita income were seen as more likely.

What was actually achieved over the 1950-1975 period exceeded all expectations [1]. The per capita GNP of developing countries as a group grew at an average of 3.4% a year [2]. This not only surpassed the growth rate of the developed countries over the same period but also achieved by the developing and developed countries over any comparable period before 1950.

The story of growth performances over the 1965-1990 period was the same, when international economic conditions have become very difficult. While the growth rate of developing countries has slowed in the years since 1975, it still exceeded or kept pace with that of developed countries. The growth performances of NICs were particularly impressive [3].

Meanwhile, international technology transfer policy was an important issue in international relations between developed and developing countries during the 1960s and 1970s. Thirty-odd years later significant changes have occurred in the world economy which have altered not only the major issues in international technology transfer for developing countries but also the link between technology transfer and opportunities for their growth [4].

Development economists are increasingly aware that approaches to the problems of developing countries differ from those of the developed world because of social, economic and political reasons. However, efforts to develop and extend the analysis that include these environmental factors are hampered by absence of empirical knowledge of the manner in which they operate. As an initial investigation, the present study of technology transfer was treated within these broader issues. The main aim was to contribute to the understanding of technological transfer by obtaining a quantitative insight using empirical data, rather than a qualitative one.

7. 2 Main Conclusions

The attempt of the current study was to find out the main classification of socio-economic characteristics of countries that affect the rate of integration of technology transfer. In chapter 6, we applied the framework theoretically discussed in chapter five for classifying the economic and social variables relating to the characteristics of countries. Such a framework makes it easier to adopt a systematic approach to the analysis of socio-economic indicators of technological transfer, as it provides greater insight into the similarities of the variables and indicates their hierarchical relationships.

The regression analysis on all eighteen variables showed that many variables were insignificant so, a smaller model was fitted using those variables in the full model with p-values ≤ 0.1. This six-variable-model has as explanatory variables transport and communications, natural disasters, manufacturing production, gross domestic investment, Buddhism religion, and revolution/civil war/war between countries. In addition, R-sq = 75.6% and R-sq (adj) = 70.1%. This six-variable-model was then compared with the two five-variable-models which were obtained from the best-subsets regression. According to the principle of parsimony, all other things being equal, a simpler model with fewer variables is usually preferred. The R-sq and R-sq (adj) values for all models were quite close to each other. Now, the best stepwise regression result was a four-variable-model. This has as explanatory variables transport and communications, Christian religion, gross national saving and natural disasters with R-sq = 70.71% high enough to be significant, with R-sq (adj) = 66.7%. The results of this best stepwise regression were compared with the results of another two five-variable-model in best-subsets and gave higher R-sq and R-sq (adj) values. The results from stepwise regression suggest that countries with the following indicators are more able to absorb and integrate foreign technologies:

- Transport and communications
- Christian Religion
- Natural disasters (negative concept)
- Gross national savings

Since this model gave a statistically significant R-sq = 70.71% and R-sq (adj) = 66.7% and satisfies the principle of parsimony it was chosen as the preferred model.

7.3 Economic Implications

Having discussed the results from a statistical perspective, we now discuss the economic interpretation of the model. As has already been mentioned, the four main indicators identified by the stepwise regression to explain the variation in the process of technology integration are gross national savings, transport and communications, natural disasters and Christian religion. The following discussion will attempt to show the relevance of these variables. Additionally, one of the variables, school enrolment ratios for the first and second level, had entered in the stepwise regression model with the largest value of F = 8.01 at the first step indicating its importance as an indicator for the process of technology integration. After the last step its F statistic became insignificant, so it dropped from the model. However, given this initial indication of its importance, it seems reasonable to also discuss education and its impact on economic development along with the other indicators appearing in the final model.

7.3.1 Education

For individuals and for countries, education is the key to creating, adapting, and spreading knowledge. Basic education increases people's capacity to learn and to interpret information. But that is just the start. Higher education and technical training are also needed to build, for example, a labour force that can keep up with a constant stream of technological advances. Educated farmers tend to adopt new technologies first, and in so doing provide those who follow with valuable, free information about how best to use the new methods. A study investigated the relationship between the proportions of college students majoring in various disciplines in 1970 and subsequent real growth in GDP per capita. The study found a significant positive association between the proportion of engineering majors and later growth. And for the 55 countries with college enrolments of at least 10,000 in 1970, the proportion of college students in engineering was significantly and positively associated with subsequent levels of physical capital investment. It has confirmed that countries with a greater science and engineering base and with a more technically skilled labour force do have faster growth [5].

One cannot discuss the relationship between education and development without explicitly linking the structure of the educational system to the economic and social character of the Third World society in which it is contained. Education can influence the future shape and direction of society in a number of ways. Thus, the linkage between education and development is a two-way process. By reflecting the socio-economic structures of the societies in which they function, educational systems tend to perpetuate, reinforce and reproduce those economic and social structures. On the other hand, educational reform, whether introduced from within or outside the system, has the great potential for inducing corresponding socio-economic reform in the nation as a whole. There are six specific economic components of development – growth, inequality and poverty, population and fertility, internal migration, rural development and external migration [6].

7.3.2 Religion

As for the relationship between religion (as dummy variable) and economic development, we can say that for instance, Philippines is a Christian country, Thailand is a Buddhist country and Indonesia is predominantly a Muslim country. Does this affect in any way the process of transfer of new modern technologies? How conscious of religion are the businessmen in these countries? Chatterji's survey attempted to explore their views on this difficult question [7]. The findings seem to show certain ways of thinking on the part of Southeast Asian businessmen about the relations between material welfare and spiritual nemeses.

The business world in Southeast Asia has several other systems of religious beliefs besides those three mentioned above. Most Westerners are Christians, while, there are other systems of religious beliefs in Asia, for instance, in Japan, China, India and so on. Since, moreover, the business enterprises in Southeast Asia are often joint ventures and the participation ratios of overseas Chinese in these joint ventures are relatively high, the ethnic problems related to overseas Chinese arise along with other anti-foreigner problems. In particular the Chinese government policy tries to provide preferential treatment for non-Chinese indigenous ethnic groups. There may be some active opposition towards Westerners or Japanese, which may or may not affect the decisions on adopting new technologies. The findings of the survey seem to show significant differences among the three countries with regard to the mode of decision-making.

Investment is always made with some degree of risk, and how such actions are considered in the context of religious or spiritual circumstances is important for understanding the thinking of entrepreneurs in these countries. The survey findings on these issues seem to show something of the psychology of businessmen. Here again businessmen in Indonesia seem to be influenced by religious factors much more significantly than those in Thailand and the Philippines. From the observations mentioned above it seems safe to presume that religion has a relationship with economic action, although the strength of the relationship varies between countries. For example, Islam in Indonesia has closer relations with economic affairs than Buddhism in Thailand and Catholicism in the Philippines.

Another aspect of religion's influence on economic action concerns the conception of success or failure in business. This may be influenced by the nature of religions or their teachings; whether, for example, the religion is submissive to fate or emphasises nemesis [8].

In Europe's own history, economic transformation had not occurred in isolation, but involved changes in the whole social system. In particular, the rise of capitalism had been accompanied by the rise of Protestantism.

Since Protestantism is seemingly unimportant as a modernising ideology in the modern world, this debate might appear archaic. Yet, in modified form, it still lies at the heart of contemporary arguments about development.

Development, moreover, is not to be measured solely in terms of how much steel is produced or how many television-sets per head. For much depends on how that production is achieved, how the product is distributed and what it is used for that influences what kinds of relations are fostered between people and the kind of society and culture generated [9].

7.3.3 Natural Disasters

Natural disasters is another dummy variable which appeared in the stepwise regression model. Its negative impact on the economics of a country is clear. The disasters affecting the areas include those associated with flooding, famine, drought, and earthquakes; many people have been killed every year and everywhere in the world. Conventional analysis of the relationship between humankind and the environment has tended to emphasise nature as a set of determinants, without adequately integrating nature with social and economic systems. In order to understand the relationship between humans and nature, it is more important to discern how human systems themselves place people in relation to each other and to the environment than it is to interpret natural systems. The main concept by which "social causation" is explained is "vulnerability", which is a measure of the degree and type of exposure to risk generated by different societies in relation to hazards.

There are particular characteristics of different groups of people (derived from economic, social and political processes) which mean that with the impact of a particular type of hazard of a given intensity, some avoid disaster and others do not. The processes that make people more or less vulnerable are largely (but not exactly) the same as those that generate differences in wealth, control over resources, and power, both nationally and internationally [10].

It has been obvious to many victims of disaster for some time that their suffering is not simply the result of an "Act of God". This is now being more widely understood. It is easy to identify war and civil disturbance as relevant economic and political factors. What is more difficult but essential is to identify the processes and conflicts which generate and maintain vulnerability to disaster in the more general sense. This is more difficult to substantiate, because it usually involves analysis of the means by which some people live (and survive hazards better) at the expense of others. While many will condemn wars, and be critical of desertification, famine and pestilence, or population growth, there is more reluctance (especially among those who have power) to accept that the conditions which create vulnerability in some people have as their counterpart a more comfortable life for others [11].

There is a long history of damaging floods in Bangladesh. It appears that within recent records, many people have been killed by the highest flood levels, in 1987 and 1988. This involved the areas with the highest population in Bangladesh [12].

In 1970, a huge earthquake at 7.7 on the Richter scale happened in Peru, which was the worst historic natural disaster of the western hemisphere. The earthquake devastated the North-central coastal and Andean regions of Peru [13].

The United Nations Food and Agriculture Organisation (FAO) has repeatedly warned of catastrophic food shortages during the 1990s. In a majority of African countries, the average per capita calorie intake has now fallen below minimal nutritional standards. Of Africa's 630 million people, the FAO estimates that more than 200 million suffer from inadequate food supplies. Whereas the severe famine of 1973-1974 took the lives of hundreds of thousands and left many more with permanent damage from malnutrition, its geographic impact was limited to the Sahelian belt. By contrast in 1982-1984 and again in 1987-1988, the food crises became much more widespread, with more than 22 nations threatened by severe famine, including, in addition to the Sahelian nations, Zambia, Tanzania, Malawi, Uganda, Botswana and Angola. These happenings have been due largely to the sluggish industrialisation and national development of these nations [14].

7.3.4 Transport and Communications

A country's infrastructure constitutes part of its social organisation in a broad sense. It represents the network of institutional and other channels through which the social division of labour can be realised. It confronts the social carriers of technology as possibilities and limitations of operation and forces them to make their technology choices as a response to the possibilities it offers [15].

The concept of infrastructure consists of four principal dimensions:

1. The physical infrastructure includes systems of transportation and telecommunication and to some extent different kinds of public works. This part of the infrastructure makes possible the movement of goods, labour, and other inputs to the production.
2. Economic infrastructure consists of the channels through which the participants obtain access to financial resources to realise the transactions with other production units and participants (capital market, credit institutions, regulations of investments, subsidies).

3. Social infrastructure consists of systems of health and education particularly seen as a matter of the qualifications of the labour force.
4. Technological infrastructure covers various types of institutions dealing with the generation and diffusion of technology and the education of scientific personnel.

The optimal function of a given technology requires infrastructural equipment of a certain quality and quantity. As a given infrastructure is developed in accordance with commonly used technologies, so carriers of new technologies will necessarily find some limitations in the infrastructural development and this forces them to make choices. The level of development of the infrastructural dimensions, therefore, decisively influences the behaviour of the social carriers of technology.

The carriers of technology can decide to dedicate some of their own resources to compensate for the deficiencies of the given infrastructure, typically through in-house training and education, private road-construction and other private systems of transportation. This strategy will be relevant among other things in relation to projects of technology transfer from developed to less developed countries. It implies a move of technology from well developed to less-developed infrastructural surroundings.

Infrastructure investment is one of the types of investment which is very important to developing countries. Just as the productivity of physical capital depends on investment in human capital, so it also depends on the existence of infrastructure investment - for example, in transport and communications and power facilities. Good infrastructure improves productivity and reduces production costs in the private sector. Apart from this obvious benefit, the adequacy of infrastructure can make a crucial difference to a country's development programme in a number of ways, such as diversifying production, expanding trade, improving environmental conditions, coping with population growth and reducing poverty [16].

The World Bank's "World Development Report" for 1994 was devoted to the topic of infrastructure for development. Currently, developing countries invest $200 billion a year in new infrastructure – transport, power, water, sanitation, telecommunications, irrigation and so on. They estimate it accounts for 20% of total investment and 4% of GDP and the need for such investment is still huge.

7.3.5 Gross National Savings

Saving is necessary to fund investment. In a primitive subsistence economy, without money or monetary assets, saving and investment will tend to be simultaneous acts, in the sense that saving and investment will be done by the same people and saving will be invested in the sector in which the saving takes place.

In classical theory saving and investment are one and the same thing. All savings find investment outlets through variations in the rate of interest. Investment and development process are led by savings. It is this classical view of the development process that underlies such phrases in the development literature as the "mobilisation of savings for development".

The level of saving and the ratio of saving to national income in developing countries are likely to be a function of many variables affecting the ability and willingness to save. The main determinants of the ability to save are the average level of per capita income, the rate of growth of income, distribution of income between rich and poor and the age composition of the population. In turn, the willingness to save depends on such monetary factors as the existence of acceptable and reliable monetary institutions, interest rate offered in relation to risk and time preference, and general societal attitudes towards consumption and the accumulation of wealth [17].

The grouping of these two variables, investment and saving, both significant in the third factor of the factor analysis shows the consistency of the data collected as well as the regular pattern of the sample of countries under study. The close relationship between investment and saving to a certain extent tends to show that, among the countries studied those that have higher gross domestic investment and therefore savings, tend to have relatively greater industrial production. The dimension expressed by this factor is very relevant to the present study. In order to get some insight into these relationships, the notion of investment and saving has to be explored more deeply.

Investment is that part of national income or expenditure devoted to the production of capital goods and services over a given period of time. "Gross" investment refers to the total expenditure on new capital goods, while "net" investment refers to the additional capital goods produced in excess of those that wear out and need to be replaced [18].

