1-1-1975

Transfer of technology within multinational corporations : an exploratory analysis.

Jean-Pierre Jeannet
University of Massachusetts Amherst

TRANSFER OF TECHNOLOGY WITHIN MULTINATIONAL CORPORATIONS - AN EXPLORATORY ANALYSIS

A Dissertation Presented

By

JEAN-PIERRE JEANNET

Submitted to the Graduate School of the University of Massachusetts in partial fulfillment of the requirements for the degree of

DOCTOR OF PHILOSOPHY

September 1975

Major Subject: Business Administration

TRANSFER OF TECHNOLOGY WITHIN MULTINATIONAL CORPORATIONS - AN EXPLORATORY ANALYSIS

A Dissertation

By

JEAN-PIERRE JEANNET

Approved as to style and content by:

Bertil Liander, Associate Professor of Marketing, SBA
Chairman

Victor P. Buell, Associate Professor of Marketing, SBA
Member

D. Anthony Butterfield, Associate Professor of Management, SBA
Member

Kenneth G. Picha, Dean, School of Engineering
Outside Member

John T. Conlon, Director of Graduate Programs
School of Business Administration

MAY 1975

ABSTRACT

Jean-Pierre Jeannet

This research has been undertaken to analyze and measure technology flows focusing on technology transfers within multinational corporations, e.g. transfers within the worldwide network of subsidiaries. The definition of technology is restricted to manufacturing technology only.

A model was developed that assumes technology transfers are a function of the degree of multinationality of a corporation. This degree of multinationality is operationalized as (a) the number of years passed since the formation of the first manufacturing subsidiary abroad, (b) the number of foreign countries with manufaceuring subsidiaries, and (c) the number of foreign research facilities. The dependent variable, technology transfers, has been operationalized as number of transfers between the headquarters country and its foreign subsidiaries. It has also been categorized as research, development, and engineering. According to the model, multinational corporations are assumed to show differing patterns of technology transfers depending on their degree of multinationality.

For a preliminary testing of the model, a convenience sample of 14 New England based corporations was selected, with the companies showing differing degrees of multinationality. A combination of the cross-sectional and time series analysis was chosen as the basis for the experimental design.

The data analysis was performed using the multiple regression program of the SPSS package.

Generally, the model has been confirmed by the data. Multinational corporations are shown to be heavy technology exporters at first. At later stages of their development, the companies turn increasingly to technology imports as a source for new technologies. Furthermore, the level of which such transfers take place tends to rise as the multinational corporation matures.

The results of this research are in conflict with the traditional view that all multinational corporations are heavy technology exporters. Consequently, extrapolations into the future should not be done based upon the large number of multinationals that are still in their early stages of development.

This research is a contribution to the field of international business. It represents the first attempt to systematically analyze the patterns of technology flows within multinational corporations. Previously, such analysis was restricted to licensing data which represents only one small segment of all technology transfers.

Table of Contents

FOREWORD

The research presented in the form of this dissertation represents a first attempt to uncover the magnitude of technology transfers taking place within multinational corporations (MNCs). The contribution of MNCs to economic development, particularly through the transfer of advanced technology, has received attention from numerous researchers. Yet, a detailed analysis of how much is actually transferred has been missing. Consequently, upon the initiative of Dean K.G. Picha from the School of Engineering at the University of Massachusetts, in the summer of 1972 the School of Business Administration was approached to investigate these flows of technology. The intent was to use such findings as a basis for a conference on US technology that had been proposed earlier yet did not come out of the planning stage due to a lack of data. After an exhaustive literature survey and some exploratory research in Washington, the project finally gained momentum.

The progress of this research was originally hampered by the lack of an existing research methodology that could be applied to the problem of transfers of technology. Also, since no prior study had been undertaken on this subject, a data base had to be created. Due to the extent of the work to be accomplished, the nature of this research was defined to accomplish the following:

1. Focus on the transfers of technology within MNCs, more specifically on the transfers between the headquarters' organization on one side and the various subsidiaries on the other side. Inter-subsidiary transfers were excluded from the analysis as well as transfers consummated outside the network of a MNC's network of affiliates.

2. Develop a model that describes the flow of technology within any given MNC.

3. The definition and assembly of a data base on technology transfers within MNCs.

4. Test the model based on the data collected.

The organization of this dissertation follows logically from the above objectives. Chapter I contains a survey of the relevant literature on technology transfers. The survey is clustered around the three major concepts involved, the concepts of technology, technology transfer, and the multinational corporation.

In Chapter II, a model is developed that describes the flows of technology within a MNC. The model consists of 17 major equations that are actually hypotheses under investigation. Furthermore, MNCs are grouped in three categories, emerging, growing, and mature MNCs to account for different degrees of multinationality. Multinationality is operationalized as time since the first foreign venture, number of countries with manufacturing subsidiaries, and number of research organizations abroad. These are the independent variables with technology transfers becoming the dependent variable in the model.

Chapter III concentrates on the research methodology and outlines the sample design, data collection procedures, the experimental design, and finally the data analysis. All results are then presented in Chapter IV and the conclusions are contained in Chapter V.

This dissertation would not have been possible without the support of many individuals. First of all, I would like to thank my advisor, Bertil Liander, for his continuous support and guidance particularly during those time periods when the success of the research was in question. A special thanks goes to Dean K.G. Picha for his ideas and the contacts he provided that eventually enabled me to finish this project. I am also thankful to the other members of my committee, D. Anthony Butterfield and Victor P. Buell, for their constructive criticism of earlier versions of this dissertation. I am grateful to the management of Sprague Electric, Mr. Scherr in particular, whose contribution to a large extent ensured the cooperation of the other corporations and their executives whose names unfortunately cannot be mentioned. And at last the progress of this dissertation was significantly furthered by a contribution of the Merrill Trust Fund of the University of Massachusetts.

List of Tables

List of Graphs

CHAPTER I

THE ROLE OF THE MULTINATIONAL CORPORATION IN THE TRANSFER OF TECHNOLOGY - A LITERATURE SURVEY

1. Introduction

1.1. Purpose. The purpose of this chapter is to analyze and categorize all pertinent literature published in the area of transfer of technology by multinational corporations (MNC).[1] Emphasis will be on measurements of such technology transferred, particularly with respect to U.S. based MNC. This survey served as a background for this research.

1.2. Organization. Following the title, three concepts have to be introduced: the concept of the multinational corporation (MNC), the concept of technology, and the concept of technology transfer. Each concept is defined and surveyed as far as necessary to understand the background for this research.

2. The Concept of the Multinational Corporation

2.1. Definitions. Despite the fact that MNCs have been studied for the past two decades no uniquely acceptable definition has been found.

The term "multinational corporation" was used the first time by David Lilienthal of TVA in an address given in Phila-

[1] MNC will be used throughout this study as an abbreviation for multinational corporation.

delphia in 1958.[2] The address was later published in a book of essays in 1960.[3] Some authors prefer the term "international" or "transnational" to multinational, but in all cases it is used to describe the same phenomenon.

The British economist John H. Dunning used a simple definition for a conference at the University of Reading (UK).[4] He simply defines a multinational production enterprise (MPE) as

> "an enterprise which owns or contracts production facilities (i.e. factories, mines, oil refineries, distribution outlets, offices, etc.) in more than one country."

The most extensive review of definitions has been advanced by Aharoni.[5] He realized that many writers used different criteria to consider a corporation as multinational or not. Some of the definitions surveyed will now be organized using Aharoni's framework. First, there is a possibility of distinguishing among corporations using a <u>struc</u>-

---

[2]Martyn, Howe, <u>Multinational Business Management</u>, D.C. Heath and Company, Lexington, Mass., 1970, p. 1.

[3]Anshen, Melvin, and Bach, George L., eds., <u>Management and Corporations, 1985</u>, New York, McGraw-Hill, 1960, pp. 119.

[4]Dunning, John H., ed., <u>The Multinational Enterprise</u>, London, George Allen & Unwin Ltd., 1971, p. 16.

[5]Aharoni, Yair, "On the Definition of a Multinational Corporation," <u>Quarterly Review of Economics and Business</u>, Vol. II, Autumn 1971.

tural criterion. The number of foreign operations could be used as such a criterion. In his essay, Lilienthal used this criterion:[6]

> "corporations which have their home in one country but operate and live under the laws and customs of other countries as well."

As a second alternative, Aharoni suggests ownership patterns as a possible classification criterion. Full ownership by the parent company does provide control over subsidiaries. Behrman cites this as an important fact for any MNC.

> "What distinguishes the multinational enterprise from its predecessors is the centralization of policy and integration of key operations among the affiliates."[7]

Nationality of top management is said to be another criterion.[8] Organizational structure is, according to Aharoni, "the final possibility of defining multinationality." Under this criterion, a company would be considered multinational if the corporation realigns "the company's organizational responsibilities on a world-wide concept of operations."[9]

---

[6] Lilienthal, David, in Anshen, Melvin, and Bach, G.L., eds. op. cit.

[7] Behrman, Jack N., Some Patterns in the Rise of the Multinational Enterprise, Graduate School of Business Administration, University of North Carolina at Chapel Hill, 1969, p. xiii; see also Jacoby, Neil H., "The Multinational Corporation," The Center Magazine, Vol. 3, No. 3, May 1970, p. 38, for a similar definition.

[8] Aharoni, Yair, op. cit.

[9] Ibid.

As Aharoni points out, none of these structural criteria are really satisfying. One still would have to decide how many foreign operations are needed to qualify a company as multinational. The ownership pattern does, in addition, not always reflect control patterns within a company. Even more questionable is the criterion of the nationality of top management. How many countries should be represented? Organizational structure, however, seems to be quite different among companies intuitively qualifying as multinationals, suggesting that also this last criterion does not fully capture "multinationality."

Aharoni identifies a second set of different criteria which he calls performance yardsticks. "The absolute measure will classify a corporation as multinational if it has committed a certain amount of resources to foreign operations."[10] One could use assets, number of employees, sales, or earnings as type of measurements. Any of these measurements have to be qualified, and in the end, a decision on what a significant percentage constitutes, has still to be made.[11] Many corporations have such extensive facilities in the United States that even 10 or more plants abroad form only 15 percent of their sales. Nevertheless, such a company might still classify as multinational given a different criterion.

---

[10] Ibid.

[11] Bruck, J.K., and Lees, F.A., "Foreign Content of US Corporate Activities," Financial Analysis Journal, Sept.-Oct. 1966, and "Foreign Investments, Capital Control, and the Balance of Payments," The Bulletin, New York University Institute of Finance, April 1968.

Thirdly, Aharoni defines behavioral characteristics as another criterion.[12] He cites Peter Drucker as a prime exponent of this "school" who defines MNCs as having:

> "corporate headquarters in the U.S. but in their organization, their business, their scope, they are worldwide...."[13]

In other words, a company that thinks "worldwide" qualifies as multinational. But since one can hardly operationalize this definition, it loses its attractiveness.[14]

Aharoni then goes on to conclude that the problem of definition arises because we do have many different forms of MNCs. For future research, Aharoni uses the following definitions:[15]

> "A Multinational Corporation: A corporation which controls a multinational cluster. A Multinational Cluster: A group of corporations each created in the country of operation, but all controlled by one headquarters.
>
> While the latter term refers to the cluster as a whole the former is reserved for the headquarters. In order to qualify as a multinational corporation, the company should control a multinational cluster in a minimum number of countries. The number of countries must be large enough so that the multinational corporation should be involved in the international cluster as consisting of corporations

---

[12] Aharoni, Yair, op. cit.

[13] Drucker, Peter F., The Concept of the Corporation, The New American Library, New York, 1964, p. 244; see also "Multinational Companies," Business Week, April 20, 1963, pp. 63.

[14] Aharoni, Yair, op. cit.

[15] Aharoni, Yair, op. cit.

> in at least five countries. This of course, is an arbitrary number. The number of countries may be one vector in describing different multinational corporations."

Aharoni further subdivides MNCs according to type of operations, size, and area of operation. For the purpose of this study, the definition of a multinational manufacturer is of central importance. Such a company is defined as

> "controlling an international cluster of manufacturing and/or assembly plants."[16]

Fur future use in the context of this study, we define a MNC according to Aharoni's definition. In most cases, as will be seen later for reasons then explained, a multinational manufacturer is implied.

2.2. Organizational patterns in multinational corporations. In the previous section, the main concern was what kind of a company would qualify as "multinational." In this section, we will concentrate on the many possible organizational patterns among multinational firms.