Investment is therefore that part of the current output of goods and services devoted to adding to the stock of capital and thus to raising the future potential of a community. It is mainly referred to as capital formation.

The computations of gross domestic investment consist of subtracting the private and general government consumption from the gross domestic product (GDP) and adding the difference between exports and imports, that is [19]:

$$I = GDP - C + X - M$$

where, I represents the gross domestic investment, C is the private and general government consumption, X is exports, and M is imports. It is well known that investment provides a major force to the process of economic growth.

While Multinational Corporations (MNCs) invest in developing countries to make profits, they will increase incomes, diffuse technology and domestic savings in these countries. The exchange of commodities and services in trade will reflect the principle of division of labour and hence bring gains from trade to these countries. The migration of skilled labour, instead of constituting a troublesome brain drain, will help to remove impediments to progress such as inadequate remuneration of the educated elite.

On the other hand, Streeten [20] shows the repercussions that investment and savings have on economic growth when their level of equilibrium is different. He emphasises the responsibility of government to maintain an aggregate equilibrium between investment and saving in developing countries.

Even though the savings rate is regarded as a key performance indicator by development economists, the formulation of policies designed to increase savings propensity has suffered from a limited knowledge of the nature of the savings function in developing countries. It would be interesting to review the hypotheses regarding national saving related to developing countries.

7.4 Recommendations for Further Research

There are some issues which need to be discussed which are important to the present study and also need further investigation.

7.4.1 Technology and Technology Transfer in Africa

The introduction of technology in the development process has been based essentially on transfer from the industrialised zones, rather than on the encouragement of indigenous technological development founded on the traditions, knowledge and socio-economic objectives of the countries of the Third World. In addition to the lack of indigenous technological capacities, the relative failure of the technology transfer process is due to many causes. Some of these causes derive from the inherent ineffectiveness of the process itself, in which the profit motive of the so-called 'donors' is not always in harmony with the basic needs of the recipients. The other causes are due to political, financial, and social factors in the recipient countries [21]. Some of these other factors are discussed here.

AIDS (Acquired Immune Deficiency Syndrome) is a weakening of the immune system by the Human Immunodeficiency Virus, HIV.

According to the United Nations programme on HIV/AIDS (UNAIDS) 2000, globally, 36.1 million adults and children were living with HIV/AIDS at the end of 2000. Of infected adults, 47.3% were women. In 2000, the global adult HIV prevalence rate was 1.1%. During that year, 5.3 million people were newly infected with HIV and there was 3 million adult and child death due to HIV/AIDS. Since the beginning of the epidemic, there has been 21.8 million AIDS death.

Over 25 million adults were living with HIV/AIDS in Sub-Saharan Africa and 83% of the world's AIDS deaths have been in this region [22]. Since the most productive age group has been infected with AIDS and it is a fatal and widespread disease, it will have a larger impact on African development than other more common diseases. So, because of the importance of this terrible human toll which is now impacting economically on countries in Africa, we include later a special section on technology transfer in Africa with particular reference to AIDS and its impact on African development. However, before this we discuss other factors affecting this development.

In recent decades famines have been particularly acute in a number of traditionally vulnerable regions such as China, Bangladesh and the Sahelian-Ethiopian band of Africa. Often these regions have been associated with wars and civil struggle, as in Bangladesh and Kampuchea during the 1970's, and in Nigeria during the Biafran war of 1968-69 [23].

The twin problems of drought and famine in Africa have preoccupied many African scholars, researchers, policy makers and entrepreneurs. In almost every African society there are stories about past famines and droughts. Indeed, many people born in the famines of 1930-31 and 1943-44 were named after them.

Of all the human factors, which cause famines in Africa, war is the most conclusive. The countries, which have suffered chronic famines, actual, periodic cases of mass starvation, have been only those countries chronically at war: Ethiopia, Sudan, Chad, Mozambique and Angola. Although Ethiopia is one of the world's poorest nations, its government spends vast sums of money fighting several wars at once. For example, trying to put down the 26-year-old rebellion in Eritrea, the 11-year-old rebellion in Tiger, supporting rebellions in Somalia and southern Sudan, and roughly 20 other smaller rebellions [24].

The fact that over 95% of all research and development activities in the world are carried out in the industrialised countries is probably the most important clue for African advancement to work more on the science and technology.

This enormous imbalance automatically leads to excessive dependence, which in turn creates many problems for developing countries.

The Vienna Programme of Action, which was adopted by the United Nations Conference on Science and Technology for Development in 1979, emphasised two basic areas of concern. They are the strengthening of the science and technology capacities of the developing countries and the restructuring of the existing pattern of international scientific and technological relations, including the transfer of technology. In its effort to strengthen domestic, scientific and technological capabilities, Africa will have to resort to co-operation with countries which are further advanced in this area. A distinctive feature of the flow of science and technology is the increasingly important role played by governments. Technology flows are generally channelled through transnational corporations.

The flow of technology to the developing countries, including Africa, takes place through direct foreign investment, turnkey arrangements for the supply of machinery, equipment and plants, that is, embodied technology, the establishment of joint ventures, and the licensing of know-how, either patented or not [25].

7.4.2 Aids in Africa

As we discussed in the previous section and according to the United Nations, AIDS is now one of the most dangerous epidemics and is in fourth place among all causes of death world wide. In particular, is the number one cause of death in African countries. It's estimated that 2.8 million people died of AIDS in 1999.

AIDS is a weakening of the immune system by the human immunodeficiency virus, HIV. The sufferer loses the ability to fight infection and may fall victim to illnesses such as pneumonia, diarrhoea, and tumours.

AIDS was first identified in the early 1980s, but the first case of the disease may have occurred much earlier-in Africa in the late 1950s. In Africa, the problem has been exacerbated by poverty, illiteracy, weak educational and public health systems, and the low social status of women. Drug treatments and public education have curbed its spread in some parts of the world but, this has not been the case in Africa.

Most researchers believe humans acquired AIDS from chimpanzees, which sometimes carry a similar virus, by eating them or being bitten by them. A minority view holds that a vaccine made from infected chimpanzee tissue spread it [26].

While some countries still have the opportunity to avert a full-scale AIDS epidemic, others already find themselves facing the consequences of widespread HIV infection. What can be done that is effective and affordable to help people with AIDS in developing countries?

Anti-retroviral therapy, which has achieved dramatic improvements in the health of some individuals in high-income countries, is currently unaffordable and too demanding of clinical services to offer realistic hope in the near term for the millions of poor people infected in developing countries. An analysis of alternative treatment and care options concludes that community-initiated care provided at home, while often shifting costs from the national taxpayer to the local community. It also greatly reduces the cost of care and thereby offers hope of affordably improving the quality of the last years of life of people with Aids [27].

The HIV virus is transmitted in body fluids including blood, semen, vaginal fluid, and breast milk.

Only a blood test can prove HIV infection. Many infected people have no symptoms for many years, but early signs may include weight loss, dry cough, recurring fever, tiredness, swollen glands, and diarrhoea. Better testing for HIV is a priority in many countries. It helps carriers of HIV become aware of the fact. According to UN, poor countries can achieve a lot by improving education and information [28].

Around 20% of South African adults had HIV in 1999, up from 13% in 1997.

According to the United Nations Programme on HIV/AIDS (UNAIDS), every day around 1500 people were newly infected with HIV in South Africa in the year 1999. Four million people were already HIV-positive in the same year and there is no sign that the rate of infection is slowing down [29].

According to UNAIDS, in the year 2000, around 95% of the world's AIDS orphans live in Africa.

7.4.3 Impact of Aids on African Development

AIDS has already taken a terrible human toll, not only among those who have died but also among their families and communities. Short of an affordable cure, this toll is certain to rise. Around 90% of HIV infections are in developing countries, where resources to confront the epidemic are most scarce, but the course of the epidemic is not carved in stone [30].

The most basic impact of HIV/AIDS is on those who contract the disease. There is no cure for AIDS and no vaccine to prevent infection with HIV, but there are drugs and medication to relieve symptoms and treat opportunistic infections which can ease suffering and prolong the productive lives of people with HIV, sometimes at low cost. These drugs also can slow down the spread of the virus and the rate at which it weakens the immune system. In some patients the virus has been reduced to undetectable levels. But as the immune system collapses, available treatments become increasingly expensive and their efficacy less certain.

As has already been stated, because AIDS affects primarily the most productive age group and is fatal and widespread, it will have a larger impact on African development than other more common diseases. Infection rates are higher in urban than in rural areas and studies suggest that they are highest among urban high-income-skilled-men and their partners. Macroeconomic models show that the greater the infection rate among educated workers and the greater the propensity to finance medical care out of savings, the more detrimental is the impact of AIDS on the growth of per capita income. Regardless of the macroeconomic effect, most households and businesses directly affected by AIDS will be economically worse off, at least in the short run. Governments need to assess the potential economic impact of AIDS, implement cost-effective programmes to mitigate the impact, and target prevention programmes to the economic sectors most sensitive to HIV infection [31].

Over [32] in an article estimates the macroeconomic impact of AIDS on the Sub-Saharan economies by projecting the growth trajectories of 30 countries with and without the AIDS epidemic over the period 1990-2025. He defines the "impact" of the epidemic to be the difference between the trend growth rates with and without AIDS. If the only effect of the AIDS epidemic were to reduce the population growth rate, it would increase the growth rate of per capita income in any plausible economic model. The central question addressed by this paper is whether the specific characteristics of the AIDS epidemic would be sufficient to reverse this prediction, such that per capita income growth rate would be negative rather than positive. The characteristics examined are the effect of the epidemic on savings and the distribution of the epidemic by productivity class of worker, which the paper calls the "socio-economic gradient" of the epidemic.

The paper shows that an AIDS epidemic can reduce the growth rate of per capita income in the average country even when it is evenly distributed across productivity classes of workers, provides at least 50% of treatment costs are extracted from savings. Either raising the percentage of treatment costs financed from savings or biasing the epidemic toward the more productive workers increases the negative impact on per capita growth and the two combined effects interact to produce an even larger impact, especially on the ten countries with the most advanced epidemics. For the most probable assumptions, that 50% of the treatment costs are financed out of savings and that each education class of workers has doubled the risk of negative contracting HIV of the one below it. The net effect of the AIDS epidemic on the growth of per capita GDP is a reduction of about a third of a percentage point in the ten countries with the most advanced epidemics. This is a substantial impact in countries that have been struggling to escape from a period of negative growth rates.

7.4.4 Statistics on AIDS

We have discussed the impact of AIDS on African Development. In relation to this, we have collected some recent data related to AIDS. They have been obtained from two sources, World Development Indicators 2000 [33] and a joint work of UNAIDS/WHO [34].

At a glance, the number of people (adults and children) living with HIV/AIDS (end 1997) is the highest in Sub-Saharan Africa, which is a terrible figure of 21 million. An overview is shown in Table 7.1.

As we can see from this table while the number of all people living with HIV/AIDS in Western Europe, North Africa and Middle East, Eastern Europe and Central Asia, East Asia and Pacific, North America, Caribbean, and Latin America is 3,770,000, this figure only in Sub-Saharan Africa is 21,000,000. Also, around 69% of all people living in the world with HIV/AIDS is in Sub-Saharan Africa (at end 1997).

Table 7.1: Population (1997), Estimated Number of People Living with HIV/AIDS, (End 1997), Estimated AIDS Deaths (1997) by Region

Population 1997		Estimated Number of People Living with HIV/AIDS (End 1997)	Estimated AIDS Deaths	
Region	**Total (Thousands)**	**Adults & Children**	**Adults & Children (1997)**	**Adults & Children, Cumulative**
Western Europe	400,181	480,000	15,000	190,000
N. Africa & Middle East	322,211	210,000	13,000	42,000
Sub-Saharan Africa	593,027	21,000,000	1,800,000	9,600,000
S. & S. East Asia	1,859,821	5,800,000	250,000	730,000
Eastern Europe & Central Asia	373,424	190,000	<1,000	5,400
East Asia & Pacific	1,451,707	420,000	5,000	11,000
N. America	301,591	860,000	29,000	420,000
Caribbean	30,932	310,000	18,000	110,000
Latin America	455,247	1,300,000	81,000	470,000
Total	5,837,110	30,600,000	2,300,000	11,700,000

Sources: 1) UNAIDS/WHO (http://hivinsite.ucsf.edu/social/un/2098.3ceb.html)

2) World Development Indicators 2000

During the period of this study (1983-1992) little data was available on AIDS. Its impact has significantly increased since and any model of economic development or technological transfer using a more recent timeframe would need to include it as a variable.

We can say that further empirical studies should be carried out to validate the present study, in particular:

1. The reliability and accuracy of the present model should be assessed by using different sets of corresponding data, for different countries, and for different periods of time.
2. Other indicators, more specific information representative of the economies of developing countries such as man's hour work, wages, employment, policies, together with managerial capacities should be investigated. Political facets that can be quantified, e.g., stability of regimes, could usefully be explored.
3. The appropriateness of other statistical and economic techniques and models, rather than those have been applied in this study, could usefully be investigated.
4. Other measures related to the type of technology imported, i.e., whether it is capital or labour intensive in conjunction with their quantity and output, should be investigated. This would require a comparative study between two or more types of technology. The results would explain further facets of technological transfer.
5. As we discussed in this chapter in detail, AIDS is now one of the most dangerous epidemics worldwide. So, because of its importance, an attempt to include it in some form in a model would be necessary. Possible variables might be the numbers of people living with HIV/AIDS, number of AIDS cases and AIDS death.

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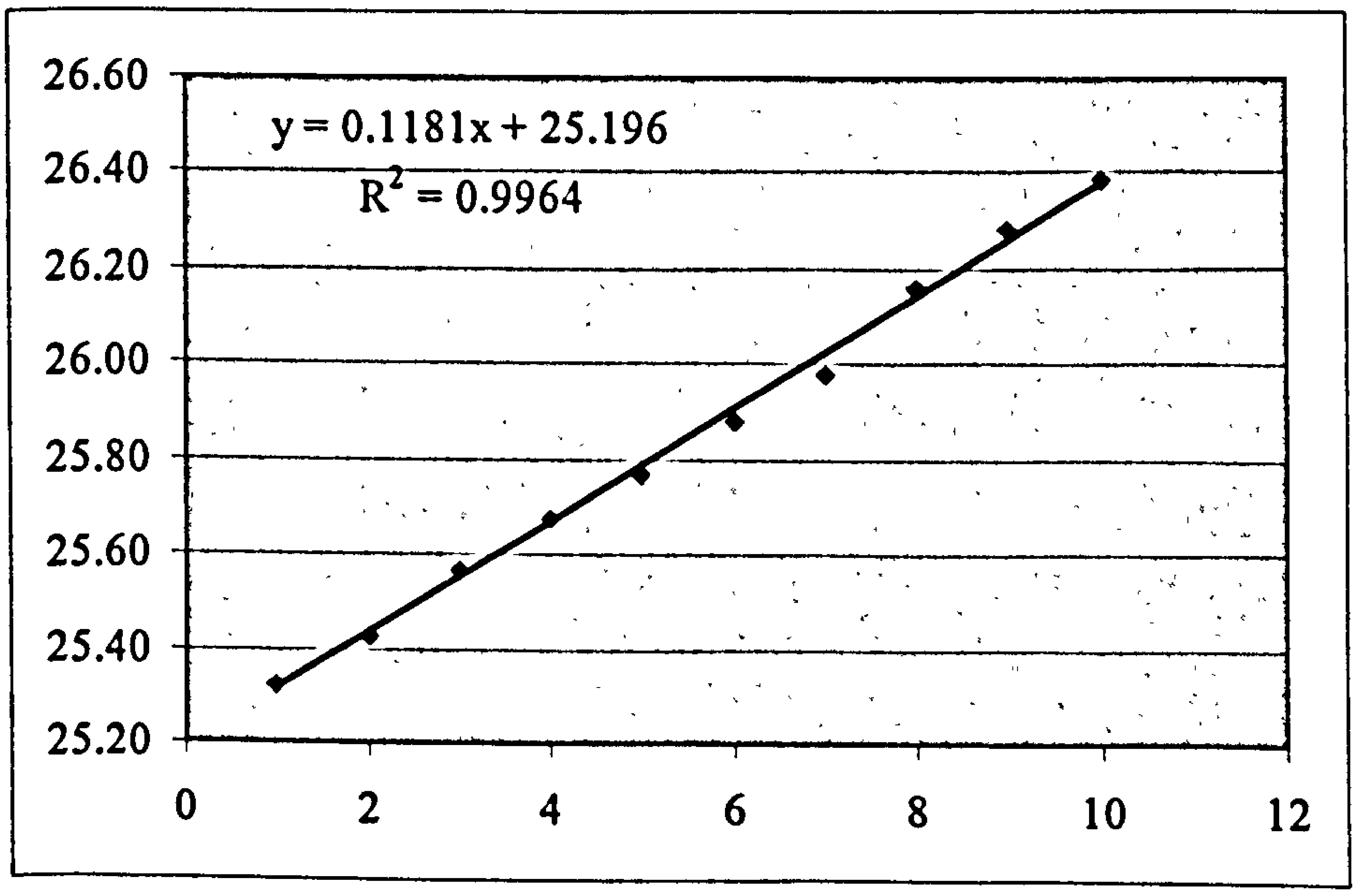
Appendix A, Fig. 1

Bangladesh
1983-1992

Year	GIP in current prices (billion Bangladesh takas)		Ln GIP
1983	99.6	1	25.32
1984	110.6	2	25.43
1985	126.9	3	25.57
1986	141.9	4	25.68
1987	155.6	5	25.77
1988	173.3	6	25.88
1989	191.6	7	25.98
1990	229.1	8	26.16
1991	259.0	9	26.28
1992	288.4	10	26.39

Trend of GIP % = 12.54



Appendix A, Table 1

Trend of GIP, Imported Technology & Integration of Technology Index

Countries	Trend of GIP (%)	Imported Technology (% of GIP)	Integration of Technology Index
Bangladesh	12.54	9.79	1.28
Bhutan	4.88	24.41	0.2
Bolivia	37.99	13.52	2.81
Botswana	23.96	37.18	0.64
Cameroon	2.7	9	0.3
Chile	30.97	28.15	1.1
Colombia	33.28	11.28	2.95
Costa Rica	48.16	24.08	2
Ecuador	36.94	16.79	2.2
El Salvador	21.94	18.28	1.2
Gabon	35.63	14.25	2.5
Honduras	44.68	22.34	2
Indonesia	16.77	16.13	1.04
Iran	11.17	18.88	0.59
Jamaica	40.68	18.49	2.2
Kenya	34.55	34.55	1
Mauritania	5.62	37.45	0.15
Morocco	14.99	16.66	0.9
Nigeria	35.11	10.64	3.3
Pakistan	15.42	15.61	0.99
Paraguay	34.03	16.52	2.06
Philippines	20.72	13.81	1.5
Rwanda	2.8	19.99	0.14
Senegal	7.5	21.18	0.35
Sierra Leon	57.82	17.01	3.4
Somalia	17.36	52.6	0.33
Sri Lanka	6.8	22.67	0.3
Syria	12.79	15.99	0.8
Tanzania	28.31	56.62	0.5
Thailand	17.21	26.78	0.64
Tunisia	11.24	30.01	0.37
Uganda	29.55	29.55	1
Uruguay	27.26	14.24	1.91
Zambia	58.8	28.00	2.1

Appendix A, Table 2

Bangladesh

1983-1992

Machinery & Equipment as % of Merchandise Imports = 20.71

Value of Merchandise Imports in US dollars = 2676.8×10^6

GIP as % of GDP = 30.7

GDP in current US dollars = 18451.6×10^6

$$\text{Imported Technology as \% of GIP} = \frac{20.71\% \times 2676.8 \times 10^6}{30.7\% \times 18451.6 \times 10^6} \times 100 = 9.79$$

Trend of GIP % = 12.54

Therefore:

$$\text{Integration of Technology} = \frac{\text{Trend of GIP}}{\text{Imported Technology}} = \frac{12.54}{9.79} = 1.28$$

Appendix A, Table 3

List of Variables & Units

y	Integration of Technology Index
x1	Gross Domestic Investment (GDI) (% of GDP)
x2	Gross National Saving (GNS) (% of GDP)
x3	Gross Industrial Product (GIP) (% of GDP)
x4	Total Educational Expenditure (% of GNP)
x5	Manufacturing Production (% of GDP)
x6	Energy Consumption/Capita (KG of Oil Equivalent)
x7	School Enrolment Ratios for First & Second Level (% of Total Pupil)
x8	Adult Illiteracy Ratio (% of Total Population)
x9	Labour Force in Industry (% of Total Labour Force)
x10	Transport & Communications (% of GDP)
x11	Number of Scientists & Engineers Engaged in R & D (Per Million People)
x12	Expenditure for R & D (% of GNP)
x13	Natural Disasters (Drought/Famine/Floods/Earthquake)
x14	Kind of Religion (Christian)
x15	Kind of Religion (Muslim)
x16	Kind of Religion (Buddhism)
x17	Exports of Manufactured Goods (% of Total Exports)
x18	GNP/Capita (US dollars)
x19	Imports of Manufactured Goods (% of Total Imports)
x20	Population (Millions)
x21	Revolution/Civil War
x22	War Between Countries
x23	Revolution/Civil War/War Between Countries

Appendix A, Table 4

List of Countries

1 Bangladesh (Asia)

2 Bhutan (Asia)

3 Bolivia (South America)

4 Botswana (Africa)

5 Cameroon (Africa)

6 Chile (South America)

7 Colombia (South America)

8 Costa Rica (Central America)

9 Ecuador (South America)

10 El Salvador (Central America)

11 Gabon (Africa)

12 Honduras (Central America)

13 Indonesia (Asia)

14 Iran (Asia)

15 Jamaica (Central America)

16 Kenya (Africa)

17 Mauritania (Africa)

18 Morocco (Africa)

19 Nigeria (Africa)

20 Pakistan (Asia)

21 Paraguay (South America)

22 Philippines (Asia)

23 Rwanda (Africa)

24 Senegal (Africa)

25 Sierra Leone (Africa)

26 Somalia (Africa)

27 Sri Lanka (Asia)

28 Syria (Asia)

29 Tanzania (Africa)

30 Thailand (Asia)

31 Tunisia (Africa)

32 Uganda (Africa)

33 Uruguay (South America)

34 Zambia (Africa)

Appendix A,
Table 5

Data for 34 Countries

Countries	y	x1	x2	x3	x4	x5	x6	x7	X8	x9	x10	x11	x12	x13	x14	x15	x16	x17	x18	x19	x20	x21	x22	x23
Bangladesh	1.28	12.4	6.4	30.8	2	8	49	40	68.6	13.5	11.5	39	0.1	1	0	1	0	60.2	179	53.3	103.8	0	0	0
Bhutan	0.2	36.8	4	28	3.6	18	12	17	66.4	2.6	4	31	0.1	0	0	0	1	0.9	166	51.6	1.4	0	0	0
Bolivia	2.81	11.2	3.5	46	2.7	11	260	74	24.6	18.4	11.5	400	0.2	0	1	0	0	10	558	82.4	6.7	0	0	0
Botswana	0.64	29.8	29.7	72.1	7.9	6	411	83	28.2	15.7	2.8	320	0.8	1	0	0	0	7.6	1351	62.5	1.2	0	0	0
Cameroon	0.3	11.2	10.5	60	3.2	11	143	26	45.6	9.9	6.8	41	0.5	0	0	0	0	4	150	89	18	0	0	0
Chile	1.1	20.1	15.1	45.2	3.7	18	820	92	6.1	26.5	6.1	511	0.7	1	1	0	0	20	1694	74.9	12.6	0	0	0
Colombia	2.95	19.6	19.8	44	2.9	19	755	75	13	27	8.6	99	0.04	1	1	0	0	30	1275	89	30.9	0	0	0
Costa Rica	2	25.6	17.7	32.5	4.9	21	571	76	7.1	26.8	5.1	539	0.2	0	1	0	0	28.5	1335	75.5	2.8	0	0	0
Ecuador	2.2	20	14.4	46.1	3.4	17	641	60	14.7	19.7	8.8	169	0.2	1	1	0	0	2.1	1095	83.2	9.9	0	0	0
El Salvador	1.2	16	6	27	2.3	17	213	42	26.9	14	4.4	200	0.01	0	1	0	0	28.8	960	61.9	4.9	1	0	1
Gabon	2.5	33.8	29.4	54.3	4.7	7	1118	76	40.2	12.5	6.9	189	0.2	0	1	0	0	30	3555	79.6	1.1	0	0	0
Honduras	2	19.3	9.8	28.3	3.8	15	194	75	28.5	21.3	5.9	129	0.5	0	1	0	0	7.6	736	70.2	4.7	0	0	0
Indonesia	1.04	31.5	28.9	43	1.7	16	240	81	23.8	14.3	5.9	181	0.2	1	0	1	0	28.4	561	73.8	155.5	0	0	0
Iran	0.59	25.3	23.4	33.4	4.6	10	1021	79	39.9	27.3	7.1	523	0.5	1	0	1	0	3.6	3030	82.3	51.1	0	1	1
Jamaica	2.2	22.6	15	49.4	6.2	22	917	72	1.7	20.5	8.3	8	0.04	0	1	0	0	30	1000	58.3	2.3	0	0	0
Kenya	1	22.6	16.7	22.4	6.3	12	101	72	32.1	7.1	6.1	130	0.2	1	1	0	0	25	370	67.4	22.2	0	0	0
Mauritania	0.15	23	2.8	31.6	4.8	10	117	33	68.1	9.6	5.3	43	0.1	1	0	1	0	5.1	462	68.2	1.8	1	0	1
Morocco	0.9	23.6	20	38.6	6.6	18	250	53	57.3	24.9	6.3	55	0.1	0	0	1	0	48.5	813	55.9	23.6	1	0	1
Nigeria	3.3	27	23	39	1.3	24	142	76	50.4	9.3	11	300	0.1	0	0	1	0	20	577	60	89.8	0	0	0
Pakistan	0.99	18.9	23.7	33.9	2.7	18	214	33	65.4	23.1	8.1	142	0.9	1	0	1	0	72.6	385	57.4	104.2	0	1	1
Paraguay	2.06	23.5	19.9	39.9	1.6	20	227	70	10.4	21.2	4.1	80	0.2	0	1	0	0	9.5	1115	69.7	4.1	0	0	0
Philippines	1.5	20.9	19.6	40.5	2.2	25	240	95	11.7	17.5	5.4	139	0.2	1	1	0	0	62.8	654	67.3	58.1	1	0	1
Rwanda	0.14	15.1	4.1	28.7	3.5	16	38	46	44.2	3.1	5.8	24	0.1	1	1	0	0	5.6	339	67.8	6.4	1	1	1
Senegal	0.35	12.1	3.9	27.7	3.8	17	133	37	66.1	7.9	9.9	224	0.1	1	0	1	0	19.1	570	50.9	6.9	1	1	1
Sierra Leon	3.4	38	25	49.8	2	3	79	80	77.6	15	13	157	0.6	1	0	0	0	50	271	60	3.9	0	0	0
Somalia	0.33	25.6	1.2	12.3	0.6	5	59	13	78.3	8.3	6.4	10	0.04	1	0	1	0	4	134	67.7	7.3	0	0	0
Sri Lanka	0.3	23.6	16	35.5	3.1	15	152	85	12.1	20.6	10.3	173	0.2	1	0	0	1	51.8	428	64.5	16.4	0	0	0
Syria	0.8	18.9	7.7	31.5	5	6	880	85	35.8	32.1	9.3	144	0.1	0	0	1	0	29.4	1327	52.8	9.9	1	1	1
Tanzania	0.5	28.7	8.5	14.5	4.3	5	34	32	38.4	5.1	8	25	0.1	1	1	0	0	5	192	72.6	22.9	0	1	1
Thailand	0.64	31.2	26.4	50	3.7	28	365	80	6.9	13.1	4	173	0.2	0	0	0	1	57.7	1005	74.9	53.9	0	0	0
Tunisia	0.37	24.9	19.6	35.1	5.7	14	520	78	41	32.3	6.3	388	0.3	1	0	1	0	62.7	1235	69.5	7.7	0	0	0
Uganda	1	7	15	11	2.5	10	25	90	47.8	4.4	8	600	0.1	1	1	0	0	2	202	72.1	15.3	0	0	0
Uruguay	1.91	12.4	15	40.4	2.9	17	759	92	4.2	28.8	6.2	688	0.5	0	1	0	0	38.7	2105	66.8	3.1	0	0	0
Zambia	2.1	14	10	59.1	3.5	27	388	90	29.6	8.3	6.8	50	0.1	1	1	0	0	35	705	71.4	7.2	0	0	0