Throughout the literature, there are two different approaches. The first and most popular approach is to observe the structure of a company's organization. Such distinctions range from two types[17] up to eight different types.[18]

---

[16] Ibid.

[17] Jacoby, Neil H., "The Multinational Corporation," The Center Magazine, Vol. III, No. 1, May 1970.

[18] Phatak, Arvind V., Evolution of World Enterprises, American Management Association, Inc., 1971.

Jacoby[19] distinguishes between two basic organizational forms:

> "A <u>world corporation</u> format, in which the basic business functions of finance, marketing, manufacturing, and research and development are the primary pillars of organization and domestic and foreign operations are merged; or an <u>international division</u> format, in which all foreign operations are separated from domestic ones in an 'international division'."

Similar to Jacoby, Phatak also calls a fully developed multinational a company with a "world-wide structure"[20] if "it has grouped all its operations on a product or geographical basis without formal distinction between its domestic and foreign activities."[21] He calls this Pattern Eight. Patterns One to Three "do not possess the essential characteristics of a world/oriented structure mentioned in the preceding definition."[22] These are essentially still companies with an international division. Patterns Four to Six "have organization structures that approach world/oriented structure."[23] Companies falling into this middle category have less formal distinction between domestic and international business than the previous group, but still not enough as to qualify as a pure MNC.

---

[19] Jacoby, Neil H., *op. cit.*

[20] Phatak, Arvind V., *op. cit.*, p. 202.

[21] *Ibid.*

[22] *Ibid.*

[23] *Ibid.*

Except for Pattern Eight ("world-oriented structure"), Phatak does not name the other pattern other than by numbers. They are merely illustrated with real companies.

A similar approach has been chosen by Robinson who classified MNCs by the location of authority over associated foreign enterprises.[24] A "foreign oriented" [25] company provides simply a foreign department at headquarters level, and "international"[26] company has an international division, and finally, the "multinational" company[27] operates with regional divisions on equal levels.

The second approach used in describing patterns of evolving corporations is based on their managerial behavior. The Task Force on the Structure of Canadian Industry distinguishes three types of multinationals:[28]

> a "national corporation operating extra-nationally, insisting on the primacy of the methods it uses at home,"
>
> "a multi-national corporation in a genuine sense, sensitive to local traditions, and respecting local jurisdictions and policies,"
>
> a "'global' corporation with such pervasive operations that it is beyond the effective reach of the national policies of any country."

---

[24] Robinson, Richard D., International Management, Holt, Rinehart and Winston, New York, 1967, p. 152.

[25] Ibid.

[26] Ibid.

[27] Ibid.

[28] Task Force on the Structure of Canadian Industry, Foreign Ownership and the Structure of Canadian Industry, Queens Printer, Ottawa, 1968, p. 33.

Probably the most developed behavioral typology for MNCs today has been advanced by Perlmutter.[29] MNCs are divided into three groups:

> The "ethnocentric" group (home-country oriented) can be best illustrated by: "This works at home, therefore it must work in your country."[30]
>
> The "polycentric" (or host country oriented) group consists of firms who "by experience or by the inclination of a top executive (usually the founders), begin with the assumption that host-country cultures are different and that foreigners are difficult to understand."[31]
>
> Within the "geocentric" group (world-oriented) "senior executives do not equate superiority with nationality. Within legal and political limits, they seek the best men, regardless of nationality, to solve the company's problems anywhere in the world."[32]

Ultimately, according to Perlmutter and others, MNCs tend to become geocentric. But today, most companies are either polycentric or still ethnocentric.

Looking even further ahead, Perlmutter speculates that multinational corporate activity will expand into "global industrial systems" which would develop through the same

---

[29] Perlmutter, Howard V., "Three Conceptions of a World Enterprise," Revue Economique et Sociale, May 1965; "The Tortuous Evolution of the Multinational Corporation," Columbia Journal of World Business, January-February 1969; "The Multinational Firm and the Future," The Annals, September 1972.

[30] Perlmutter, Howard V., Columbia Journal of World Business, op. cit.

[31] Ibid.

[32] Ibid.

stages as the individual corporations, but this time groups of MNCs together.[33]

2.3. The extent of activities of multinational corporations. The size of all MNCs together is considerable. Polk[34] estimates that all MNCs account for about $450 billion annually in production. By approximating World GNP at $3000 billion annually, that amounts for the MNCs to a sixth of all world production. He concludes:

> "I think it may be accepted that at this level of relative importance internationalized activities suggest not just a special area of overlap among national economies but rather the solid underpinning of an emergent world economy."[35]

Dunning adds that foreign production of multinational corporations is growing at a rate of 10 percent per annum, twice as fast as the growth of World GNP and 40 percent faster than world exports.[36] But because MNCs are concentrated in the fast-growing technologically advanced industries, their share of World GNP will rise still further in the future.[37]

---

[33] Perlmutter, Howard V., The Annals, op. cit., pp. 139.

[34] Polk, Judd, "The Emergent World Economy," read before the Subcommittee on Foreign Economic Policy of the Joint Economic Committee, Congress of the United States, 91st Congress, second Session, reprinted in Kapoor, A. and Grub, Philip D., The MultinationalEnterprise in Transition, The Darwin Press, Princeton, N.J., 1972, pp. 67-80.

[35] Ibid., p. 74.

[36] Dunning, John H., ed., The Multinational Enterprise, George Allen Unwin Ltd., London, 1971, p. 19.

[37] Ibid.

Not all countries participate equally in this international business. For 1968, Polk estimated total international direct investment at $94.0 billion.[38] Of these assets, 55 percent were owned by US corporations, 20 percent by UK companies, and the rest by mostly European and Japanese enterprises.

Robock and Simmonds,[39] by using United Nations Sources, estimated total world direct foreign investment (for non-communist countries) at $95.2 billion for 1966. Like Polk, they found that 57.4 percent of all investments are owned by US corporations, but only 17 percent by UK firms, with the remainder by Europeans (20 percent) and Japan (only 1.3 percent).

2.3.1. Extent of US multinational corporations. Since 1965, scholars at Harvard University have worked on the Multinational Enterprise Project. Based on the fact that relatively few US corporations account for the bulk of US foreign investment, Harvard looked at Fortune 500 companies only.[40] In addition, only corporations with 6 or more subsidiaries (or who at one time had six or more subsidiaries) were considered, amounting to 187 corporations.[41] These cor-

---

[38] Polk, Judd, "The New World Economy," Columbia Journal of World Business, January-February 1968.

[39] Robock, Stefan H. and Simmonds, Kenneth, "International Business: How big is it? The Missing Measurements," Columbia Journal of World Business, May-June 1970.

[40] Foreign Affiliate Survey, 1967-1968, US Department of Commerce, Washington, D.C., July 1970, p. 1.

[41] Vernon, Raymond, Sovereignty at Bay, Basic Books, Inc., New York, 1971, pp. 7-11.

porations account for 80 percent of US foreign direct investment.[42]

When compared to all other US corporations, US MNCs occupy a dominant position in many important industries. Nationwide, 187 US MNCs accounted for 45.7 percent of all US manufacturing output with 39.2 percent of all relative assets.[43] For 7 industries (SIC-codes) the percentage ranges from 86.2 percent for motor vehicles and equipment, to 64 percent for electrical machinery. Other industries where MNCs account for more than 64 percent of all manufacturing output in the US are: drugs, fabricated metal products, petroleum refining, chemicals, and rubber and plastics products.

Many writers have contended that US MNCs are larger than MNCs originating in Europe. This led to the well-known "American Challenge" argument.[44] In a recent research study, Hymer and Hawthorn found,[45] however, the same degree of concentration among non-US MNCs. Consequently, they find no difference between the two types based on size. Particularly important is the fact that US MNCs did not grow faster than their European counterparts in the period of 1957-1967.

---

[42] Vaupel, James W. and Curhan, Joan P., The Making of Multinational Enterprise, Graduate School of Business Administration, Harvard University, Boston, 1969 (Foreword).

[43] Ibid., p. 15.

[44] Servan-Schreiber, J.J., Le défi américain, Editions Denoël, Paris, 1967.

[45] Hymer, Stephen and Hawthorn, Robert, "Multinational Corporations and International Oligopoly: The Non/American Challenge," in Kindleberger, Ch.P., ed., The International Corporation, The MIT Press, Cambridge, 1970, pp. 57-91.

Since the purpose of this study had been limited to concentrate on the role of US MNCs, we will now focus on them for the remainder of this literature survey.

2.3.2. Geographical distribution of US foreign direct investment. According to the Survey of Current Business, total US foreign direct investment as of 1969 amounted to $67,702 million.[46] About a third of these investments are in Canada, another third in Europe, and the remaining third distributed over the rest of the world.

Segmented according to industries, 45 percent of all US foreign direct investment is in manufacturing, 30 percent in petroleum, and 8 percent in mining and smelting.[47]

Due to the large size of the US foreign direct investment, its share in some of the smaller national economies can be considerable.[48] For Canada, where a third of this investment is located, US subsidiaries account for 100 percent of Canadian sales (as of 1964) in transport equipment and non-electrical machinery. In chemicals, rubber products, and electrical machinery, the US share is still over 50 percent. Such concentrations have lead to strong political action on the part of the Canadian Government. The behavior of the US

---

[46] Survey of Current Business, October 1970, p. 28.

[47] Ibid.

[48] Vernon, Raymond, op. cit., p. 22.

subsidiaries has also been the subject of a number of studies.[49] Some of these writings will be discussed in detail when the extent of research done by US MNCs abroad is considered.

Other areas of the world have high concentrations of US MNCs, too, but not to such an extent as Canada. For Europe, US market share (for local production) is considerably less than 10 percent.[50] Behrman[51] reports that in 1966, US enterprises accounted for only 16.7 percent of total foreign direct investment in Italy.[52] In Germany, however, the US' 38 percent of total foreign direct investment is the largest foreign investor.[53]

2.4. Operational characteristics of US multinational corporations. This literature survey of operating characteristics of US MNCs is limited to research, development, and engineering operations because they are the focus of this research.

---

[49] Felthan, Q.C. and Rauenbusch, W., "Canada," in Nationalism and the Multinational Enterprise, Hahlo, H.P., eds., et.al., Oceana Publications, Inc., Dobbs Ferry, N.Y., 1973, pp. 39-87. Hymer, Stephen, "Direct Foreign Investment and the National Economic Interest," in Nationalism in Canada, Russell, Peter, ed., McGraw-Hill, Toronto, 1966, pp. 191-202. Safarian, A.E., Foreign Ownership of Canadian Industry, McGraw-Hill Co. of Canada, Toronto, 1966.
Task Force on the Structure of Canadian Industry, Foreign Ownership and the Structure of Canadian Industry, Queen's Printer, Ottawa, 1968.

[50] Vernon, Raymond, op. cit., pp. 22.

[51] Behrman, Jack N., Some Patterns in the Rise of the Multinational Engerprise, University of North Carolina at Chapel Hill, 1969.

[52] Ibid., p. 148.

[53] Ibid., p. 153.

According to a comprehensive report by the US Tariff Commission,[54]

> "US companies' actual research efforts are still generally concentrated at home, presumably because of communications advantages, government-sponsored programs, inertia, management limitations, or economies of scale."

A survey conducted by the Conference Board confirms the above statement:[55]

> "The research and development function is not one that can be easily decentralized. In spite of their desire to make maximum use of the capabilities of their foreign units, most companies cooperating in the survey make limited use of them for R & D. In spite of pressures to decentralize research activities, most companies carry out the bulk of it in the United States."[56]

Other authors also agree that US MNCs do concentrate their R & D work in the United States.[57] However, there are strong reasons to believe that the portion spent abroad is increasing over time. In a 1963 report by the Stanford Re-

---

[54] US Senate Committee on Finance, "Implications of Multinational Firms for World Trade and Investment and for US Trade and Labor," US Government Office, Washington, D.C., February 1973, p. 155.

[55] Duerr, Michael G., R & D in the Multinational Company, The Conference Board, Ottawa, 1970.

[56] Ibid., p. 2.