Appendix A, Table 6

Kind Of Religion (Majority)

1 Bangladesh (Muslim)

2 Bhutan (Buddhism)

3 Bolivia (Christian/Roman Catholic)

4 Botswana (Indigenous Beliefs)

5 Cameroon (Indigenous Beliefs)

6 Chile (Christian/Roman Catholic)

7 Colombia (Christian/Roman Catholic)

8 Costa Rica (Christian/Roman Catholic)

9 Ecuador (Christian/Roman Catholic)

10 El Salvador (Christian/Roman Catholic)

11 Gabon (Christian)

12 Honduras (Christian/Roman Catholic)

13 Indonesia (Muslim)

14 Iran (Muslim)

15 Jamaica (Christian/Protestant)

16 Kenya (Christian/Roman Catholic)

17 Mauritania (Muslim)

18 Morocco (Muslim)

19 Nigeria (Muslim)

20 Pakistan (Muslim)

21 Paraguay (Christian/Roman Catholic)

22 Philippines (Christian/Roman Catholic)

23 Rwanda (Christian/Roman Catholic)

24 Senegal (Muslim)

25 Sierra Leone (Indigenous Beliefs)

26 Somalia (Muslim)

27 Sri Lanka (Buddhism)

28 Syria (Muslim)

29 Tanzania (Christian)

30 Thailand (Buddhism)

31 Tunisia (Muslim)

32 Uganda (Christian)

33 Uruguay (Christian/Roman Catholic)

34 Zambia (Christian)

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<u>Appendix A, Table 7</u>

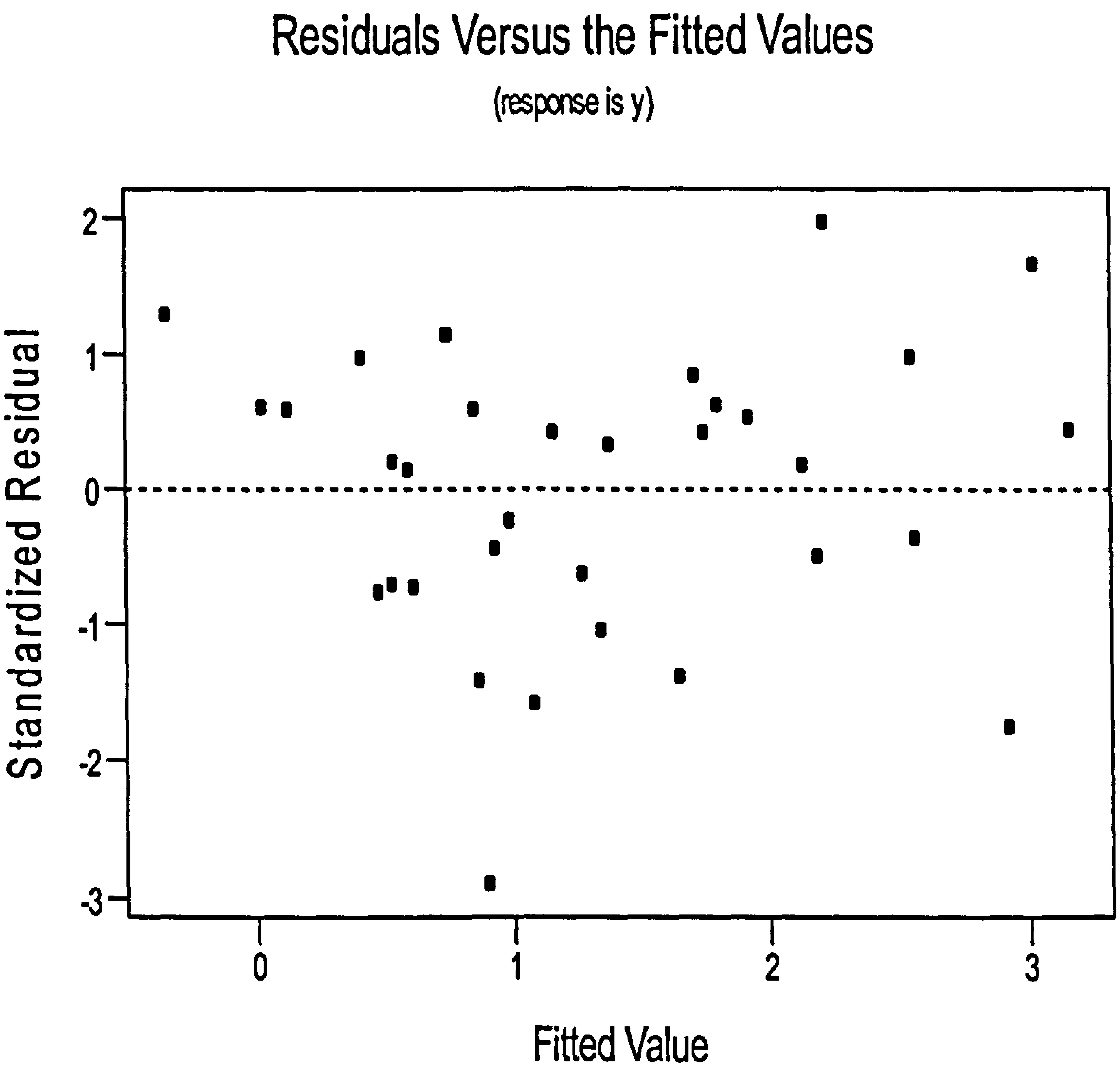
Natural Disasters (Drought/Famine/Floods/Earthquake) & Political Factors (Revolution/Civil War/War Between Countries), 1983-1992

1.	Bangladesh	(drought/famine/floods)	18.	Morocco	(civil war)
2.	Bhutan	—	19.	Nigeria	—
3.	Bolivia	—	20.	Pakistan	(drought/floods/war between countries)
4.	Botswana	(drought/floods)	21.	Paraguay	—
5.	Cameroon	—	22.	Philippines	(earthquake/revolution)
6.	Chile	(floods/earthquake)	23.	Rwanda	(drought/famine/civil war/war between countries)
7.	Colombia	(drought/floods)	24.	Senegal	(drought/civil war/war between countries)
8.	Costa Rica	—	25.	Sierra Leone	(drought)
9.	Ecuador	(earthquake)	26.	Somalia	(drought)
10.	El Salvador	(civil war)	27.	Sri Lanka	(floods)
11.	Gabon	—	28.	Syria	(civil war/war between countries)
12.	Honduras	—	29.	Tanzania	(drought/floods/famine/war between countries)
13.	Indonesia	(floods/earthquake)	30.	Thailand	—
14.	Iran	(earthquake/war between countries)	31.	Tunisia	(drought)
15.	Jamaica	—	32.	Uganda	(drought/floods/famine)
16.	Kenya	(drought/floods/earthquake)	33.	Uruguay	—
17.	Mauritania	(drought/famine/civil war)	34.	Zambia	(drought/famine)

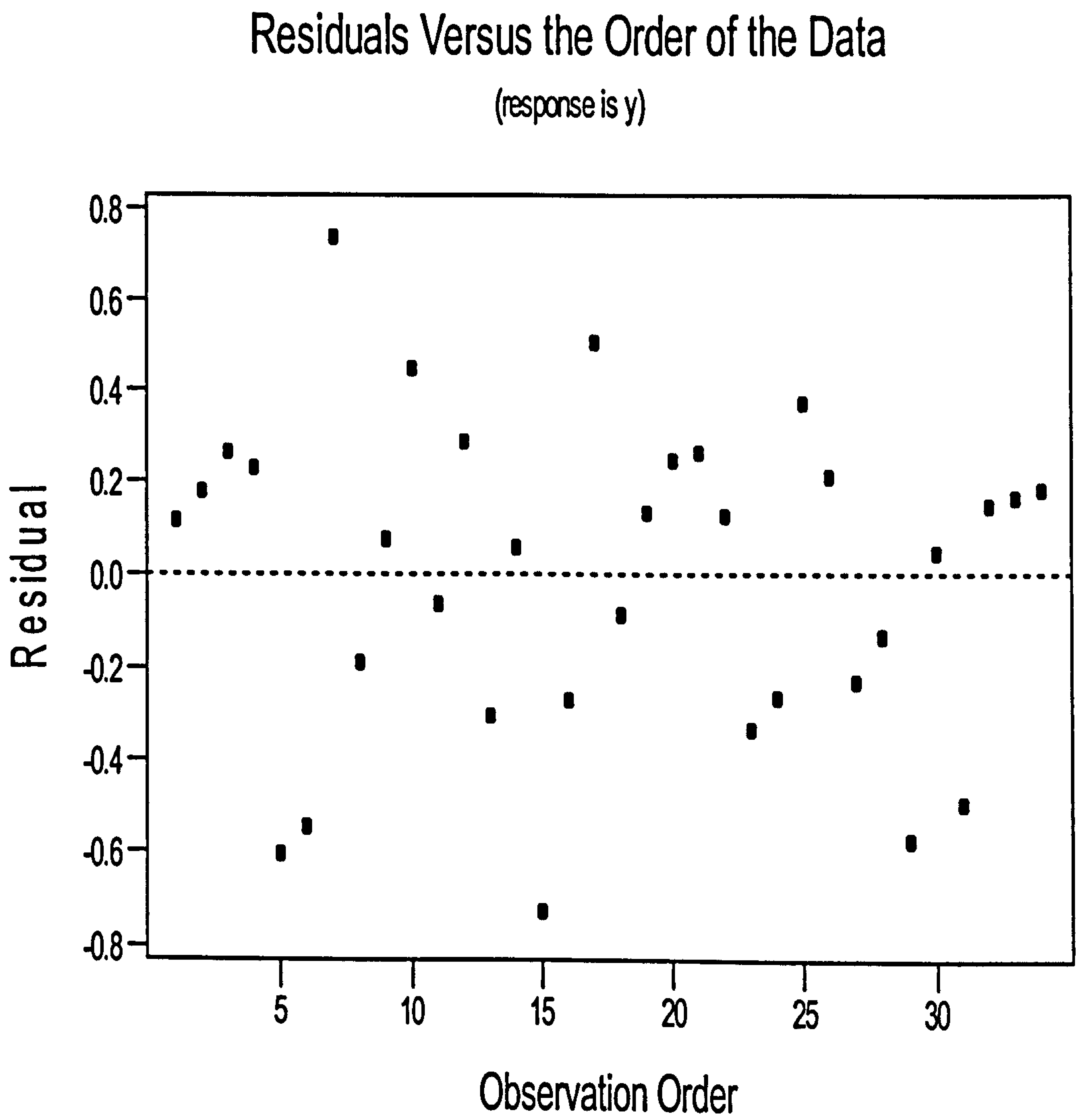
Sources:

1. 1999,The World Guide 1999/ 2000", New Internationalist Publications Ltd., Oxford.
2. Merriman, P.A., & Browitt, C.W.A., 1993, "Natural Disasters", Thomas Telford Services Ltd., London.
3. Lemma, Aklilu & Malaska, Pentti, 1991, "Africa Beyond Famine", Tycooly Publishing, London.
4. 1999, "The Europa World Year Book 1999", Europa Publications Ltd., Vol. 1 & 2, London.
5. Tobin, G.A. & Montz, B.E., 1997, "Natural Hazards", the Guilford Publications, N.Y.

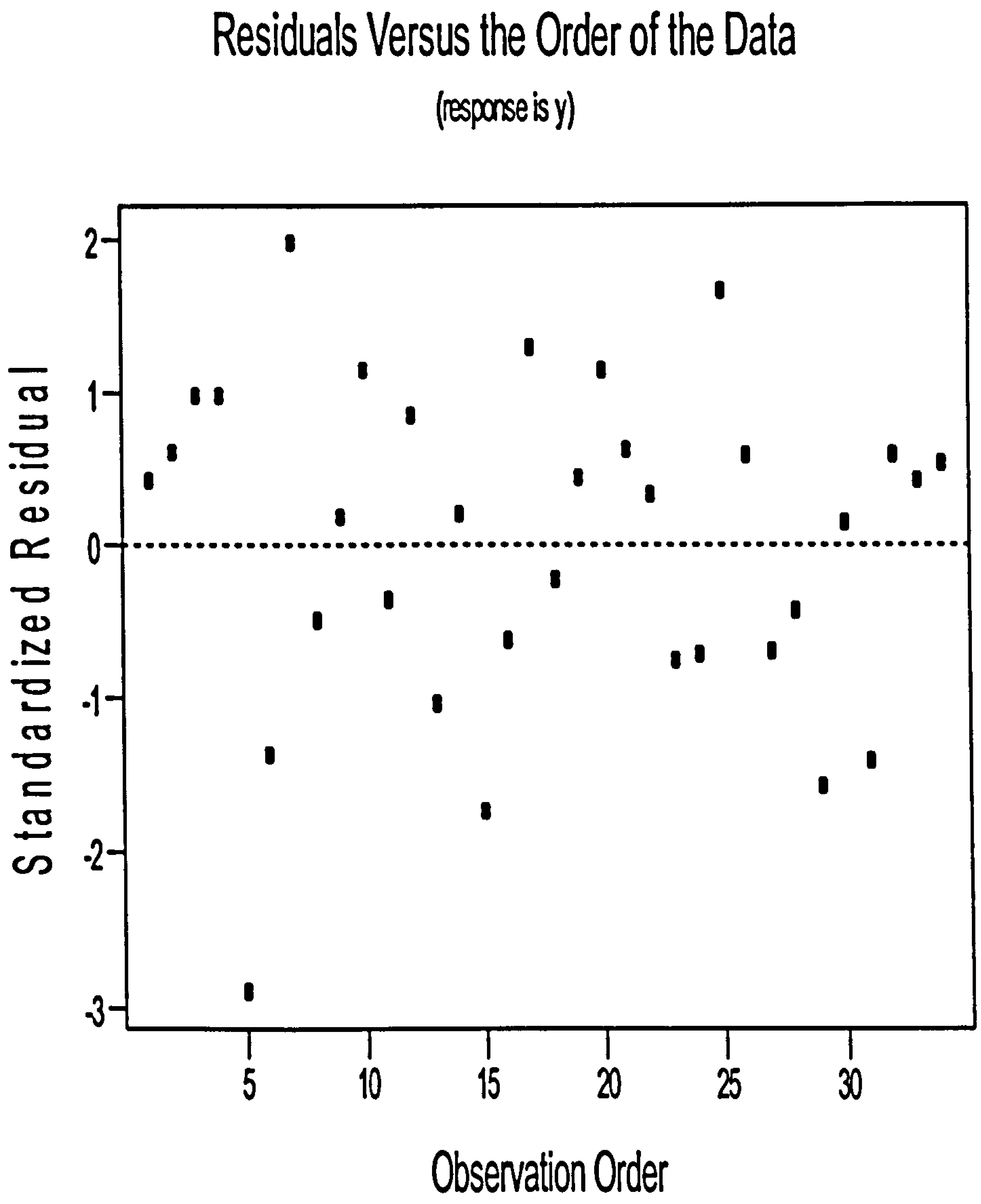
Appendix B, Fig. 1



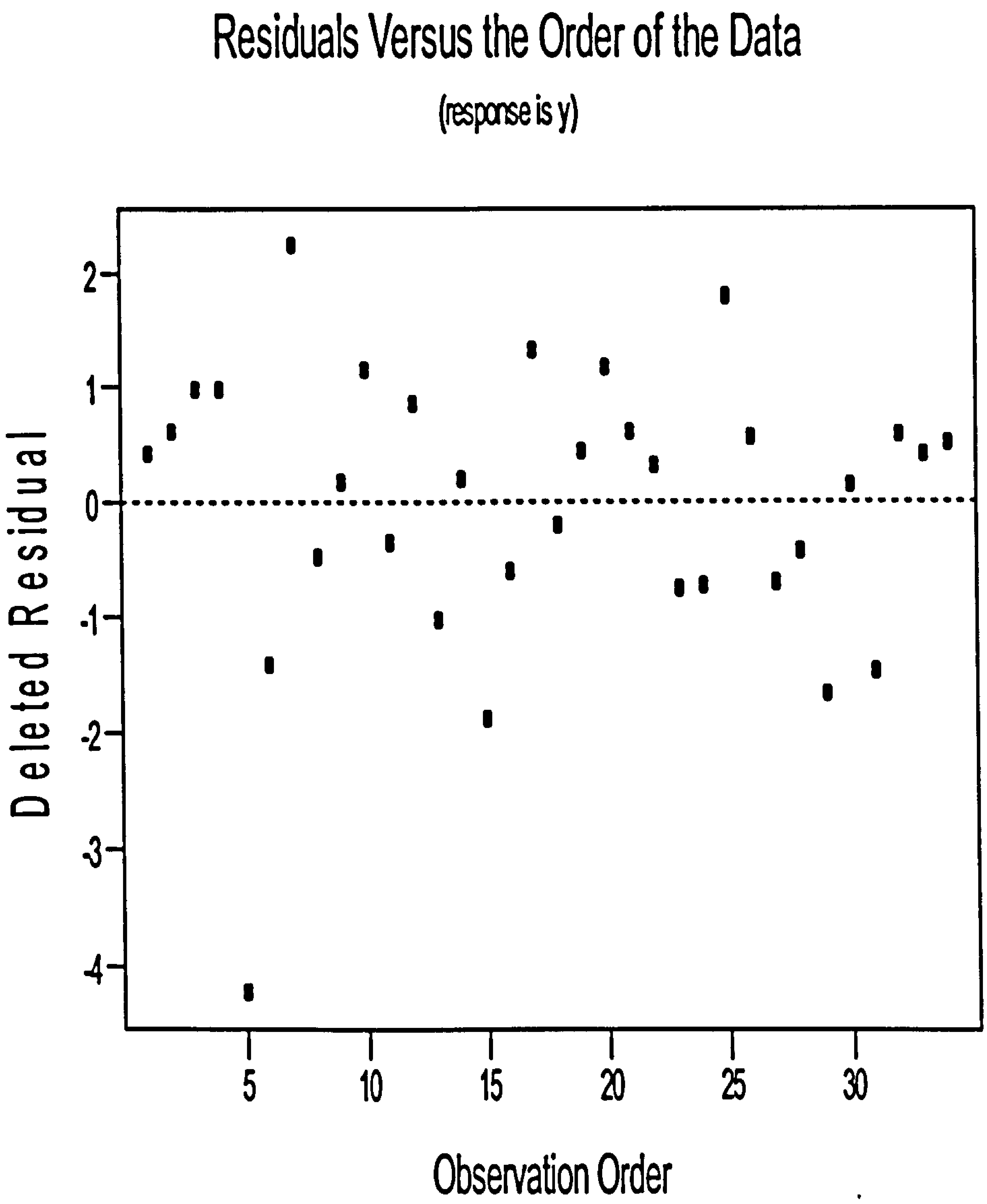
Appendix B, Fig.2



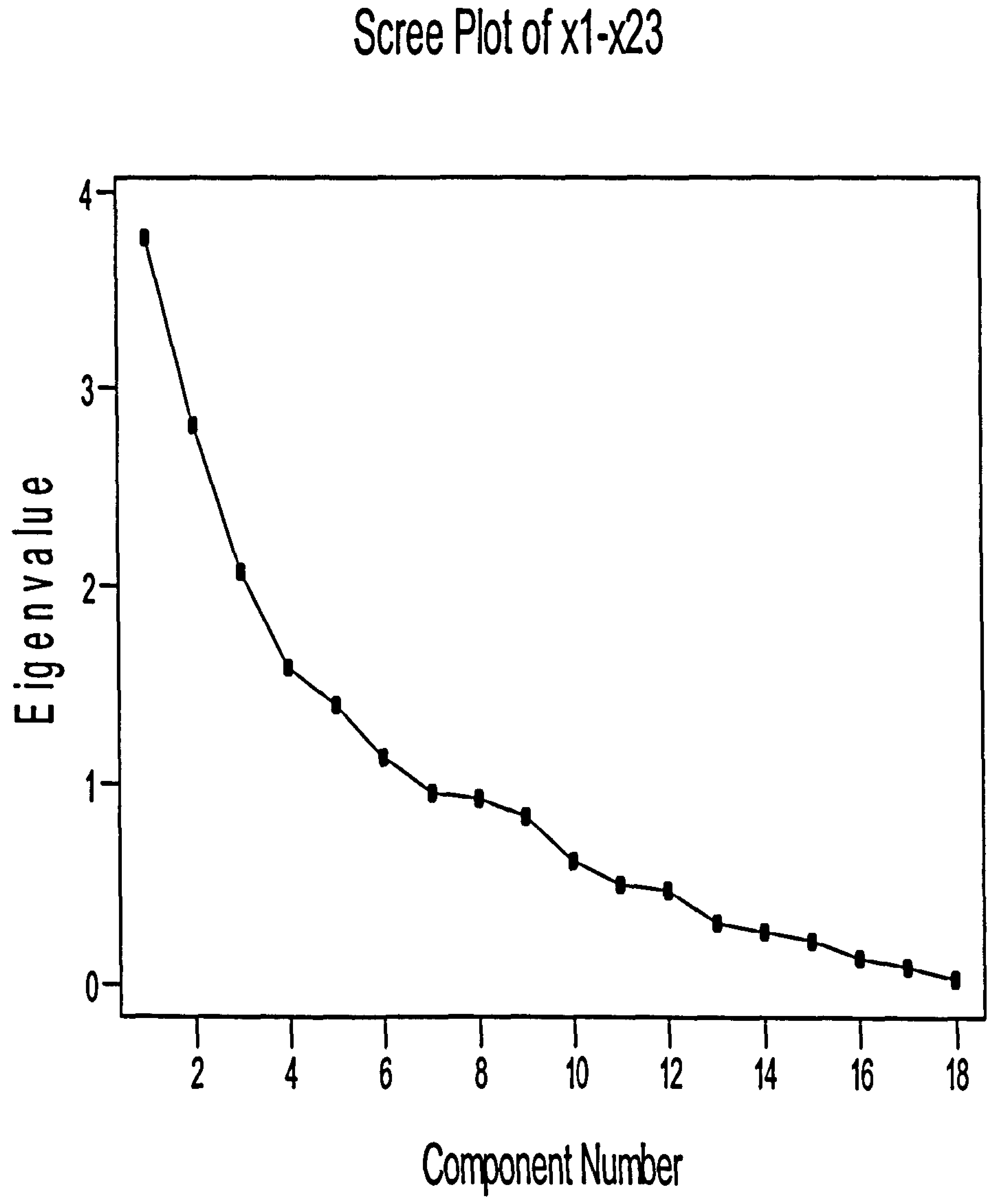
Appendix B, Fig. 3



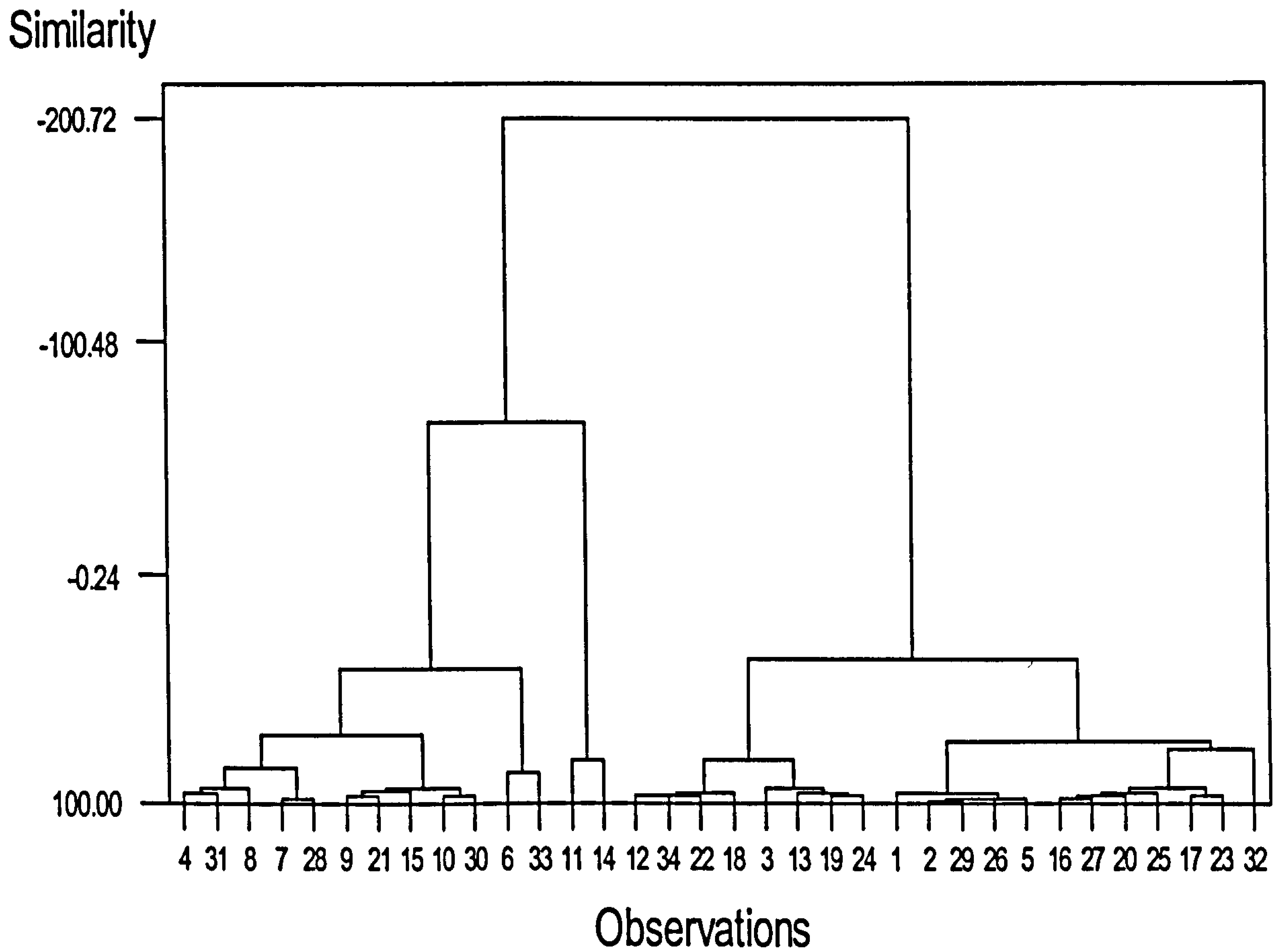
Appendix B, Fig. 4



Appendix B, Fig. 5



Appendix B, Fig. 6



Appendix B, Table 1

Residuals & Standardized Residuals

Countries	Res.	Stan. Res.
Bangladesh	0.116065	0.42003
Bhutan	0.181021	0.61625
Bolivia	0.262102	0.99201
Botswana	0.227582	0.98282
Cameroon	-0.603763	-2.90167
Chile	-0.54655	-1.37278
Colombia	0.736933	1.99317
Costa Rica	-0.189463	-0.49265
Ecuador	0.073195	0.18076
El Salvador	0.450669	1.1425
Gabon	-0.064025	-0.35683
Honduras	0.287941	0.86029
Indonesia	-0.30375	-1.02579
Iran	0.05703	0.20356
Jamaica	-0.723358	-1.73668
Kenya	-0.27045	-0.62317
Mauritania	0.509312	1.29655
Morocco	-0.084361	-0.22167
Nigeria	0.135193	0.44816
Pakistan	0.248614	1.1601
Paraguay	0.266141	0.63131
Philippines	0.123995	0.3349
Rwanda	-0.331357	-0.75162
Senegal	-0.265112	-0.72467
Sierra Leon	0.376182	1.67737
Somalia	0.212651	0.58597
Sri Lanka	-0.22781	-0.70493
Syria	-0.13117	-0.43274
Tanzania	-0.577622	-1.56588
Thailand	0.046789	0.13987
Tunisia	-0.494474	-1.40975
Uganda	0.152314	0.59162
Uruguay	0.166284	0.42317
Zambia	0.183252	0.53691