[57] Behrman, Jack W., Some Patterns in the Rise of the Multinational Enterprise, Graduate School of Business Administration, University of North Carolina at Chapel Hill, 1964, p. 82. Martyn, Howe, Multinational Business Management, D.C. Heath & Co., Lexington, 1970. Robinson, Richard D., International Management, Holt, Rinehart and Winston, New York, 1973, p. 145.

search Institute[58] total R & D by US companies spent abroad amounted to only 5 percent. That portion increased to 6 percent by 1966.[59] In its detailed report, the US Tariff Commission hypothesizes a 10 percent growth for R & D spending aborad. At that rate, the Commission estimated the portion spent abroad by MNCs at 8 percent for manufacturing firms.[60]

There are considerable differences in the various industries. In 1966, a total of $526 million was spent on research and development aborad, with the largest sums going for transportation equipment ($134 million) and electrical machinery ($103 million). In percentages, each of these two industries accounted for only 5 percent of total R & D spending abroad compared to what was spent in the US. In plastics (28 percent), soaps and cosmetics (16 percent), food products (12 percent), industrial machinery and equipment (19 percent), the relative weights are considerable, but the absolute amounts spent abroad are smaller than for the first two industries.[61]

Most of the R & D spending abroad is concentrated in a few countries.[62] Canada with 27 percent, United Kingdom with

---

[58] Stanford Research Institute, Long-Range Planning Report No. 198, 1963.

[59] US Department of Commerce, Bureau of Economic Analysis, International Investment Division, in Tariff Report, p. 582.

[60] Committee on Finance, US Senate, _op_. _cit_.

[61] _Ibid_.

[62] _Ibid_., p. 583.

25 percent, West Germany with 20 percent, and France with 8 percent account for the largest portion. The remaining 20 percent are thinly distributed over many countries among which are Australia, Belgium, Italy, and the Netherlands.

Some authors have analyzed the behavior of US MNCs in particular countries. As Vernon writes:[63]

> "On the research criterion, US subsidiaries score fairly well. In Canada, for instance, US-controlled subsidiaries did more research in relation to sales than their Canadian counterparts - though not so much relative to sales as their parents in the United States."

This conclusion is supported by Safarian in his analysis on foreign operations in Canada.[64]

Dunning considers US investment in the UK as beneficial with respect to R & D.[65] To the same conclusions came Brash with respect to the Australian economy.[66]

> "Actually, it is possible that American-affiliated firms devote a higher percentage of their resources to research than do other firms in the Australian economy...."[67]

---

[63] Vernon, Raymond, Sovereignty at Bay, Basic Books, New York, 1971, p. 162.

[64] Safarian, A.E., Foreign Ownership of Canadian Industry, McGraw-Hill of Canada, Toronto, 1966, Chapter 6.

[65] Dunning, John H., "Technology, United States Investment, ad and European Economic Growth," in Kindleberger, Ch.P., ed., The International Corporation, MIT Press, Cambridge, Ma., 1970. See also by the same author The Role of American Investment in the British Economy, PEP Broadsheet No. 507, 1969, and Dunning and Steuer, M., The Effects of US Investment on UK Technology, Moorgate and Wall Street, 1969.

[66] Brash, Donald T., American Investment in Australian Industry, Harvard University Press, Cambridge, Mass., 1966.

[67] Ibid., p. 154.

The establishment of R & D capabilities has become an objective for many countries to advance and further their economic growth. Particularly Canada has tried to attract R & D efforts of foreign MNCs.[68] Foreign governments have often criticized MNCs for overcentralizing research departments. Franko[69] reports that "roughly 70 percent of the European companies with US operations .... in our sample reported that they do R & D in the U.S." This led Sametz to the statement that "the US subsidiary in Europe adds to its unpopularity by its tendency to do its basic R & D at home (and) European subsidiaries in the US are more likely to be doing their R & D in the US...."[70] However, there are no hard data to date to prove this last statement.

There are instances, however, where major US MNCs maintain world-wide networks of foreign laboratories. One of the best examples is International Telephone and Telegraph Company (ITT).

"Originally well centralized, at ITT some 30 years ago, it (R & D) became too decentralized just preceding and follow-World War II under the influence, first, of nationalistic

---

[68] Robinson, Richard D., _op_. _cit_., p. 148.

[69] Franko, L.G., _European Business Strategies in the US_, Business International, Geneva, 1971, p. 23.

[70] Sametz, Arnold W., "The Foreign Multinational Company in the US," Salamon Brothers Center for the Study of Financial Institutions, New York University, Working Paper No. 9., p. 13.

tendencies, and second, of the fast growth of a number of our companies abroad during the reconstruction period and economic pickup that followed. In the last three years ... we took advantage of our research and engineering strength here in the United States as well as in the major foreign countries to reassign the work of product development."[71]

Currently, ITT employs over 20,000 scientists worldwide and does extensive research in UK, France, and Germany.[72] A scientist is defined as a research person with an education of a US B.S. or equivalent.

IBM is another US MNC that has large R & D facilities abroad.[73] IBM operates a Nordic Development Laboratory in Sweden, a Research Laboratory in Switzerland, as well as laboratories in France, Great Britain, and Germany.[74] Another case in point is Eastman Kodak Corporation. Kodak has research laboratories in France, England, and Australia.[75]

While such extensive R & D work abroad is rare, it can be said that many US MNCs do local engineering in overseas

---

[71] Martyn, Howe, op. cit., p. 149.

[72] Busignies, Henry, Chief Scientist ITT in private conversation with the author.

[73] Papo, Maurice, "How to establish and operate multinational labs," Research Management, January 1971.

[74] Ibid., p. 13.

[75] Hanson, W.T., Jr., "Multinational R & D in Practice - Two Case Studies, Research Management, January 1971, p. 47.

plants. Usually, that activity is part of their manufacturing operations.

After this review of the MNC, the focus shifts to the concept of technology, its exact meaning and its importance to a nation's economy.

3. The Concept of Technology

3.1. Definitions. "Technology is the applications of science to the solving of well-defined problems."[76]

"Technology is knowledge systematically applied to the useful arts."[77]

While both above definitions are very much the same, Hawthorne continues to write that "technology is specific" in the sense that it "is developed on a much narrower front" than basic science.[78]

3.2. Elements of technology. Hall and Johnson classify technology into three major categories:[79]

---

[76] Hawthorne, Edward P., The Transfer of Technology, OECD, Paris, 1971, p. 19.

[77] Quinn, James B., "Scientific and Technical Strategy at the National and Major Enterprise Level," in The Role of Science and Technology in Economic Development, UNESCO Science and Policy Studies and Documents, Paris, 1970, p. 84.

[78] Hawthorne, Edward P., op. cit., p. 19.

[79] Hall, G.R., and Johnson, R.E., The Technology Factor in International Trade, Vernon, R., ed., National Bureau of Economic Research, New York, 1970, pp. 305-358.

General technology refers to information common to an industry or trade. Hall and Johnson include here skills such as arithmetics, blueprint reading by the labor force, and computer programming. According to these authors, all firms of a certain industry have this knowledge, and therefore they call it "the ticket of admission to the industry."

System-specific technology can be possessed by firms or individuals and differentiates them from their rivals. It gives them their competitive edge. Included are ingenious procedures for a particular system, solutions to unique problems or requirements. This technology refers to information acquired by a firm for manufacturing a particular item. Other companies trying to produce the same item would probably acquire the same technology also.

Firm-specific technology cannot be attributed to any specific item the firm produces but rather results from the firm's several activities. Another firm manufacturing the same products would not necessarily acquire this same technology.

Using the typology of Hall and Johnson, for the purpose of this study our interest centers on system-specific technology.

According to Hawthorne,[80] technology can be "used as a means of identifying purely technical aspects of a product or

---

[80] Hawthorne, E.P., *op. cit.*, p. 20.

manufacturing process" or "in clarifying the vital characteristics of a particular market."

The following seven elements are at times part of technology:[81]

Function	Element
1. Research	New scientific and technical knowledge. Ideas and innovations. Research facilities.
2. Development and design	Techniques and studies of application of knowledge to practical use.
3. Production	Techniques. Equipment. Production control. Scale of production.
4. Materials	Specification. Quality control. Control of supply.
5. Marketing	Know-how and management of marketing and selling. Characteristics and control of markets.
6. General Management	Business know-how and management techniques.
7. Finance	Control of access to finance.

One can group the seven elements into two main groups: general production know-how (1-4, corresponding with system-specific technology) and general management know-how (5-7, corresponding to firm-specific technology). For the purpose of this study, we are concerned with general production know-how only. This does by no means, however, imply that management know-how is unimportant.

Research is often said to be either basic which "contributes to a society's growth principally through pushing

[81] Ibid., p. 21, Table 1.

back the walls of ignorance, mystique and dogma,"[82] or _applied_ which "can attack a society's specific problems and point a way toward their solution."[83] Often, science is replaced for research implying we can use above definitions for basic science and applied science as well.

If basic research is excluded from element one (research, p. 22 of this study), we can classify elements 1 through 5 as research, development, and engineering (R, D, & E) by use of definitions refined by the National Academy of Sciences:[84]

Research is applied, if it is directed toward practical applications of scientific knowledge - in contrast to basic research directed toward increasing scientific knowledge. (Element 1, Hawthorne).

Development is the systematic use of knowledge gained from research for the production of useful materials, devices, systems, methods, or processes, exclusive of design or pro-production engineering (element 2).

The _engineering_ aspect is concerned with actual construction, assembly, layout, and testing of models for pilot processes and procedures - to produce a system that will work. (elements 3 and 4).

---

[82] Quinn, James B., "Scientific and Technical Strategy," _op. cit._, p. 83.

[83] _Ibid_.

[84] _US International Firms and R, D, &E in Developing Countries_, Washington, D.C., 1973, p. XV, National Academy of Sciences.

For the remainder of this study, these last definitions will be used when reference is made to R,D,&E of MNCs.

3.3. The economic importance of technology.

3.3.1. Technology and economic growth.

This section is not designed to give a complete overview over economic growth theories and their relationships with technology. But since this very relationship gives the whole matter its overall importance, the subject of economic growth should nevertheless be treated even at the risk of being simplistic.

Traditional economic theory was mainly concerned with tariffs, monopoly, trade unions, business cycles, monetary and fiscal policy. Technological progress was considered exogenous or determined by forces other than economic. Schmookler writes:[85]

> "Hence, except for a few economists, largely those of a heterodox stripe preoccupied with problems of economic development, like Marx, Veblen, Schumpeter, and Kuznets, technological change was generally ignored until the last decade or so."

Schmookler also implies that the above attitude was wrong, and,

> "...as several independent studies in the last dozen years have shown, the accumulation of intellectual capital - reflected in the production of better products and the use of better methods - has been much more important than the accumulation of physical capital explaining the rise of output per worker in advanced countries when the period studied covers several decades."[86]

---

[85] Schmookler, Jacob, Invention and Economic Growth, Harvard University Press, Cambridge, Mass., 1966, p. 4.

[86] Ibid., p. 320.

Among the first writers in the area were Abramovitz[87] and Solow.[88] Solow used data on US economic indicators from 1909 to 1949. He concludes[89] that while gross output per man-hour doubled over the interval (1909-1949), 87.5 percent of the increase is attributable to technical change and the remaining 12.5 percent to increased use of capital.

Other studies in the area have been authored by Denison,[90] Williams,[91] and Nelson, et.al.[92]

According to Arrow, technology can be reflected in "learning by doing" resulting in a non-capital-embodied technology.[93] Solow can be called the proponent of capital embodied technology, implying that all innovations have to be reflected in capital goods, eventually.[94] Both of these opinions are

---

[87] Abramovitz, Moses, "Resources and Output Trends in the United States Since 1870," American Economic Review, Vol. 46, No. 2, May 195

[88] Solow, Robert M., "Technical Change and the Aggregate Production Function," Review of Economics and Statistics, 39, 1957, pp. 312.

[89] Ibid., p. 320.

[90] Denison, Edward F., The Sources of Economic Growth in the United States and the Alternatives Before US, Supplementary Paper No. 13, Committee on Economic Development, New York, 1962.

[91] Williams, Bruce R., Technology, Investment and Growth, Chapman and Hall Ltd., London, 1967.

[92] Nelson, Richard R., and Peck, Merton J. and Kalacheck, Edward P., Technology, Economic Growth and Public Policy, The Brookings Institution, Washington, D.C., 1967.

[93] Arrow, Kenneth J., "The Economic Implications of Learning By Doing," Review of Economic Studies, June 1962, pp. 155-173.

[94] Solow, Robert M., "Technical Progress, Capital Formation, and Economic Growth," American Economic Review, Vol. 52, No. 2, May 1962.

important and will be used in the later part of this survey to justify the economic impact of technology transfer.