Appendix B, Table 2

Correlations (Pearson)

	y	x1	x2	x3	x5	x7	x9	x10
x1	0.060							
x2	0.311	0.498						
x3	0.352	0.167	0.499					
x5	0.191	-0.102	0.149	0.214				
x7	0.448	0.007	0.561	0.381	0.250			
x9	0.216	-0.034	0.323	0.222	0.103	0.467		
x10	0.424	-0.193	-0.112	-0.065	-0.271	0.050	0.039	
x11	0.141	-0.197	0.265	-0.001	0.006	0.546	0.400	-0.008
x12	0.001	0.097	0.437	0.394	-0.171	0.190	0.337	-0.083
x13	-0.277	-0.047	0.020	-0.168	-0.247	-0.012	-0.171	0.167
x14	0.422	-0.320	-0.116	-0.051	0.238	0.313	0.009	-0.148
x15	-0.291	0.015	-0.038	-0.275	-0.173	-0.285	0.155	0.215
x16	-0.308	0.357	0.016	0.003	0.263	-0.057	-0.163	-0.140
x17	0.114	0.075	0.386	0.170	0.291	0.266	0.388	0.192
x18	0.217	0.179	0.455	0.336	-0.011	0.449	0.513	-0.197
x19	0.202	-0.096	0.188	0.258	0.013	0.222	0.113	-0.116
x20	0.012	0.084	0.377	-0.015	0.176	0.017	-0.014	0.172
x23	-0.412	-0.146	-0.240	-0.340	-0.068	-0.315	-0.005	-0.058

	x11	x12	x13	x14	x15	x16	x17	x18
x12	0.352							
x13	-0.041	0.148						
x14	0.166	-0.174	-0.120					
x15	-0.065	-0.061	0.195	-0.692				
x16	-0.132	-0.115	-0.161	-0.311	-0.215			
x17	-0.027	0.144	0.072	-0.217	0.191	0.155		
x18	0.466	0.217	-0.220	0.201	-0.050	-0.148	0.009	
x19	0.228	0.083	0.050	0.395	-0.375	-0.145	-0.310	0.325
x20	-0.065	0.088	0.219	-0.359	0.486	-0.015	0.386	-0.159
x23	-0.182	-0.085	0.147	-0.129	0.381	-0.201	0.052	-0.021

	x19	x20
x20	-0.067	
x23	-0.297	0.060

Appendix B, Table 3

Principal Component Analysis

Eigenanalysis of the Correlation Matrix

Eigenvalue	3.7606	2.8127	2.0725	1.5857	1.3991	1.1265
Proportion	0.209	0.156	0.115	0.088	0.078	0.063
Cumulative	0.209	0.365	0.480	0.568	0.646	0.709
Eigenvalue	0.9442	0.9140	0.8267	0.6097	0.4937	0.4593
Proportion	0.052	0.051	0.046	0.034	0.027	0.026
Cumulative	0.761	0.812	0.858	0.892	0.919	0.945
Eigenvalue	0.3023	0.2611	0.2066	0.1208	0.0877	0.0168
Proportion	0.017	0.015	0.011	0.007	0.005	0.001
Cumulative	0.962	0.976	0.987	0.994	0.999	1.000

Variable	PC1	PC2	PC3	PC4	PC5	PC6
x1	0.080	0.211	0.386	0.382	0.147	-0.029
x2	0.370	0.287	0.119	0.123	-0.084	-0.202
x3	0.322	0.067	0.189	0.113	-0.121	0.003
x5	0.133	-0.023	0.290	-0.565	0.009	-0.290
x7	0.409	0.019	-0.076	-0.197	-0.150	0.096
x9	0.303	0.165	-0.236	-0.182	0.284	0.188
x10	-0.091	0.143	-0.244	-0.098	-0.406	0.523
x11	0.297	-0.031	-0.307	-0.027	0.074	0.178
x12	0.242	0.188	-0.127	0.315	-0.032	-0.004
x13	-0.102	0.144	-0.230	0.183	-0.432	-0.305
x14	0.158	-0.455	-0.105	-0.227	-0.103	-0.189
x15	-0.199	0.415	-0.243	-0.015	0.201	-0.049
x16	-0.026	0.058	0.525	-0.041	0.035	0.249
x17	0.110	0.381	0.072	-0.395	-0.080	0.076
x18	0.359	-0.007	-0.142	0.114	0.383	-0.048
x19	0.237	-0.248	-0.089	0.188	-0.233	-0.278
x20	-0.023	0.402	-0.002	-0.147	-0.283	-0.350
x23	-0.217	0.109	-0.232	-0.116	0.396	-0.352

Variable	PC7	PC8	PC9	PC10	PC11	PC12
x1	0.198	0.157	-0.386	-0.107	-0.154	-0.052
x2	0.082	0.093	-0.149	-0.218	-0.031	0.120
x3	-0.593	0.108	0.116	0.078	0.454	-0.004
x5	-0.009	-0.039	0.216	0.033	0.187	-0.068
x7	0.202	-0.034	-0.235	-0.122	0.333	-0.090
x9	-0.102	0.013	-0.008	0.348	-0.365	-0.314
x10	-0.081	0.288	-0.177	0.081	0.057	0.403
x11	0.480	-0.231	0.293	-0.165	0.152	0.138
x12	-0.281	-0.540	0.260	-0.119	-0.240	0.193
x13	0.177	-0.351	-0.292	0.336	0.251	-0.306
x14	-0.004	-0.006	-0.314	-0.181	-0.267	0.068
x15	0.101	0.274	0.213	0.030	0.161	-0.284
x16	0.336	-0.243	0.098	0.446	0.056	0.268
x17	-0.145	-0.176	-0.278	0.138	-0.282	-0.026
x18	0.094	0.249	-0.153	0.156	0.185	0.155
x19	0.074	0.304	0.220	0.550	-0.228	0.130
x20	0.165	0.234	0.266	-0.176	-0.210	0.251
x23	-0.131	-0.164	-0.262	0.166	0.184	0.545

Variable	PC13	PC14	PC15	PC16	PC17	PC18
x1	0.342	0.225	-0.154	0.415	-0.128	-0.013
x2	-0.005	-0.118	-0.266	-0.612	0.343	0.161
x3	-0.062	-0.029	0.009	0.351	0.225	0.245
x5	0.334	0.464	-0.152	-0.120	-0.107	-0.174
x7	0.219	-0.484	0.202	0.019	-0.445	-0.059
x9	0.367	-0.085	0.185	0.030	0.366	-0.032
x10	0.251	0.309	-0.050	-0.097	-0.008	-0.010
x11	-0.072	0.115	-0.361	0.358	0.242	0.073
x12	0.158	0.202	0.150	-0.113	-0.372	0.048
x13	-0.001	0.224	0.100	0.011	0.177	-0.034
x14	-0.007	0.210	0.205	0.100	0.024	0.597
x15	0.009	0.097	-0.044	-0.083	-0.314	0.575
x16	-0.035	-0.059	0.265	-0.092	0.051	0.338
x17	-0.519	-0.012	-0.315	0.174	-0.202	-0.011
x18	-0.409	0.385	0.345	-0.114	-0.104	-0.232
x19	0.036	-0.146	-0.313	0.034	-0.261	0.010
x20	-0.042	-0.090	0.443	0.290	0.144	-0.112
x23	0.225	-0.208	-0.125	0.099	0.039	0.042

Appendix B, Table 4

Factor Analysis

Principal Component Factor Analysis of the Correlation Matrix

Unrotated Factor Loadings and Communalities

Variable	Factor1	Factor2	Factor3	Factor4	Factor5	Factor6
x1	0.156	0.354	0.556	0.481	0.174	-0.030
x2	0.718	0.481	0.171	0.155	-0.099	-0.214
x3	0.625	0.113	0.273	0.143	-0.144	0.003
x5	0.258	-0.039	0.417	-0.711	0.010	-0.308
x7	0.793	0.033	-0.110	-0.248	-0.178	0.102
x9	0.588	0.277	-0.340	-0.229	0.336	0.200
x10	-0.177	0.240	-0.352	-0.123	-0.480	0.555
x11	0.576	-0.052	-0.441	-0.034	0.088	0.188
x12	0.469	0.315	-0.183	0.397	-0.038	-0.005
x13	-0.198	0.242	-0.331	0.230	-0.511	-0.324
x14	0.305	-0.762	-0.152	-0.285	-0.122	-0.201
x15	-0.387	0.696	-0.350	-0.019	0.237	-0.052
x16	-0.051	0.097	0.755	-0.051	0.041	0.264
x17	0.213	0.639	0.103	-0.497	-0.095	0.081
x18	0.697	-0.012	-0.205	0.144	0.453	-0.051
x19	0.460	-0.417	-0.128	0.237	-0.276	-0.295
x20	-0.046	0.674	-0.003	-0.186	-0.335	-0.371
x23	-0.420	0.183	-0.334	-0.146	0.468	-0.374
Variance	3.7606	2.8127	2.0725	1.5857	1.3991	1.1265
% Var	0.209	0.156	0.115	0.088	0.078	0.063

Variable	Factor7	Communality
x1	0.193	0.758
x2	0.080	0.863
x3	-0.577	0.851
x5	-0.009	0.842
x7	0.196	0.784
x9	-0.099	0.753
x10	-0.079	0.772
x11	0.466	0.791
x12	-0.273	0.587
x13	0.172	0.656
x14	-0.004	0.834
x15	0.098	0.826
x16	0.327	0.763
x17	-0.141	0.747
x18	0.092	0.764
x19	0.072	0.626
x20	0.160	0.767
x23	-0.128	0.718
Variance	0.9442	13.7013
% Var	0.052	0.761

Appendix B, Table 5

Factor Analysis

Principal Component Factor Analysis of the Correlation Matrix

Rotated Factor Loadings and Communalities
Varimax Rotation

Variable	Factor1	Factor2	Factor3	Factor4	Factor5	Factor6
x1	0.163	-0.011	-0.300	0.127	0.727	-0.069
x2	-0.027	0.434	-0.602	-0.244	0.334	-0.336
x3	-0.246	0.009	-0.847	-0.208	0.068	0.156
x5	-0.192	0.007	0.080	-0.862	0.043	0.087
x7	-0.342	0.690	-0.227	-0.329	0.053	-0.066
x9	0.236	0.680	-0.320	-0.200	-0.198	0.226
x10	0.145	0.010	0.017	0.075	-0.128	-0.126
x11	-0.154	0.860	0.079	0.105	-0.037	-0.049
x12	0.062	0.260	-0.678	0.194	-0.036	-0.130
x13	0.011	-0.099	0.012	0.197	-0.143	-0.756
x14	-0.737	0.153	0.197	-0.143	-0.402	0.166
x15	0.838	0.055	0.093	0.058	-0.114	-0.307
x16	0.003	-0.132	0.169	-0.223	0.796	0.182
x17	0.377	0.146	-0.261	-0.649	0.073	-0.105
x18	-0.046	0.703	-0.305	0.082	-0.037	0.187
x19	-0.654	0.216	-0.176	0.150	-0.129	-0.212
x20	0.325	-0.017	-0.090	-0.394	0.083	-0.699
x23	0.557	-0.125	0.199	-0.004	-0.461	-0.031
Variance	2.5784	2.5655	2.1129	1.7825	1.7790	1.5463
% Var	0.143	0.143	0.117	0.099	0.099	0.086

Variable	Factor7	Communality
x1	-0.304	0.758
x2	-0.166	0.863
x3	0.016	0.851
x5	-0.215	0.842
x7	0.157	0.784
x9	0.059	0.753
x10	0.844	0.772
x11	0.077	0.791
x12	0.012	0.587
x13	0.122	0.656
x14	-0.141	0.834
x15	0.035	0.826
x16	0.017	0.763
x17	0.279	0.747
x18	-0.363	0.764
x19	-0.192	0.626
x20	0.050	0.767
x23	-0.372	0.718
Variance	1.3368	13.7013
% Var	0.074	0.761

Appendix B, Table 6

Factor Analysis (Split Sample 1)

Principal Component Factor Analysis of the Correlation Matrix

Rotated Factor Loadings and Communalities
Varimax Rotation

Variable	Factor1	Factor2	Factor3	Factor4	Factor5	Factor6
x1	0.065	-0.511	-0.115	-0.632	-0.205	-0.074
x2	0.467	-0.737	-0.216	-0.243	-0.094	0.050
x3	-0.074	-0.813	0.112	-0.021	-0.118	-0.240
x5	-0.088	0.027	0.053	-0.302	0.869	0.027
x7	0.674	-0.473	0.096	0.251	0.320	0.098
x9	0.815	-0.097	-0.121	0.093	-0.029	-0.189
x10	-0.096	0.221	-0.171	0.702	-0.246	-0.164
x11	0.777	0.239	0.019	0.135	-0.218	0.080
x12	0.335	-0.431	0.131	-0.032	-0.664	-0.003
x13	-0.047	-0.123	-0.388	0.322	-0.122	0.727
x14	0.169	0.068	0.641	0.353	0.540	-0.004
x15	0.179	0.275	-0.812	0.070	-0.181	0.258
x16	-0.227	0.125	-0.050	-0.803	0.160	-0.287
x17	0.205	-0.321	-0.396	0.151	0.377	-0.151
x18	0.720	-0.185	0.077	-0.221	-0.101	0.076
x19	0.263	-0.218	-0.058	0.117	0.032	-0.164
x20	-0.067	-0.126	-0.879	0.032	0.201	0.067
x23	0.003	0.240	-0.054	-0.025	0.087	0.835
Variance	2.8282	2.3596	2.3100	2.0987	2.0367	1.5787
% Var	0.157	0.131	0.128	0.117	0.113	0.088