Once technology has been shown to be of critical importance to economic growth (as reflected in real national output per person employed), various efforts have been made to forecast the rate and direction of technological growth. In a summary of articles published by the National Bureau of Economic Research,[95] Schmookler attempted to predict inventiveness (as reflected by patent statistics in the United States):[96]

> "When time series of investment (or capital goods output) and the number of capital goods inventions are compared for a single industry, both the long-term and the long swings exhibit great similarities, with the notable difference that lower turning points in major cycles or long swings generally occur in capital goods sales before they do in capital goods patents."[97]

Above observation led Schmookler to conclude that (1) invention is largely an economic activity which, like other economic activities, is pursued for gain, (2) expected gain varies with expected sales of improved capital goods are largely determined by present capital goods sales.[98]

---

[95] Nelson, Richard R., ed., The Rate and Direction of Inventive Activity, National Bureau of Economic Research, Princeton University Press, Princeton, 1962.

[96] Schmookler, Jacob, op. cit.

[97] Ibid., p. 205.

[98] Ibid., p. 206.

Schmookler contends that inventions are usually made because men want to solve economic problems or capitalize on economic opportunities.[99] From this follows that inventions are an endogenous variable contrary to the belief of many economists.[100]

Other economists working on the problem of forecasting technological inventiveness include Mansfield[101] and Nelson.[102] Their work will be discussed in more detail in connection with research and the MNC.

3.3.2. Technology and international trade. In the following section, the connection between the theory of international trade and technology will be outlined. For the purpose of this paper, the impact of technology on trade will be considered a major determinant of international trade, and the only one to be analyzed. For a detailed and complete survey of the theory see Bhagwati[103] or Chipman.[104]

Under the name "trade cycle model," Vernon made the im-

---

[99] Ibid., p. 207.

[100] Ibid., p. 209.

[101] Mansfield, Edwin, The Economics of Technological Change, W.W. Norton, New York, 1968.

[102] Nelson, Richard R., et. al., op. cit.

[103] Bhagwati, J., "The Pure Theory of International Trade: A Survey," Survey of Economic Development, Vol. II, 1965, and Bhagwati, J., Trade, Tariffs and Growth, Cambridge, 1969.

[104] Chipman, John, "Survey of the Theory of International Trade," Part 1, Econometrica, 23, No. 3, July 1965, pp. 477-519, and Part 2, op. cit., No. 4, October 1965, pp. 685-760.

pact of technology on international trade well known.[105] The model claims that US manufactured exports go through a trade cycle during which the United States starts as a net exporter, loses its market over time, and finally becomes a net importer in a certain product. A good description of the four distinct phases and its implications for international marketing is given by Wells.[106]

Various empirical tests of the model have been reported.[107] The model has been supported by the data implying that US exports depend on an advantage in research and development efforts. The data shows that the United States achieves a trade surplus for all industries that

---

[105] Vernon, Raymond, "International Investment and International Trade in the Product Cycle," Quarterly Journal of Economics, Vol. 80, May 1966, pp. 190-207, and Gruber, William; Metha, Dileep and Vernon, Raymond, "The R & D Factor in International Trade and International Investment of United States Industries," Journal of Political Economy, February 1967, pp. 20-37.

[106] Wells, Louis T. Jr., "A Product Life Cycle for International Trade," Journal of Marketing, Vol. 32, July 1968, pp. 1-6.

[107] Gruber, William, et. al., op. cit., see also Hufbauer, Gary C., Synthetic Materials and the Theory of International Trade, Harvard University Press, Cambridge, 1966. Also Gruber, William, and Vernon, Raymond, in Vernon, ed., The Technology Factor in International Trade, National Bureau of Economic Research, New York, 1970.

are technology intensive such as aircraft, drugs, chemicals, and scientific instruments. This is best synthesized by Keesing:[108]

> "There turns out to be a powerful correlation between the intensity of R & D activity in American industries and their export performance. The association is probably heightened by a tendency for industries that conduct intensive R & D activity to exhibit at the same time economies of scale and high requirements for skills in production. Capital requirements, however, are inversely associated with R & D.
>
> R & D 'explain' competitive trade success in manufacturing industries considerably better than any other variable tested. This finding is consistent with a view that the world economic role of the United States involves the systematic export of new products."

---

[108] Keesing, Donald B., "The Impact of Research and Development on United States Trade," Journal of Political Economy, February 1967, p. 45.

We can now conclude that technology is not just a major determinant of economic growth but a major factor in the determination of a nation's international trade. The following section will explain the role MNC play in this context.

3.4. The multinational corporation and technology. According to the Tariff Commission Report,[109] in manufacturing, US MNCs accounted for 52 percent of the total R & D effort (1966), and for 1970, the MNCs' share increased to 56 percent (estimated). While the increase from 1966 to 1970 might also be due to more companies becoming multinational, the concentration of R & D in a few companies is still a fact. For some specific manufacturing such as chemicals, instruments, or food products the MNCs account for over 80 percent of R & D spent in those industries. Since a large number of MNCs are in the research intensive industries in the first place, it becomes apparent that such corporations can affect any nation's technology base considerably.

An extensive literature in the area of research economics has developed in recent years. The basic questions asked are: What factors influence the rate of technological development? Are larger corporations bound to be more successful in R & D than smaller ones?

Mansfield, in answering the first question, found, based

---

[109] US Senate Committee on Finance, Subcommittee on International Trade, "Implications of Multinational Firms for World Trade and Investment and for US Trade and Labor," US Government Printing Office, Washington, D.C., 1973, p. 556, Table 1.

on data in chemicals and petroleum industry, that the rate of technological change is directly related to the rate of growth of cumulated research and development expenditures.[110] This points to the MNC as a more efficient organization to carry out research and development.

In section (3.3.2.) it was concluded that technology is an important determinant of international trade. Since World War II, the US balance of trade has consistently benefitted from the exports of high technology products as sold by leading MNCs.[111] The conclusion here is that the United States is not just dependent on MNCs for its technological leadership as a nation but also for their positive contribution to the balance of trade.

This last point, however, is under dispute both from the labor organizations' point of view and from the vantage point of some politicians.[112] Both of these groups criticize the MNCs for failing to contribute to the economic growth of the United States by exporting jobs and technology.

After this review of the concept of technology, attention is now turned towards technology transfers and their main elements.

---

[110] Mansfield, Edwin, Economics of Technical Change, W.W. Norton & Co., New York, 1968, p. 31. For a detailed analysis see Mansfield, Industrial Research and Technological Innovation, W.W. Norton, New York, 1968.

[111] US Senate Committee on Finance, op. cit., Chapter III.

[112] Kujawa, Duane, ed., American Labor and the Multinational Corporation, Praeger Publishers, New York, 1973.

4. The Concept of Technology Transfer

4.1. Definitions. The term "technology" will be used in the same context as in section 3 of this chapter. Elements of technology that we are concerned with are again: Research, Development, and Engineering as defined in section (3.2.).

4.2. Modes of transfer. R, E, & E can be transferred through various channels.[113] For the purpose of this study, the concept of technology transfer as advanced by Quinn has been adopted.[114] Basically, Quinn classifies all transfers of technology into direct and indirect flows.[115]

4.2.1. Direct flows. Sale of products can be considered the most common way to transfer technology. Quinn names specifically hand tools, test equipment, transportation and communication devices, and other goods "that embody technology which purchasers can use directly."[116] Pavitt agrees

---

[113] Baranson, Jack, Industrial Technologies for Developing Economies, Frederick A. Praeger, New York, 1969.
Boretsky, Michael, US Technology: Trends and Policy Issues, Program of Policy Studies in Science and Technology, The George Washington University, Washington, D.C., 1973.
Hawthorne, Edward P., The Transfer of Technology, OECD, 1971.
Pavitt, Keith, "The Multinational Enterprise and the Transfer of Technology," in The Multinational Enterprise, Dunning, John H., ed., George Allen & Unwin Ltd., London, 1971.

[114] Quinn, James B., "Scientific and Technical Strategy at the National and Major Enterprise Level," in The Role of Science and Technology in Economic Development, Science Policy Studies and Documents, No. 18, UNESCO, Paris, 1970, and Quinn, "Technology Transfer by Multinational Companies," Harvard Business Review, November-December 1969.

[115] Quinn, James B., Harvard Business Review, op.cit., p. 151.

[116] Ibid.

with Quinn that such types of transfer are very common and voluminous. High technology trade amounts to 72 percent of total OECD exports (1966). Pavitt concludes:

> "These trends suggest that international technology transfer through producer's goods trade has increased rapidly amongst the Western European countries, on the one hand, and amongst the USA, Canada, and Japan on the other."[117]

Training of users and product services are essential technology transfers in areas such as the computer field. Software packages are made available to the buyer of the computer, and often the personnel to operate the machine are also trained by the manufacturer. The same can be said for the increasing use of suppliers of "turn-key" plants in industry.

Direct foreign investment, manufacture, and training of workers transfer great amounts of technology. Such investments occur frequently in growth sectors and technologically complex areas of an industry. In general, a new plant is usually equal or technologically superior to local competitors. With the investment, the technology to produce has therefore been transferred.

By operating training programs for local nationals, the labor force acquires new skills at various levels of operations. Such personnel can take on a new job with a local firm based on his newly gained experience.

---

[117] Ibid.

In 1965, plant and equipment expenditures of US subsidiaries in UK amounted to 10 percent of all such expenditures there.[118] For most other EEC countries the respective figure was averaging 4.5 percent. Since all these plants represent technology transfers in one way or another, the total is considerable.

Purchases of materials and components can stimulate technology transfers in less developed industries. This process is also called diffusion.[119] It involves sophisticated companies requiring more technological expertise from their local suppliers. "Such technology transfers take place continuously through transactions with firms in high technology industries."[120]

Research, development, and engineering in local laobratories of MNCs offer training facilities for local nationals that otherwise might not exist. Contact is maintained with other laboratories of the MNC or research organizations in the host country, therefore speeding up the diffusion process.

Some cases exist where research, development or engineering work is done in one country to be implemented for produc-

---

[118] Dunning, John H., "Technology, United States Investment, and European Economic Growth," in The International Corporation, Kindleberger, ed., MIT-Press, Cambridge, Mass., 1970, p. 141-176.

[119] For a definition see US International Firms and R,E,&E in Developing Countries, National Academy of Sciences, Washington, D.C., 1973, p. XVII.

[120] Pavitt, Keith, op. cit., p. 68.

tion in another country. This is a transfer of technology, also.[121]

Licensing agreements, know-how contracts, or patent exchanges are another very common form of transfer of technology. Boretsky[122] has called this form the export of technology in "naked" form. He considers under this heading patent rights and licenses, together with appropriate instructions, blueprints and other technical assistance on the part of the seller to assure exploitation of the know-how for a fixed "running" fee rather than the export of such technology embodied in products manufactured in the United States.[123] Often, such technology is also called "proprietary" knowledge because it can be identified and patented by the inventor.[124]

In the past, payments resulting from the sale of technology through licenses, royalties, or patents have been recorded under the "technological balance of payments."[125] For the United States, this balance of payments has always been positive implying the country is selling more technology than

---

[121] Picha, K.G., "Engineering Progress Abroad - An Asset or Liability to the Profession," General Electric Engineering Education Management Conference, 1972.

[122] Boretsky, M., op. cit., p. 66.

[123] Ibid., p. 97.

[124] Dunning, John H., "Technology, United States Investment, and European Economic Growth," in The International Corporation, Kindleberger, ed., MIT-Press, Cambridge, 1970, p. 159.

[125] Quinn, James B., Harvard Business Review, op. cit., p. 151.

it is buying abroad.[126] For the OECD area, detailed data is available also.[127]

4.2.2. Indirect flows. Indirect flows are those "beyond technologies directly transferred by its operations".[128] This includes observation and imitation by outside companies or competitors, a technique in which the Japanese and Italians have been very successful. Also, technology is transmitted through the creation of primary markets when an advanced operation brings out a new product. Imitators realize its sales potential and try to sell in the same markets.

Indirect flows include also visits by researchers and specialists across national borders. To quantify such transactions would be quite an impossible task, however.

4.3. The economic impact of technology transfer. The effect on overall growth of transferred technology is generally discussed by developmental economists. Primarily, their aim is to prescribe the best form of transfer and what type of technology is best suited for specific conditions. The purpose of this proposed study is not to suggest what kind of technology could best be transferred, but rather to measure the amount so transferred by MNCs. Consequently, there is no need to discuss developmental economics any further in the

---

[126] Boretsky, M., *op. cit.*, p. 108.