Variable	Factor7	Communality
x1	-0.294	0.811
x2	0.032	0.878
x3	0.132	0.767
x5	-0.025	0.858
x7	-0.012	0.863
x9	-0.087	0.741
x10	-0.312	0.764
x11	0.132	0.751
x12	0.095	0.766
x13	-0.262	0.884
x14	0.202	0.901
x15	-0.138	0.890
x16	-0.150	0.845
x17	-0.596	0.845
x18	0.208	0.667
x19	0.834	0.857
x20	0.102	0.850
x23	0.039	0.767
Variance	1.4947	14.7066
% Var	0.083	0.817

Appendix B, Table 7

Factor Analysis (Split Sample 2)

Principal Component Factor Analysis of the Correlation Matrix

Rotated Factor Loadings and Communalities
Varimax Rotation

Variable	Factor1	Factor2	Factor3	Factor4	Factor5	Factor6
x1	0.082	0.362	0.074	0.578	-0.184	0.033
x2	0.617	0.639	0.095	0.097	0.214	0.077
x3	0.123	0.759	-0.157	0.246	0.168	0.154
x5	-0.019	-0.067	-0.054	0.192	0.904	0.077
x7	0.807	0.187	-0.294	-0.030	0.287	-0.151
x9	0.461	0.362	0.336	0.130	0.020	-0.364
x10	0.122	-0.145	0.146	-0.261	-0.157	-0.707
x11	0.829	-0.037	0.145	-0.165	-0.117	0.060
x12	0.065	0.861	0.144	-0.190	-0.168	0.004
x13	-0.016	0.049	-0.061	-0.765	-0.101	-0.132
x14	0.131	-0.244	-0.741	-0.369	0.148	0.269
x15	0.054	-0.175	0.853	-0.089	-0.020	-0.177
x16	-0.129	-0.063	-0.132	0.685	0.236	-0.135
x17	0.131	0.394	0.046	0.005	0.545	-0.604
x18	0.682	0.217	-0.008	0.283	-0.184	0.275
x19	0.299	0.147	-0.165	-0.131	-0.023	0.712
x20	0.084	0.133	0.633	-0.254	0.554	0.004
x23	-0.142	-0.126	0.083	-0.200	0.018	-0.004
Variance	2.6101	2.4046	2.0403	1.9900	1.8014	1.7821
% Var	0.145	0.134	0.113	0.111	0.100	0.099

Variable	Factor7	Communality
x1	0.239	0.569
x2	0.179	0.891
x3	0.025	0.730
x5	-0.024	0.868
x7	0.078	0.885
x9	-0.493	0.850
x10	0.141	0.670
x11	0.135	0.772
x12	0.010	0.831
x13	0.092	0.628
x14	-0.041	0.858
x15	-0.363	0.933
x16	0.354	0.707
x17	-0.111	0.849
x18	-0.355	0.829
x19	0.138	0.682
x20	0.210	0.841
x23	-0.830	0.773
Variance	1.5350	14.1637
% Var	0.085	0.787

Appendix B, Table 8

Regression Analysis (Full Model)

The regression equation is

```
y = - 2.12 + 0.0490 x1 + 0.0028 x2 + 0.0046 x3 + 0.0480 x5 + 0.00197 x7
         + 0.0005 x9 + 0.247 x10 +0.000042 x11 + 0.020 x12 - 0.492 x13
         + 0.443 x14 - 0.352 x15 - 1.63 x16 + 0.00021 x17 +0.000044 x18
         - 0.0014 x19 + 0.00103 x20 - 0.461 x23
```

Predictor	Coef	StDev	T	P
Constant	-2.120	1.457	-1.46	0.166
x1	0.04904	0.01977	2.48	0.025
x2	0.00277	0.02731	0.10	0.921
x3	0.00458	0.01639	0.28	0.784
x5	0.04798	0.02667	1.80	0.092
x7	0.001974	0.007671	0.26	0.800
x9	0.00048	0.01830	0.03	0.979
x10	0.24681	0.04621	5.34	0.000
x11	0.0000423	0.0008795	0.05	0.962
x12	0.0198	0.6647	0.03	0.977
x13	-0.4920	0.2347	-2.10	0.053
x14	0.4426	0.8260	0.54	0.600
x15	-0.3521	0.8687	-0.41	0.691
x16	-1.6279	0.8819	-1.85	0.085
x17	0.000206	0.006756	0.03	0.976
x18	0.0000437	0.0002693	0.16	0.873
x19	-0.00144	0.01325	-0.11	0.915
x20	0.001033	0.004438	0.23	0.819
x23	-0.4612	0.2568	-1.80	0.093

S = 0.5118   R-Sq = 87.1%   R-Sq(adj) = 71.6%

Analysis of Variance

Source	DF	SS	MS	F	P
Regression	18	26.5494	1.4750	5.63	0.001
Error	15	3.9298	0.2620		
Total	33	30.4792			

Source	DF	Seq SS
x1	1	0.1107
x2	1	3.1931
x3	1	1.4401
x5	1	0.2803
x7	1	2.4032
x9	1	0.0002
x10	1	6.9048
x11	1	0.0167
x12	1	0.2908
x13	1	2.1993
x14	1	6.7188
x15	1	0.8440
x16	1	1.1686
x17	1	0.0036
x18	1	0.1094
x19	1	0.0162
x20	1	0.0050
x23	1	0.8447

Unusual Observations

Obs	x1	y	Fit	StDev Fit	Residual	St Resid
5	11.2	0.3000	0.9038	0.4676	-0.6038	-2.90R

R denotes an observation with a large standardized residual

Appendix B, Table 9

Regression Analysis

The regression equation is

y = - 1.47 + 0.0449 x1 + 0.0642 x5 + 0.219 x10 - 0.550 x13 - 1.98 x16 - 0.779 x23

Predictor	Coef	StDev	T	P
Constant	-1.4730	0.6084	-2.42	0.022
x1	0.04494	0.01362	3.30	0.003
x5	0.06421	0.01580	4.06	0.000
x10	0.21941	0.04078	5.38	0.000
x13	-0.5497	0.1924	-2.86	0.008
x16	-1.9797	0.3635	-5.45	0.000
x23	-0.7790	0.2057	-3.79	0.001

S = 0.5252   R-Sq = 75.6%   R-Sq(adj) = 70.1%

Analysis of Variance

Source	DF	SS	MS	F	P
Regression	6	23.0324	3.8387	13.92	0.000
Error	27	7.4468	0.2758		
Total	33	30.4792			

Source	DF	Seq SS
x1	1	0.1107
x5	1	1.1929
x10	1	8.4657
x13	1	2.4279
x16	1	6.8800
x23	1	3.9552

Unusual Observations

Obs	x1	y	Fit	StDev Fit	Residual	St Resid
31	24.9	0.3700	1.3774	0.1546	-1.0074	-2.01R

R denotes an observation with a large standardized residual

Appendix B, Table 10

Stepwise Regression (Full Model)

F-to-Enter: 4.00 F-to-Remove: 4.00

Response is y on 18 predictors, with N = 34

Step	1	2	3	4	5	6
Constant	0.1418	-0.9502	-1.1763	-1.5398	-1.5387	-1.3016
x7	0.0181	0.0173	0.0121	0.0001		
T-Value	2.83	2.98	2.20	0.01		
x10		0.160	0.185	0.220	0.220	0.240
T-Value		2.80	3.57	4.53	4.75	5.84
x14			0.75	1.05	1.05	0.99
T-Value			2.88	4.05	4.74	5.09
x2				0.050	0.050	0.051
T-Value				2.78	3.75	4.37
x13						-0.62
T-Value						-3.17
S	0.873	0.792	0.712	0.644	0.633	0.555
R-Sq	20.07	36.25	50.05	60.56	60.56	70.71

Appendix B, Table 11

Stepwise Regression (with No School Enrolment Ratios)

F-to-Enter: 4.00 F-to-Remove: 4.00

Response is y on 17 predictors, with N = 34

Step	1	2	3	4
Constant	0.1099	-0.5675	-1.5387	-1.3016
x10	0.168	0.197	0.220	0.240
T-Value	2.65	3.60	4.75	5.84
x14		0.94	1.05	0.99
T-Value		3.58	4.74	5.09
x2			0.050	0.051
T-Value			3.75	4.37
x13				-0.62
T-Value				-3.17
S	0.884	0.755	0.633	0.555
R-Sq	18.00	42.03	60.56	70.71

Appendix B, Table 12

Regression Analysis (on the Four Variables Identified by the Stepwise Regression)

The regression equation is
y = - 1.30 + 0.0509 x2 + 0.240 x10 - 0.625 x13 + 0.993 x14

Predictor	Coef	StDev	T	P
Constant	-1.3016	0.4087	-3.18	0.003
x2	0.05089	0.01165	4.37	0.000
x10	0.24004	0.04111	5.84	0.000
x13	-0.6246	0.1971	-3.17	0.004
x14	0.9933	0.1950	5.09	0.000

S = 0.5549 R-Sq = 70.7% R-Sq(adj) = 66.7%

Analysis of Variance

Source	DF	SS	MS	F	P
Regression	4	21.5508	5.3877	17.50	0.000
Error	29	8.9284	0.3079		
Total	33	30.4792			

Source	DF	Seq SS
x2	1	2.9425
x10	1	6.5047
x13	1	4.1191
x14	1	7.9844

Unusual Observations

Obs	x2	y	Fit	StDev Fit	Residual	St Resid
27	16.0	0.3000	1.3605	0.1830	-1.0605	-2.02R

R denotes an observation with a large standardized residual

Appendix B, Table 13

Best Subsets Regression

Response is y

Vars	R-Sq	R-Sq (adj)	C-p	S	x1	x2	x3	x5	x7	x9	x10	x11	x12	x13	x14	x15	x16	x17	x18	x19	x20	x23
1	20.1	17.6	63.0	0.87255					X													
1	18.0	15.4	65.4	0.88376							X											
2	42.0	38.3	39.4	0.75497							X				X							
2	36.2	32.1	46.2	0.79173					X		X											
3	60.6	56.6	19.9	0.63299		X					X				X							
3	59.0	54.9	21.7	0.64563			X				X				X							
4	70.7	66.7	10.1	0.55487		X					X			X	X							
4	67.2	62.7	14.1	0.58704	X		X				X				X							
5	73.8	69.1	8.5	0.53453	X			X			X					X	X					
5	73.5	68.8	8.8	0.53720		X	X				X			X	X							
6	80.6	76.2	2.6	0.46843	X			X			X			X		X	X					
6	79.2	74.6	4.2	0.48421	X			X			X					X	X					X
7	85.1	81.1	-0.7	0.41773	X			X			X			X		X	X					X
7	84.4	80.2	0.2	0.42787	X			X			X			X	X		X					X
8	86.3	81.9	-0.0	0.40906	X			X			X			X		X	X		X			X
8	86.3	81.9	-0.0	0.40927	X		X	X			X			X	X		X					X
9	86.8	81.8	1.4	0.40983	X	X	X	X			X			X	X		X					X
9	86.7	81.7	1.5	0.41151	X		X	X	X		X			X	X		X					X
10	86.9	81.2	3.2	0.41656	X	X	X	X			X			X	X	X	X					X
10	86.9	81.2	3.3	0.41695	X		X	X	X		X			X	X	X	X					X
11	87.0	80.5	5.1	0.42398	X	X	X	X	X		X			X	X	X	X					X
11	87.0	80.5	5.1	0.42442	X			X	X		X			X	X	X	X		X		X	X
12	87.1	79.7	7.0	0.43325	X		X	X	X		X			X	X	X	X		X		X	X
12	87.0	79.6	7.1	0.43360	X	X	X	X	X		X			X	X	X	X				X	X
13	87.1	78.7	9.0	0.44366	X		X	X	X		X			X	X	X	X		X	X	X	X
13	87.1	78.7	9.0	0.44370	X		X	X	X		X			X	X	X	X	X	X		X	X
14	87.1	77.6	11.0	0.45494	X	X	X	X	X		X			X	X	X	X		X	X	X	X
14	87.1	77.6	11.0	0.45506	X		X	X	X		X		X	X	X	X	X		X	X	X	X
15	87.1	76.4	13.0	0.46732	X	X	X	X	X		X		X	X	X	X	X		X	X	X	X
15	87.1	76.4	13.0	0.46733	X	X	X	X	X	X	X			X	X	X	X		X	X	X	X
16	87.1	75.0	15.0	0.48082	X	X	X	X	X	X	X	X		X	X	X	X		X	X	X	X
16	87.1	75.0	15.0	0.48084	X	X	X	X	X		X		X	X	X	X	X	X	X	X	X	X
17	87.1	73.4	17.0	0.49561	X	X	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X
17	87.1	73.4	17.0	0.49561	X	X	X	X	X	X	X	X		X	X	X	X	X	X	X	X	X
18	87.1	71.6	19.0	0.51185	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X

Appendix B, Table 14

Regression Analysis (on the 5 Variables Extracted from the Best Subsets Regression, $C_p = 8.5$)

The regression equation is
y = - 2.47 + 0.0591 x1 + 0.0731 x5 + 0.264 x10 - 0.987 x15 - 2.06 x16

Predictor	Coef	StDev	T	P
Constant	-2.4655	0.5886	-4.19	0.000
x1	0.05911	0.01387	4.26	0.000
x5	0.07308	0.01581	4.62	0.000
x10	0.26442	0.04171	6.34	0.000
x15	-0.9870	0.2065	-4.78	0.000
x16	-2.0584	0.3732	-5.52	0.000

S = 0.5345   R-Sq = 73.8%   R-Sq(adj) = 69.1%

Analysis of Variance

Source	DF	SS	MS	F	P
Regression	5	22.4789	4.4958	15.73	0.000
Error	28	8.0003	0.2857		
Total	33	30.4792			

Source	DF	Seq SS
x1	1	0.1107
x5	1	1.1929
x10	1	8.4657
x15	1	4.0165
x16	1	8.6930

Unusual Observations

Obs	x1	y	Fit	StDev Fit	Residual	St Resid
25	38.0	3.4000	3.4375	0.3894	-0.0375	-0.10 X
29	28.7	0.5000	1.7118	0.2076	-1.2118	-2.46R

R denotes an observation with a large standardized residual
X denotes an observation whose X value gives it large influence.