[127] OECD, Gaps in Technology, Paris, 1970.

[128] Quinn, James B., *Harvard Business Review*, *op. cit.*, p. 152.

context of this study.[129]

This preoccupation with the absolute amount of technology transferred is justified by the importance of all new technologies on economic growth as described in section (3.3.1.) of this chapter.

4.4. Multinational corporations and technology transfer. Most authors agree that MNCs are extremely important for the transfer of technologies across national boundaries. Quinn writes:[130]

> "Multinational companies are unquestionably the dominant institutions transferring industrial technologies across national borders."

Quinn shows the value of technological transactions between the United States and Western Europe for 1965 adding "non-royalty technology flows may dwarf those ordinarily included in "technological balance of payments figures."[131]

Dunning has also written extensively on this subject,[132] as well as Pavitt[133] and Baranson.

---

[129] For a short review see Baranson, Jack, Industrial Technologies for Developing Economies, Praeger, New York, 1969, or any textbook on international economics.

[130] Quinn, James B., "Technology Transfer by Multinational Companies," Harvard Business Review, November-December 1969, p. 150.

[131] Ibid., p. 151, Exhibit 1.

[132] Dunning, John H., "Technology, United States Investment, and European Economic Growth," in The International Corporation, Kindleberger, ed., MIT/Press, Cambridge, 1970.

[133] Pavitt, Keith, "The Multinational Enterprise and the Transfer of Technology," in The Multinational Enterprise, Dunning, ed., George Allen & Unwin Ltd., London, 1971.

The most thorough analysis to date is probably the Tariff Commission Report.[134] Chapter 6 of the report is entitled "Technology, R & D, and the Multinational Firm." MNCs are called "the dominant institutions transferring industrial technologies across national borders." And, as far as the United States is concerned, the Commission found MNCs to be the principal vehicle of technology transfer from the US to developing countries.[135]

In the Tariff Commission Report, no attempt has been made to actually measure the amount of technology transferred other than by means of a technological balance of payments. The thrust was on attempting to identify the impact of the transfers as far as the international trade position of the US is concerned.

5. Empirical Studies to Measure the Flow of Technology

In this section, specific studies will be analyzed as to their merit and methodology. While this list does not claim to be comprehensive, all studies presently known to us are included.

<u>5.1. Estimates for the US economy as a whole</u>. Boretsky, of the US Department of Commerce, published recently a mono-

---

[134] Committee on Finance, US Senate, "Implications of Multinational Firms for World Trade and Investment and for US Trade and Labor," US Government Printing Office, Washington, D.C., February 1973.

[135] <u>Ibid</u>., p. 596.

graph on US technology.[136] In his study, Boretsky was looking into the causes of the loss of the US technological advantage. He found three main causes:[137] (1) lower growth in new industrial investment in the US than in other industrialized countries, (2) smaller growth in economically relevant R & D in the US, and (3) a one-sided diffusion of existing US advanced technology in a "naked" form.[138]

It is obvious that the cause of greatest interest for this study would be the one-sided diffusion of existing US technology. The implications of such a diffusion for the US economy are obvious. They tend to be advantageous for the importing country, but detremental to the well being of the United States at large.[139] Boretsky continues to calculate the direct economic implications for the US economy using only licensing fees as a basis.[140] Since US receipts for licensing agreements grew at an average annual growth rate of 14.8 percent compared to only 13.3 percent for payments, Boretsky comes to the conclusion that the US manufacturing industry

---

[136] Boretsky, Michael, US Technology: Trends and Policy Issues, Program of Policy studies in Science and Technology, Monograph No. 17, The George Washington University, Washington, D.C., 1973.

[137] Ibid., p. 66.

[138] See section (4.2.1.) of this literature survey on licensing agreements for a definition.

[139] Boretsky, op. cit., p. 99.

[140] Ibid., p. 101.

is selling its technology faster than producing a new one.[141]

As we defined in section (4.2.), licensing is not the only way of transferring technology. In his study, Boretsky bases his conclusions on one aspect of technology transfer only. Foreign direct investments, for instance, are not included. We agree with Boretsky's conclusion that "US companies have been exporting manufacturing technology in a naked form at a much faster rate than they generate new innovations (the latter implicit in growth rates in their expenditures on R & D) and almost twice as fast as the growth of exports of US manufactured goods."

But one has to look at the evidence upon which Boretsky builds his findings. As he concedes himself[142] about the licensing fees as a data basis, "they most probably understate the true volume of the exports in question because many companies transfer technology in exchange for equity participation in foreign companies, but the true value of these equity rights is not included in the estimates of the companies' receipts."

Furthermore, the amount paid for licensing fees does not necessarily reflect the true technological value transferred. While boretsky, even in a personal conversation with this author, thinks it does, others disagree. In the Tariff Com-

---

[141] Ibid., Table 19, p. 108.
[142] Ibid., p. 107.

mission Report, serious questions with respect to pricing of technology are raised:

> "The procedures by which firms establish "prices" at which technology is transferred are almost notoriously non-economic. In the case of direct transfers to foreign affiliates, "pricing" may depend less on the value of the technology transmitted than the overall financial strategy of the firm. .....The essential point, therefore, is that technology transfers are rarely if ever priced according to rigorously applied present-value discount techniques. ....As a result, there is little certainty that published figures on inbound and outbound payments of royalties and fees actually measure the value of technology transferred in the past."[143]

Boretsky does not dwell on the part that MNCs play in the transfer of technology. His efforts are concentrated on the US economy as a whole. The interesting part, however, is his methodology in measuring such transfers. The conclusions might well be the same even when using more appropriate data, but based on this present study, serious questions still have to be raised as to the real amounts transferred. One cannot make an analysis of an iceberg by only exploring the visible tip of it.

5.2. Studies on US multinational corporations transferring technology. The Tariff Commission study has been mentioned previously.[144] On page 601 of that report, licensing

---

[143] US Senate Committee on Finance, "Implications of Multinational Firms for World Trade and Investment and for US Trade and Labor," Government Printing Office, Washington, D.C., 1973, p. 597.

[144] Ibid.

fees and royalty payments for just US MNCs are listed. However, based upon the serious deficiencies of the data explained in the previous section of this survey, the Commission was very cautious with its conclusions. The data does show, however, that MNCs account for the bulk of such transactions.[145] The Commission states:[146]

> "Whereas the rather low figures for the multinational corporations' receipts on royalties and fees may or may not suggest less transfer of technology aborad than generally has been thought to be the case, these receipts nevertheless could be viewed as offsetting the costs of a significant chunk of the heavy amounts of R & D which the MNCs themselves conduct in the United States."

As previously mentioned, some studies have been made abroad on the impact of foreign, mostly US, MNCs on the local economies. One such study, undertaken by Safarian, analyzed only elements of technology with respect to the Canadian industry.[147] The study was first aimed at identifying how many foreign companies do their own research in Canada.[148] For most companies, the activity involved relatively minor changes in products and processes.[149] About 90 percent of the affili-

---

[145] Ibid., p. 600.

[146] Ibid., p. 603.

[147] Safarian, A.E., Foreign Ownership of Canadian Industry, McGraw-Hill of Canada, Toronto, 1966, Chapter 6.

[148] Ibid., p. 181.

[149] Ibid., p. 189.

ates paying nothing and others paying the full cost of research.[151]

Safarian concludes that major transfers occur when knowledge is made available to the affiliates on an informal basis. He did not, however, attempt to measure the amounts of technology transferred.

Another study has been conducted on American investment in Australia by Brash.[152] The general conclusions are very much like those by Safarian. The study was primarily aimed at identifying the extent to which US MNCs conduct research in Australia. However, based on Brash's data, which is also broken down according to the length of operation in Australia, it becomes clear that over time MNCs tend to extend their research efforts abroad.[153]

5.3. World-wide industry studies. A series of studies have been published through the United Nations Institute for Training and Research (UNITAR). One could classify them as

---

[151] Safarian, A.E., *Foreign Ownership of Canadian Industry*, McGraw-Hill of Canada, Toronto, 1966, Chapter 6.

[152] Brash, Donald T., *American Investment in Australian Industry*, Harvard University Press, Cambridge, Mass., 1966, Chapter 6.

[153] *Ibid.*, Table VI-3, p. 149.

industry-wide case studies.[154] All of these studies, however, do not give a measurement for the amount of technology transferred. They are suggestive in the sense that they help developing countries for policy making. Since the data is aggregated on a world basis, no definite conclusions can be drawn as to the role played by US MNCs. None of the studies attempt to measure the total flow of technology across national borders.

5.4. The lack of data. The flow of technology is hard to measure. However, to measure it in terms of royalty payments clearly neglects important other elements of technology transfer. Presently, no study trying to cover all elements of technology is known to us.

To answer an important question such as whether US MNCs are net importers or exporters of technology, a new and better measurement has to be found that qualifies as the common denominator for all elements of technology transfer and yet measures the technical content well.

---

[154] Baranson, Jack, International Transfer of Automotive Technology to Developing Countries, Unitar Research Report No. 8; Chang, Y.S., The Transfer of Technology: Economics of Offshore Assembly, The Case of Semiconductor Industry, Unitar Research Report No. 11.
Stobaugh, Robert B., The International Transfer of Technology in the Establishment of the Petrochemical Industry in Developing Countries, Unitar Research Report No. 12.
Wortzel, Lawrence H., Technology Transfer in the Pharmaceutical Industry, Unitar Research Report No. 14, all by United Nations Institute for Training and Research, New York, 1971.

6. Summary of Literature Survey

For decades, economists underlined the important role of investment as a source of economic growth. In the late 1950's, however, evidence was developed that technology, or the rate of inventions, was the major determinant of economic growth. As a result of this, many nations now consider new technology their way to development and national wealth. Industrial technology is now not just a source of national pride but the ticket to economic development as well.

In the Western society, multinational corporations (MNCs) own the bulk of industrial proprietary technology. Such companies are heavily concentrated in the research intensive industries such as chemicals, drugs, engineering and aerospace. It is precisely to these industries the world looks for technological inventions to foster social and economic welfare in the future.

MNCs have been the dominant participants in foreign direct investments throughout the Western economies. Through their investments, they have also become the primary institutions transferring industrial technology across national borders. While MNCs are often charged with acting against the national interest of many nations, they are at the same time sought after to provide modern industrial technology to promote economic growth to much of the world.

Foreign nations have used all kinds of incentives to attract modern technology. Some countries, such as Canada, give tax deductions for MNCs operating local research laboratories. Others, such as Argentina in the case of General Motors and Ford, use simple political pressure to obtain the same results. Since most of today's MNCs are US based, the result must be felt in the United States in particular.

Within the United States, a heated debate is currently raging over the effects of the MNCs' actions on the US economy. The US MNCs have been charged with exporting jobs and technology and therefore jeopardizing future economic growth in the US. Such attacks culminated with the introduction of the Burke-Hartke bill in US Congress. The bill proposed to curb US foreign direct investment and exports of technology but was never passed by Congress. Furthermore, with the opening of research centers abroad, US MNCs find themselves in a position to do research and development abroad, an action that would result in an export of engineering jobs.

General concern over the US balance of trade has led to a reorientation of traditional trade theory. It is said that the US thrives on a technological advantage. Consequently, to remain in a strong and competitive position in world trade, the US industry needs a technological advantage over other trading nations. Much has been speculated about the declining technological advantage of the US. Some reports have been published, but the data base leaves much to be desired.

7. Research Needs

7.1. Problem areas. Today, both governments in industrialized and developing countries are making policy decisions in the area of technological development without a reliable data base. The results are conflicting views on both sides. The US government, e.g., suspects US based MNCs of exporting advanced technology to the detriment of its own economy while at the same time the countries that are the beneficiaries of such technology transfers charge the MNCs with selling second hand technology. Only a unified approach centering on the MNCs will clear up this discrepancy.

More specifically, US MNCs have been charged with exporting technology at a faster rate than creating new ones at home.[155] The effect would be a negative one on the balance of trade. Such charges have been substantiated with the use of data that leaves much to be desired.[156] Presently, we cannot answer the question: How much technology is exported by US based MNCs each year?, and: What are the trends of these exports?

Another side of the US based MNCs' transactions is the

---

[155] Kujawa, Duane, ed., American Labor and the Multinational Corporation, Praeger Publishers, New York, 1973.

[156] Boretsky, Michael, US Technology: Trends and Policy Issues, Program of Policy Studies in Science and Technology, The George Washington University, Washington, D.C., 1973.

amount of technology imported. In recent years, some MNCs have created research facilities abroad. Some of the work done in those laboratories is transferred back for us in the US. In addition, MNCs have contracted for licenses with independent foreign companies and acquired new technology for their own domestic use. Similar to the case with exports, no reliable data has been collected on technology imports by US based MNCs. Consequently, we cannot answer questions such as: How much technology has been imported by MNCs on an annual basis?, or: How fast are these imports growing over time?

To our knowledge, no unified analytical framework to study the behavior of MNCs with respect to technology transfer has been developed. We believe the absence of such a model is the cause of the existing limited data base.

Following from the lack of data on both imports and exports of technology, no reasonable estimate of the net amount of retained technology can be made. With the term "net amount of retained technology" we mean that part of the total technology of a country that is only used and available in that particular country. It represents the net technological advantage of that country over the rest of the world. From the point of view of the United States, the net amount of retained technology of the US at any one point in time is equal to the total accumulated technological know-how less that technology made available to other countries. It represents the technological base from which US industry competes in world trade.

In the past, researchers have always treated MNCs as one single category. In other words, a company was categorized to be a MNC or a domestic company, and no further classifications were made. However, some US MNCs have been multinational for decades while others or most of them for that matter, turned multinational within the last ten years. To make intelligent decisions for the future with respect to technology, we have to be able to forecast international technological transactions. Most of our MNCs are "newcomers" and could, therefore, show a different pattern of technological transactions than some of the long established MNCs. Since any presently assembled data base would undoubtedly be dominated by "newcomers," trend extrapolations based on such data would not truly reflect what might happen in the future. Consequently, another problem today is the lack of data broken down as to the "extent of multinationality of companies. We cannot, at present, answer a question such as: Are long established MNCs behaving differently than newcomers to the field?

7.2. Research objectives. This research tries to satisfy four objectives:

(1) Development of a Model
A simple model will be suggested that attempts to describe the flow of technology within MNCs. The model will account for various levels of multinationality among MNCs.

(2) Definition of a Data Base
Using the above model as an analytical framework, a set of data will be defined and described that could be collected from MNCs over time. It will include all relevant data on technology creation, transfer, and implementation. The data units should serve as the common denominator of all forms of technology transfers.

(3) Test of the Model
Data as described under (2) will be collected from a sample of MNCs based in the United States. The proposed model will be compared with the collected data and revisions will be made as necessary.

C H A P T E R II

A MODEL FOR THE ANALYSIS OF TECHNOLOGY TRANSFERS WITHIN MULTINATIONAL CORPORATIONS

1. Definitions

This section contains all relevant definitions of concepts employed in this research study. All terms used later to describe the model and the data base are defined herein. Some of the definitions are directly drawn from the literature survey at the beginning of this paper.

1.1. The concept of the multinational corporation. The definition proposed by Aharoni[1] will be used as a basis of the research. The multinational corporation is defined as: A corporation which controls a multinational cluster operating in a minimum of 5 countries. A multinational cluster is a group of corporations, each created in the country of operation, but all controlled by one headquarters.

Due to the primary interest in manufacturing technology, the term MNC is understood to imply a multinational manufacturer. Consequently, the definition will be expanded to: A manufacturing corporation which controls a multinational cluster of manufacturing and/or assembly plants operating in at least five countries.

---

[1]Aharoni, Yair, "On the Definition of a Multinational Corporation," Quarterly Review of Economics and Business, Vol. II, Autumn 1971.

1.2. The concept of multinationality. When employing the concept of multinationality, an attempt is made to distinguish between MNCs that are more multinational than others. While the classification as a MNC based on operations in five or more countries is basically arbitrary,[2] it has been used as a basis for most of the studies that originated from the Harvard Business School.[3] The disadvantages, however, are considerable when using a simple, dichotomous classification. Rather, this dimension of multinationality needs to be defined further to facilitate the comparison of MNCs among themselves.

According to their multinationality, MNCs are grouped into three categories and then the term "multinationality" is operationalized.

The emergent MNC: Such a corporation is in the process of breaking out of its purely domestic environment to become a MNC. Therefore, companies are considered emergent MNCs if

a. they have not yet reached the state of multinationality as defined in section (1.1.) but have already at least one foreign manufacturing and/or assembly operation, or

b. classify as MNCs as defined in section (1.1.) but have not added many additional foreign operations since being considered a MNC.

---

[2] Aharoni, Yair, op. cit.

[3] Vaupel, James W. and Curhan, Joan P., The Making of Multinational Enterprise, Graduate School of Business Administration, Harvard University, Boston, 1969.

The growing MNC: The growing MNC is a corporation that has passed through the initial stage of an emerging MNC. The multinational operations are expanded considerably as new markets are added. The company does have experience in the international field and has become part of the MNCs "establishment."

The mature MNC: This is a company that has passed through the previous two stages to a point where growth is more gradual and all the important markets are penetrated. The company has been a MNC for some time. It is considered an "old timer" in the field of MNCs. Only very few MNCs have yet reached this third and final stage.

Our next step is to operationalize the concept of "multinationality." The way our definition of a MNC is set up, the number of countries a MNC operates in is one way to operationalize the concept. We could therefore distinguish between MNCs according to how many countries they have plants in and then group the companies into our three groups: emerging, growing, and mature MNCs. We have arbitrarily decided to consider a corporation with one to five countries as an emergent MNC, with 6 to 15 such operations as a growing MNC, and with 16 or more as a mature MNC.

However, as Aharoni pointed out,[4] the number of countries might not be the only criterion to be applied. One could also

---

[4] Aharoni, Yair, Op. Cit.

use the time as a criterion of multinationality. Accordingly, MNCs could be grouped as to how long ago they started with their first manufacturing and/or assembly venture abroad. Up to 7 years after the first foreign venture, a MNC would be considered in the emergent class, between 8 and 15 years from the first foreign venture in the growing class, and any MNC that has operated for 16 years or longer abroad would be considered mature.

A third approach, centering more on technology, would be to classify companies according to the number of formal research organizationas and/or programs abroad. A formal research organization would be defined as any department, group, or center that, as perceived by the MNC, effectively contributes to the MNC's program in research and development. The basic assumption here is that the more multinational a company becomes, the more likely it is to have research conducted in different countries. An emergent MNC is not expected to have any such organizations, with 1 or 2 a MNC is considered in the growing stage, and any MNC with 3 or more is considered mature.

The above three criteria are by no means the only ones, yet they are simple to establish for all MNCs. As a working definition, the three criteria above are operationalized and repeated in the following table.

Table 2-1

Multinationality of MNCs

Type of MNC	Number of COUNTRIES operating in	TIME elapsed since first foreign operation (in years)	Number of RESEARCH ORGANIZA- abroad
EMERGENT	1 - 5	1 - 7	0
GROWING	6 - 15	8 - 15	1 - 2
MATURE	16 or more	16 or more	3 or more

Each MNC will be classified for each of these three dimensions of multinationality. Only one dimension is used at a time for classification so that a MNC could be classified as both an emergent or growing MNC at the same time depending on its development along the three dimensions of multinationality.

1.3. The concept of technology. As the basic definition of technology, Hawthorne's terminology is used:[5] Technology is the application of science to the solving of well-defined problems.[6] It is used to identify purely technical aspects of a product or manufacturing process.[7]

---

[5] Hawthorne, Edward P., The Transfer of Technology, OECD, Paris, 1971.

[6] Ibid., p. 19.

[7] Ibid.. p. 20.

Consequently, technology is restricted to the production and manufacturing process excluding general management technology which is employed to "clarify the vital characteristics of a particular market."[8] The fact that general management technology is excluded from this research does not mean it is not important, but rather it should be made the subject of a separate study. In other words, this research is restricted to production know-how.

One can identify three elements of technology:[9]

> Research (applied), if it is directed towards practical applications of scientific knowledge - in contrast to basic research directed toward increasing scientific knowledge.
>
> Development is the systematic use of knowledge gained from research for the production of useful materials, devices, systems, methods, or processes, exclusive of design or production eingineering.
>
> Engineering is concerned with actual construction, assembly, layout, testing of models for pilot processes and procedures - to produce a system that will work.

Above terms will often be used in their abbreviated form of R (research), D (development), and E (engineering).

1.4. The concept of technology Transfer. The term technology is used in the same sense as defined in the preceding

---

[8] Ibid., p. 20.

[9] US International Firms and R,D, and E in Developing Countries, National Academy of Sciences, Washington, D.C., 1973, p. XV.

section. A transfer is considered as a fact when technology is moved across national borders. Consequently, technology transfer can now be defined as: any element or combination of R, D, & E transferred across national borders.

What constitutes a transfer? The assumptions underlying the concept of technology transfer are crucial for this study. Research, development, and engineering are added in this very sequence to form the final product - industrial know-how. Whenever technology is transferred, the last stage in the cycle is considered as transferred only. In other words, when a research laboratory in France researches and develops a new product and the result is transferred to the United States, only the D portion of the total effort is considered transferred. Equally, if a new product is completely researched, developed, and designed for production in the United States and then transferred for manufacturing in France, only the last (E) part of technology enters as a transfer. Consequently, R, D, or E can be considered as transferred in the following cases:

> Transfer of R: Research (R, as defined above) transferred across national borders with the implied aim of further development in a different research center.
>
> Transfer of D: Development effort (together with previous R) transferred across national borders for preparation for production.
>
> Transfer of E: Technology transferred across national borders after engineering effort has been added to previous R and D with the aim of producing in a foreign plant.

Consequently, whenever a "production-ready" system is transferred, only the E portion of the total technology is considered transferred.

The justification of this assumption can best be explained using the transfer of a production-ready system as an example. When such a system is transferred from Country A to a subsidiary manufacturing plant in Country B, the one important aspect is engineering (E) - the system that works. Subsidiary B will only be able to produce according to the E technology, or exploit the E portion only. While R & D are incorporated into the product idea, the subsidiary cannot exploit either R & D because it lacks resources and know-how. Basically, while technology is combined by subsequently adding R to D and then E, it is usually diffused by transferring first E, then D, and last R.[10]

1.4.1. Measurement of technology transfer. Any measurement used should qualify as the common denominator for technology content of the three modes as defined in the following section. In other words, a correct measure has to be applicable for measuring technology content of direct foreign investment, licensing agreements, and transfer of research results.

---

[10] National Academy of Sciences, US International Firms and R,D, & E in Developing Countries, Washington, D.C., 1973.

For this reason, it is felt that engineering man/time invested in R, D, and E would best serve as the common denominator. Time could be expressed as either hours, months, or years spent by scientists and engineers on the development of any given technology.

However, the availability of data on technology transfers is limited, and cooperation from MNCs on this basis could not be obtained. Therefore, it was decided to use the number of transactions as a common denominator for the data collection. Naturally, there are severe limitations attached to transactions since not all transactions or transfers have the same technology content or worth. In the course of this study, weights are introduced from generally accepted industry data that take the importance of the many transactions into consideration.

Historically, economists have always measured technology in monetary terms.[11] However, one would have to assume that given two investments of $10 million each, the technology content transferred would be equal, which is not necessarily so. Furthermore, the use of monetary terms in the measurement of licensing fees is only justified when such fees are

---

[11] Boretsky, Michael, US Technology: Trends and Policy Issues, Program of Policy Studies in Science and Technology, The George Washington University, Washington, D.C., 1973.

based on the true value of the technology transferred. There is sufficient evidence to believe that this is not the case.[12]

1.4.2. Modes of transfer. The following modes of technology transfer are considered:[13]

> Direct foreign investment and manufacture. With any new investment, the technology to produce has been transferred from the headquarters' unit to the new venture.
>
> Licensing agreements, know-how contracts, or patent exchanges. These are a very common form of transfer of technology. Together with appropriate instructions, blueprints, and other technical assistance on the part of the seller that assure exploitation of the know-how for a fee rather than export the products manufactured in the United States.[14] In most cases, the production knowledge is transferred. Licenses have been granted to MNCs' subsidiaries and other, non-related foreign firms.
>
> Research results. They are transferred among different laboratories of the MNC. This often includes the R and D portion of production technology. Some MNCs have only centralized laboratories for R and D, then transfer the result, and finally have E done locally in the plant where final production is to occur.