Appendix B, Table 15

Regression Analysis (on the 5 Variables Extracted from the Best Subsets Regression, $C_p = 8.8$)

The regression equation is
y = - 1.69 + 0.0396 x2 + 0.0141 x3 + 0.238 x10 - 0.555 x13 + 0.998 x14

Predictor	Coef	StDev	T	P
Constant	-1.6942	0.4572	-3.71	0.001
x2	0.03959	0.01307	3.03	0.005
x3	0.014097	0.008222	1.71	0.097
x10	0.23843	0.03981	5.99	0.000
x13	-0.5553	0.1951	-2.85	0.008
x14	0.9976	0.1888	5.28	0.000

S = 0.5372   R-Sq = 73.5%   R-Sq(adj) = 68.8%

Analysis of Variance

Source	DF	SS	MS	F	P
Regression	5	22.3990	4.4798	15.52	0.000
Error	28	8.0802	0.2886		
Total	33	30.4792			

Source	DF	Seq SS
x2	1	2.9425
x3	1	1.5826
x10	1	6.5705
x13	1	3.2504
x14	1	8.0530

Unusual Observations

Obs	x2	y	Fit	StDev Fit	Residual	St Resid
27	16.0	0.3000	1.3401	0.1775	-1.0401	-2.05R

R denotes an observation with a large standardized residual

Appendix B, Table 16

Hierarchical Cluster Analysis of Observations

Euclidean Distance, Ward Linkage

Amalgamation Steps

Step	Number of clusters	Similarity level	Distance level	Clusters joined		New cluster	Number of Obs in new cluster
1	33	98.59	48.171	2	29	2	2
2	32	98.24	60.156	2	26	2	3
3	31	97.88	72.757	2	5	2	4
4	30	97.64	80.785	16	27	16	2
5	29	97.54	84.163	7	28	7	2
6	28	97.26	93.845	9	21	9	2
7	27	97.25	94.363	10	30	10	2
8	26	97.16	97.351	12	34	12	2
9	25	96.42	122.763	19	24	19	2
10	24	96.42	122.837	16	20	16	3
11	23	96.34	125.286	12	22	12	3
12	22	96.33	125.832	17	23	17	2
13	21	95.57	151.922	4	31	4	2
14	20	95.49	154.704	1	2	1	5
15	19	95.35	159.493	12	18	12	4
16	18	95.25	162.733	13	19	13	3
17	17	95.09	168.153	16	25	16	4
18	16	94.50	188.388	9	15	9	3
19	15	93.49	223.015	4	8	4	3
20	14	93.48	223.358	3	13	3	4
21	13	93.24	231.754	9	10	9	5
22	12	92.96	241.231	16	17	16	6
23	11	86.92	448.158	6	33	6	2
24	10	84.50	531.028	4	7	4	5
25	9	81.75	625.437	11	14	11	2
26	8	81.35	639.224	3	12	3	8
27	7	76.69	798.701	16	32	16	7
28	6	73.67	902.426	1	16	1	12
29	5	70.76	1002.011	4	9	4	10
30	4	42.05	1985.764	4	6	4	12
31	3	37.00	2158.900	1	3	1	20
32	2	-65.69	5677.911	4	11	4	14
33	1	-200.72	10304.898	1	4	1	34

Final Partition

Number of clusters: 1

	Number of observations	Within cluster sum of squares	Average distance from centroid	Maximum distance from centroid
Cluster 1	34	21292432.497	593.476	2657.276

Appendix B, Table 17

Countries (1)	y (1)	Countries (2)	y (2)
Bangladesh	1.28	Botswana	0.64
Bhutan	0.2	Chile	1.1
Bolivia	2.81	Colombia	2.95
Cameroon	0.3	Costa Rica	2
Honduras	2	Ecuador	2.2
Indonesia	1.04	El Salvador	1.2
Kenya	1	Gabon	2.5
Mauritania	0.15	Iran	0.59
Morocco	0.9	Jamaica	2.2
Nigeria	3.3	Paraguay	2.06
Pakistan	0.99	Syria	0.8
Philippines	1.5	Thailand	0.64
Rwanda	0.14	Tunisia	0.37
Senegal	0.35	Uruguay	1.91
Sierra Leon	3.4		
Somalia	0.33		
Sri Lanka	0.3		
Tanzania	0.5		
Uganda	1		
Zambia	2.1		

Note:
Figures in Columns y (1) & y (2) are Integration of Technology Indices

Two Sample T-Test and Confidence Interval

Two sample T for y (1) vs y (2)

	N	Mean	StDev	SE Mean
y (1)	20	1.18	1.04	0.23
y (2)	14	1.511	0.838	0.22

95% CI for mu y (1) - mu y (2): (-0.99, 0.33)

T-Test mu y (1) = mu y (2) (vs not =): T= -1.03 P=0.31 DF= 31

Appendix C

This appendix consists of two parts. The first part is concerned with cluster analysis and the second part discusses the t-test in relation to cluster analysis.

C.1 What is Cluster Analysis?

Cluster analysis is the name for a set of multivariate techniques whose primary purpose is to group objects based on the characteristics they possess. Cluster analysis classifies objects (e.g., respondents and products) so that each object is very similar to others in the cluster with respect to some predetermined selection criterion. The resulting clusters of objects should then exhibit high internal (within-cluster) homogeneity and high external (between-cluster) heterogeneity. Thus, if the classification is successful, the objects within-clusters will be close together when plotted geometrically, and different clusters will be far apart.

In cluster analysis, the concept of the variate is a central issue, but in a quite different way from other multivariate techniques. The cluster variate is the set of variables representing the characteristics used to compare objects in the cluster analysis. Because the cluster variate includes only the variables used to compare objects, it determines the "character" of the objects.

Cluster analysis is the only multivariate technique that does not estimate the variate empirically but instead uses the variate as specified by the researcher. The focus of cluster analysis is on the comparison of objects based on the variate, not on the estimation of the variate itself. This makes the researcher's definition of the variate a critical step in cluster analysis.

Cluster analysis has been referred to as Q analysis, typology construction, classification analysis, and numerical taxonomy. Although the names differ across disciplines (i.e., sociology, economics, business, and engineering), the methods all have a common dimension: classification according to natural relationships. This common dimension represents the essence of all clustering approaches. As such, the primary value of cluster analysis lies in the classification of data, as suggested by "natural" groupings of the data themselves. Cluster analysis is comparable to factor analysis in its objective of assessing structure. But cluster analysis differs from factor analysis in that cluster analysis groups objects, whereas factor analysis is primarily concerned with grouping variables.

Cluster analysis is a useful data analysis tool in many different situations. For example, a researcher who has collected data by means of a questionnaire may be faced with a large number of observations that are meaningless unless classified into manageable groups. Cluster analysis can perform this data reduction procedure objectively by reducing the information from an entire population or sample to information about specific, smaller subgroups. For example, if we can understand the attitudes of a population by identifying the major groups within the population, then we have reduced the data for the entire population into profiles of a number of groups. In this fashion, the researcher has a more concise, understandable description of the observations, with minimal loss of information.

C.2 Objectives of Cluster Analysis

The primary goal of cluster analysis is to partition a set of objects into two or more groups based on the similarity of the objects for a set of specified characteristics. In other words, cluster analysis groups individuals or objects into clusters so that objects in the same cluster are more similar to one another than they are to objects in other clusters. The attempt is to maximise the homogeneity of objects within the clusters, while also maximising the heterogeneity between the clusters [1].

As already indicated, the next part will be a brief description of the t-test. Afterwards, we will apply the t-test to two distinct groups derived from the main cluster observations to see whether there is a significant difference between the two mean integration of technology indices.

C.3 Comparing Two Population Means Using Two Small Samples (t-test)

When dealing with small samples from two populations, we need to consider the assumed distribution of the populations because the "Central Limit Theorem" no longer applies. This section is concerned with comparing two population means when small and random samples are used. When going from large samples to small samples from normal populations, the confidence interval and hypothesis-testing procedures both remain exactly the same, except that we use the t distribution rather than the Z distribution to describe the test statistic.

When using small samples ($n_1 < 30$ or $n_2 < 30$), we define:

$$t' = \frac{\overline{X}_1 - \overline{X}_2}{\sqrt{\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2}}} \qquad (1)$$

where $\overline{X}_1$ and $\overline{X}_2$ are means estimate, s_1 and s_2 are estimated standard deviation, and n_1 and n_2 are sample sizes of population 1 and 2, respectively.

This statistic approximately follows a t distribution with degree of freedom given by:

$$df = \frac{\left[\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2}\right]^2}{\frac{\left(\frac{s_1^2}{n_1}\right)^2}{n_1 - 1} + \frac{\left(\frac{s_2^2}{n_2}\right)^2}{n_2 - 1}} \qquad (2)$$

The df should be between A and B, where A is the smaller of $(n_1 - 1)$ and $(n_2 - 1)$ and B is $(n_1 - 1) + (n_2 - 1)$.

C.4 Hypothesis Testing for μ_1 and μ_2

The five-step procedure for testing hypotheses concerning μ_1 and μ_2 applies to the small-sample situation.

Step 1. We are testing for a difference between the two means. The corresponding appropriate hypotheses are

H_0: $\mu_1 = \mu_2$ where μ_i = true mean integration of technology index for cluster i

H_a: $\mu_1 \neq \mu_2$

Step 2. The test statistic is:

$$t' = \frac{\overline{X}_1 - \overline{X}_2}{\sqrt{\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2}}}$$

which approximately follows a t distribution with df given by equation 2.

Step 3. We need df in order to determine the rejection region. Because H_a: $\mu_1 \neq \mu_2$, we will reject H_0 if t' is too large ($\overline{X}_1$ is significantly larger than $\overline{X}_2$) or if t' is too small ($\overline{X}_1$ is significantly smaller than $\overline{X}_2$). H_0 is rejected if the absolute value of t exceeds the value from the table corresponding to $\alpha/2$.

Step 4. This step is the calculation of test statistic.

Step5. The final step is drawing conclusions [2].

C.5 Applying Cluster Analysis and Results

After a brief discussion about cluster analysis and t-test, let us now conduct the above hypothesis procedures. We have applied cluster analysis on our data set. As we can see from the main cluster observations, Figure 6, Appendix B, the 34 countries have divided into two distinct groups with $n_1 = 20$ and $n_2 = 14$ (also see Table 16, Appendix B, Hierarchical Cluster Analysis of Observations).

For operational and analytical purposes, the World Bank's main criterion for classifying economies is GNP per capita. Every economy is classified as low-income, middle-income (lower-middle and upper-middle), and high-income [3].

According to the above classification, low-income and middle-income economies are sometimes referred to as developing economies. There is no implication that all economies in the same group are experiencing similar development [4].

Some analysts use the United Nations classification system. They prefer to distinguish among three major groups within the Third World: the 44 poorest countries designated by the UN as "least developed", the 88 non-oil-exporting "developing nations", and the 13 petroleum-rich OPEC (Organisation of Petroleum Exporting Countries) nations whose national incomes increased dramatically during the 1970s [5].

For this analysis, we are using the World Bank criteria for classifying economies.

Economies are divided into income groups according to 1988 GNP per capita. We have chosen the year 1988 because it is in the middle of our data period, which is 1983-1992. The groups are:

Low-income economies: \$500 or less (GNP/capita)

Lower-middle-income economies: \$500-\$2200

Upper-middle-income economies: \$2200-\$6000

High-income economies: \$6000 or more

High-income economies are also called the industrial countries and they are mostly members of Organisation for Economic Co-operation and Development (OECD) [6].

With respect to this brief introduction, if we look back in Table 17, Appendix B, we notice an interesting result. According to the above classification, all twenty countries in sample one with GNP/capita ranged \$134-\$813, are amongst low-income countries (12 countries and with GNP/capita less than \$500) and lower-middle-income countries (8 countries and with GNP/capita £500-\$2200).

In sample two, all fourteen countries with GNP/capita ranged \$960-\$3555, are amongst lower-middle-income countries (12 countries with GNP/capita \$500-£2200) and upper-middle-income countries (2 countries with GNP/capita \$2200-\$6000).

As we discussed in chapter four, the two upper-middle-income countries, Iran and Gabon, with the GNP per capita 3030 and 3555 dollar, respectively, are amongst the oil exporting countries. They are characterised by huge surpluses that can finance not only the imports of capital goods but also the imports of manpower required. Oil production represents the most dominant part of these economies. In spite of having oil resources, they are not rich enough, so still they have been classified as developing countries.

We now wish to test whether the mean integration of technology index differs significantly between the two main clusters (see Table 1, Appendix A). Can we conclude that these means are in fact the same? Using a significance level of *0.05, the corresponding appropriate* hypothesis is:

$H_0: \mu_1 = \mu_2$ where μ_i = true mean integration of technology index for cluster i

$H_a: \mu_1 \neq \mu_2$

From the Minitab printout of t-test, we obtain $t' = -1.028$ together with df = 31.

Using the tabulated critical values of t, the rejection region for this situation will be:

reject H_0 if $| t' | > t_{\alpha/2,df} = t_{0.025,31} = 2.04$

Because $|-1.028| < |2.04|$, H_0 is not rejected. See Table 17, Appendix B, for details. Consequently, the difference between the sample means (-0.331) is not significantly large (in absolute value), which leads to an acceptance of the null hypothesis. So, we conclude that there is not a significant difference in the mean index of technology integration for the two samples derived from the cluster observations.

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