---

[12] US Senate Committee on Finance, "Implications of Multinational Firms for World Trade and Investment and for US Trade and Labor," US Government Printing Office, Washington, D.C., 1973.

[13] Quinn, James B., Harvard Business Review, "Technology Transfer by Multinational Companies," November-December 1969, pp. 147-161.

[14] Boretsky, Michael, op. cit.

2. The Model

<u>2.1 Focus of the model</u>. This model of technology transfer attempts to describe a pattern that is expected to be found in most MNCs. It is based on existing data and publications in the field of research management.

Focus of the model is the MNC and its headquarters location. In other words, for a US based MNC we are concentrating on transfers between the corporate entity in the United States on the one side and all other subsidiaries abroad on the other side. Any transfers of technology from the headquarters country to a subsidiary abroad are considered an <u>export of technology</u>. Conversely, any transfer from a subsidiary abroad to the headquarters country is registered as an <u>import of technology</u>. Imports and exports of technology give us the total level of technological transactions or, in our terminology, technology transfer. Again, only transfers <u>within</u> the MNC are considered. All transactions with independent foreign firms are excluded from our analysis.

The three following hypothetical cases describe verbally a typical MNC as going through the three stages of development. The model is then further extended using these three cases as a basis.

<u>Case 1: The emerging MNC</u>. Let us assume company Z is a completely domestic corporation in the United States. It produces an advanced product that could sell well abroad.

After initial exports from the US, company Z decides to open a plant in Brazil. The effect is the transfer of the E element of the total technology company Z assembled to produce its hypothetical product in the US. This same process is repeated with subsidiaries in other countries. Consequently, the beginning stage of any MNC is characterized with a high E content of its total technology transactions. This is the case of the emerging MNC.

Case 2: The growing multinational corporation. Let us assume, corporation Z is now MNC Z according to our definition in Section 1.1. of this chapter because it has now six or more countries with manufacturing subsidiaries. Over time, these subsidiaries will achieve considerable knowledge in production engineering. With growing sophistication, the parent company need not to do E for all its subsidiaries any more. The MNC has reached a stage where subsidiaries have become self-sufficient in engineering and where technology transmitted is characterized by a high D content. This is the case of the growing MNC.

Case 3: The mature multinational corporation. The MNC Z has been in worldwide business for quite some time, now. More subsidiaries have been added. Due to the growing sophistication of its affiliates, research and development organizations or departments are added in some foreign affiliates. In many instances, subsidiaries are able to develop and engineer new products or systems based on research results only.

This is the case of the mature MNC.

2.2. The degree of multinationality and technology transfer. Multinationality as defined in Section 1.2. of this chapter is considered the independent variable affecting technology transfers. Therefore, we write as the beginning relationships:

$$R = f(M) \tag{1}$$

$$D = g(M) \tag{2}$$

$$E = h(M) \tag{3}$$

where R = total research transactions

D = total development transactions

E = total engineering transactions

M = multinationality

where $M = l_1$ (countries) (4a)

$= l_2$ (time) (4b)

$= l_3$ (research org.) (4c)

as defined in section 1.1. and Table 2-1

Since

$$T = R + D + E \tag{5}$$

where T = total technology transfers (exports plus imports)

we can write

$$T = k(M) \tag{6}$$

Equations (1), (2), (3) describe the composition of a MNC's technology transfers while equation (6) defines the total amount of technological transactions. Equation (6), however, does not explain anything yet because existing research already shows that the more multinational a corporation becomes the more likely will it get involved in technology transfers across national borders.

Previously, in Section 2.1., we defined MNCs as going through three stages to reach full "multinationality". From the above three cases we can now conclude that multinationality (M) affects the composition of technology transfer with respect to what element (R, D, and E) predominates. From equation (1), (2), (3), and (5) we conclude

$$\frac{R}{T} = f(M) \qquad (1a)$$

and

$$\frac{d\frac{R}{T}}{dM} = >0$$

As a MNC becomes more multinational, the percentage of R as compared with total technology transfers will increase.

Similarly,

$$\frac{D}{T} = g(M) \qquad (2a)$$

with

$$\frac{d\frac{D}{T}}{dM_e} < \frac{d\frac{D}{T}}{dM_g} > \frac{d\frac{D}{T}}{dM_m}$$

where the subscripts e, g, and m denote the three stages of development of a MNC,

where e = emergent stage

g = growing stage

m = mature stage

The model postulates here that D's share of total technology transfer will be greatest in the trowing stage of a MNC. This is based on the assumption that as a MNC moves through its development cycle its foreign subsidiaries will have mastered the engineering portion of the new technologies and simultaneously gained experience in development work. This enables the MNC to transfer new technologies at the D level with the E content added locally.

For engineering, we hypothesize

$$\frac{E}{T} = h(M) \qquad (3a)$$

with

$$\frac{d\frac{E}{T}}{dM} < 0$$

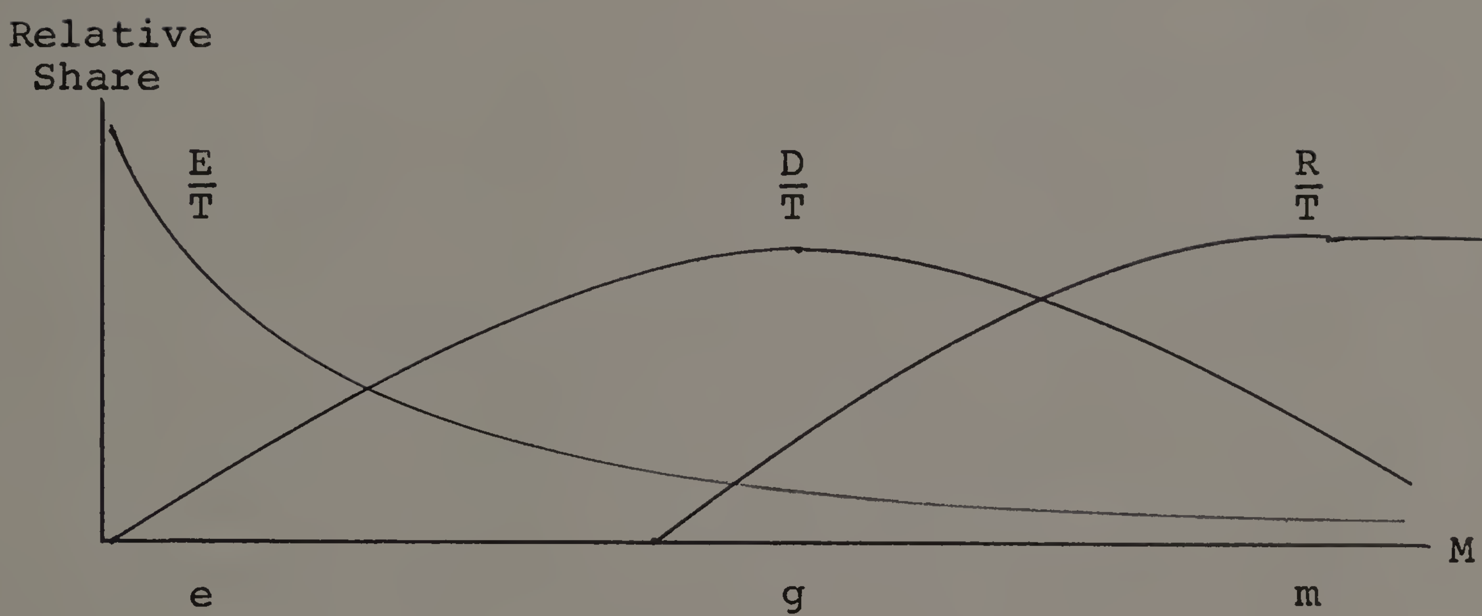
With the growing development of the MNC through the three stages, E's share of total technology transfers will decline.

We can illustrate the contents of equations (1a), (2a), and (3a) graphically. However, we do not know the exact mathematical relationships between the dependent variables (R, D, E, T) and the independent variable M. Consequently, the curves used in the following illustration are not meant to postulate any specific relationship. Rather, they are meant to illustrate the mathematically defined relationships for our convenience.

Graph 2-1

Relative Share of R, D, and E of

Total Technology Transfers T



At the present stage of the model, it is more difficult to describe the behavior of the absolute level of technology transferred over the development cycle of a MNC. We hypothesize that while technology transfers will grow in absolute terms, its relative growth will vary according to the development stage of the MNC.

Extending from equations (1), (2), and (3) we write for research transactions

$$\frac{dR}{dM} = >0 \qquad (1b)$$

The absolute level of development transfers is written as

$$\frac{dD}{dM} > 0 \qquad (2b)$$

and finally, engineering transfers are postulated as

$$\frac{dE}{dM} < 0 \qquad (3b)$$

Both the absolute level of R and D transactions are expected to rise over the development cycle of the MNC. Since only going operations will be analyzed, the dimension M is limited to such MNCs only. Any hypothesis about the level of technology transfer when $M = \infty$ is considered beyond the scope of this present model.

The patterns of transfer for E are expected to differ from the patterns for R and D. After the first and initial rush of E into newly formed subsidiaries abroad, the absolute level of E will most likely decline.

2.3. Degree of multinationality and export of technology. We now turn to formalizing the pattern of technology exports within a MNC. Again, we first extend the model from our original relationships (equations (1), (2), and (3)):

$$R_x = f(M) \tag{7}$$

$$D_x = g(M) \tag{8}$$

$$E_x = h(M) \tag{9}$$

where x = exports as defined in section 1.4. with the addition of transfer of technology from the MNC's headquarters to any of its subsidiaries abroad.

Analogous from equation (5) follows:

$$T_x = R_x + D_x + E_x \tag{10}$$

and from equation (6)

$$T_x = k(M) \tag{11}$$

where M is defined as in equations 4a - 4c.

The three cases from the preceding section are invoked again to describe a MNC going through its 3 stages of development.

Consequently, following (1a) we write the share of R_x with respect to T_x as

$$\frac{R_x}{T_x} = f(M) \tag{7a}$$

where

$$\frac{d\,\frac{R_x}{T_x}}{dM} > 0$$

We are stating that a MNC, over its development cycle, will tend to increase its R_x content of its total T_x. In other words, only mature MNCs will show a large ratio of R_x relative to its total technology exports. This development is based on the assumption that the mature MNC has over time installed significant technological capability at the E and D level to carry on those later stages of technology locally and decentralized.

On the behavior of the D_x content we say

$$\frac{D_x}{T_x} = g(M) \tag{8a}$$

and

$$\frac{d\,\frac{D_x}{T_x}}{dM_e} < \frac{d\,\frac{D_x}{T_x}}{dM_g} > \frac{d\,\frac{D_x}{T_x}}{dM_m}$$

In other words, the development content of total technology exports will be the greatest in the middle stage of a MNC. The underlying assumption is that in its initial period the MNC established a competent engineering function in its subsidiaries abroad that from now on do engineering in subsidiaries locally. Therefore, technology can be transferred at the developmental level.

On the pattern of engineering exports we theorize, similar to (3a), that

$$\frac{E_x}{T_x} = k(M) \tag{9a}$$

and

$$\frac{d\,\frac{E_x}{T_x}}{dM} < 0$$

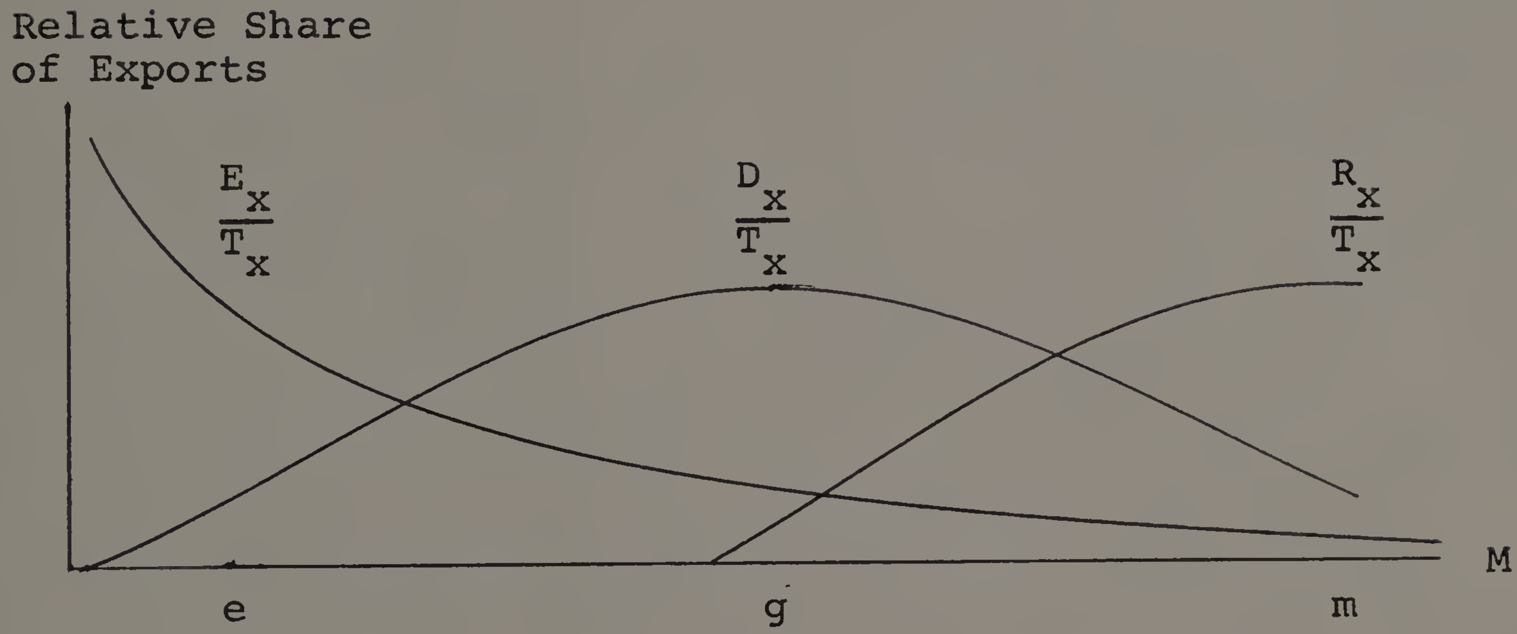
The ratio of E_x with respect to total technology exports T_x will decline over the development cycle for any MNC.

We can now illustrate these relationships graphically. Again, the functional forms used in this graph are used for convenience only and do not reflect the true relationships.

On the absolute level of technology exports, as expressed in equations (7), (8), and (9), we are assuming that each of the three elements will grow over the whole development cycle of a MNC, but that they show different growth rates in each development stage.

Graph 2-2

Relative Share of R_x, D_x, and E_x With Respect to Total Technology Exports



For R_x we say that there is little growth over the emerging and growing stage. The highest level of R_x will be attained when the MNC reaches the mature stage. Consequently, extending from (7) we write

$$\frac{dR_x}{dM} > 0 \qquad (7b)$$

where

$$\frac{dR_x}{dM_e} < \frac{dR_x}{dM_g} < \frac{dR_x}{dM_m}$$

Similarly, we can state in absolute terms that D_x will increase with higher M, but D_x will reach its peak at the growing level or one stage before R_x does. From (8) follows therefore

$$\frac{dD_x}{dM} > 0 \qquad (8b)$$

where

$$\frac{dD_x}{dM_e} < \frac{dD_x}{dM_g} > \frac{dD_x}{dD_m}$$

We now extend the same analysis to the export of engineering, E_x, and write based on equation (9)

$$\frac{dE_x}{dM} > 0 \qquad (9b)$$

and

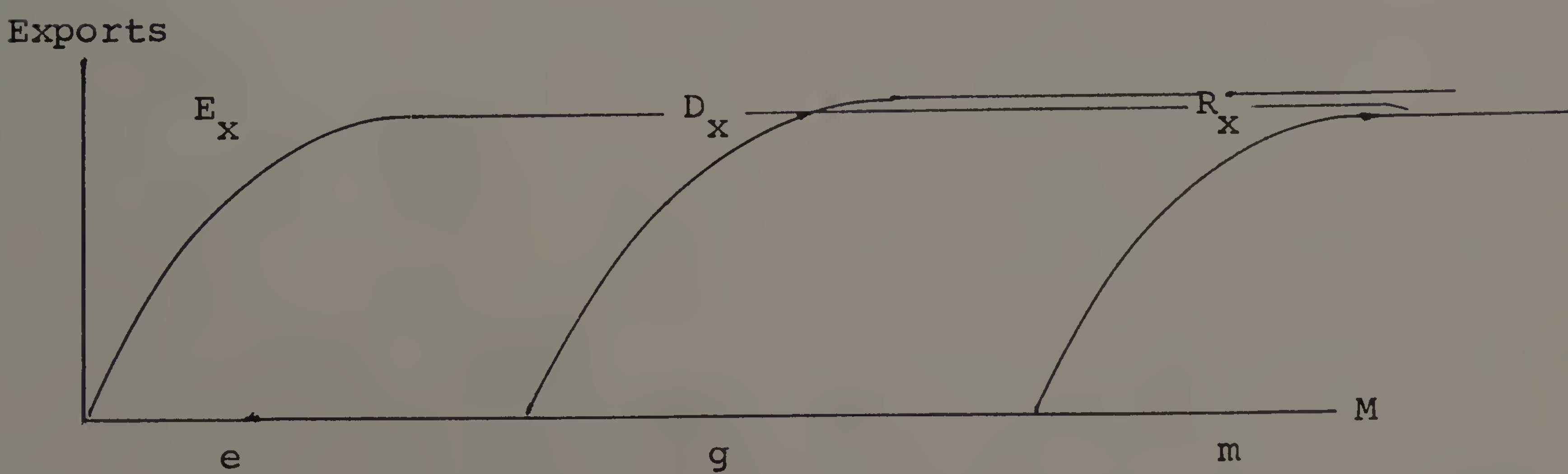
$$\frac{dE_x}{dM_e} > \frac{dE_x}{dM_g} > \frac{dE_x}{dM_m}$$

implying that the rate of growth of E_x declines over the development cycle of a MNC because more subsidiaries are self-sufficient concerning their engineering needs. We can represent these relationships in a graph. As before, the curves in this graph have been chosen for convenience only.

Graph 2-3

The Absolute Level of Technology Exports

as a Function of M



The same form of analysis can be extended to the total level of technology exports, T_x, adapting equations (10) and (11) to

$$\frac{dT_x}{dM} > 0 \qquad (11a)$$

We are expecting total technology exports will increase as the MNC develops into a mature company.

2.4. The degree of multinationality and import of technology. We shall now try to develop a pattern for the import (i) of technology within the MNC. Import is used as a transaction of technology (as defined in section 2.1. of this study) with the additional meaning of a transaction originating outside the borders of the headquarters location to the headquarters country of the MNC. At first, we again assume the degree of multinationality as our independent variable, writing our key functions

$$R_i = f(M) \qquad (12)$$

$$D_i = g(M) \qquad (13)$$

$$E_i = h(M) \qquad (14)$$

where i = imports.

From our original relationship, equation (5), follows

$$T_i = R_i + D_i + E_i \qquad (15)$$

and similar to equation (6)

$$T_i = k(M) \qquad (16)$$

where M is defined as in equations (4).

Again, the MNC is assumed as going through the three stages as developed in Section 2.1. of this chapter. First, we theorize on the various contents of each technology transaction with respect to total technology imports. We say that early in its development cycle a MNC does have little foreign R capability. Therefore

$$\frac{R_i}{T_i} = f(M) \tag{12a}$$

and

$$\frac{d\,\frac{R_i}{T_i}}{dM} > 0$$

implying that the percentage (or relative share) of R_i will increase with the development of the MNC. The percentage will be at its maximum in the mature stage. For D_i we assume initially a relatively low level, but increasing as the MNC reaches the growing stage. We write

$$\frac{D_i}{T_i} = g(M) \tag{13a}$$

and

$$\frac{d\,\frac{D_i}{T_i}}{dM_e} < \frac{d\,\frac{D_i}{T_i}}{dM_g} < \frac{d\,\frac{D_i}{T_i}}{dM_m}$$

We expect D_i/T_i to reach its maximum in the growing stage of a MNC.

The content of E_i with respect to T_i is expected to behave as follows:

$$\frac{E_i}{T_i} = h(M) \qquad (14a)$$

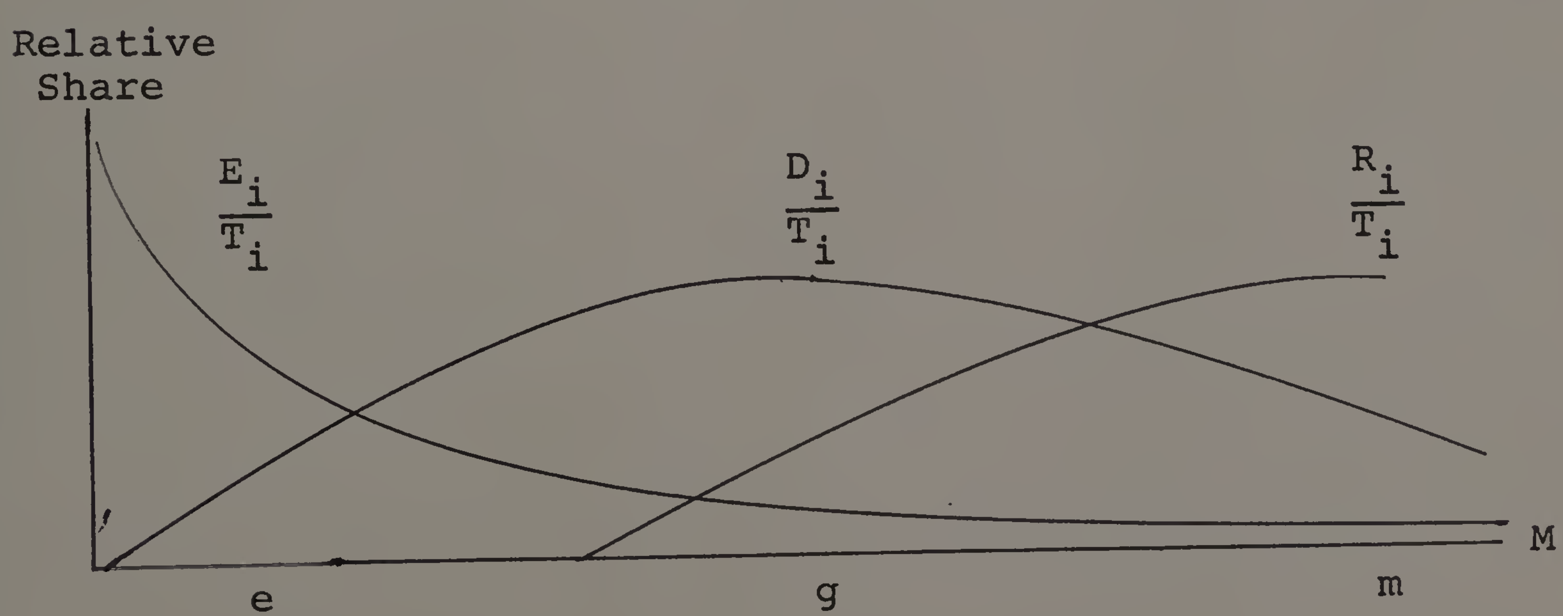
and

$$\frac{d\,\frac{E_i}{T_i}}{dM} < 0$$

With the MNC reaching a higher level of technological sophistication, its subsidiaries are more likely to participate in projects at the D and R level. This will lead to an increased number of feedbacks at these higher technological levels eventually causing a decrease in E_i share of total imports. All of the preceeding relationships are graphed in Graph 2-4.

Graph 2-4

Relative Share of R_i, D_i, and E_i With Respect to Total Technology Imports



As far as the absolute level of technology imports are concerned, they are assumed to increase considerably with the development of the MNC. Following from the previous section we expect E_i to grow strongly in the emergent stage, D_i in the growing stage, and R_i in the mature stage. Based on the initial equations (12), (13), and (14) we stipulate for R_i

$$\frac{dR_i}{dM} > 0 \qquad (12b)$$

and

$$\frac{dR_i}{dM_e} < \frac{dR_i}{dM_g} < \frac{dR_i}{dM_m}$$

On the development imports, D_i, we say

$$\frac{dD_i}{dM} > 0 \qquad (13b)$$

and

$$\frac{dD_i}{dM_e} < \frac{dD_i}{dM_g} > \frac{dD_i}{dM_m}$$

and for engineering imports we state the model as

$$\frac{dE_i}{dM} > 0 \qquad (14b)$$

and

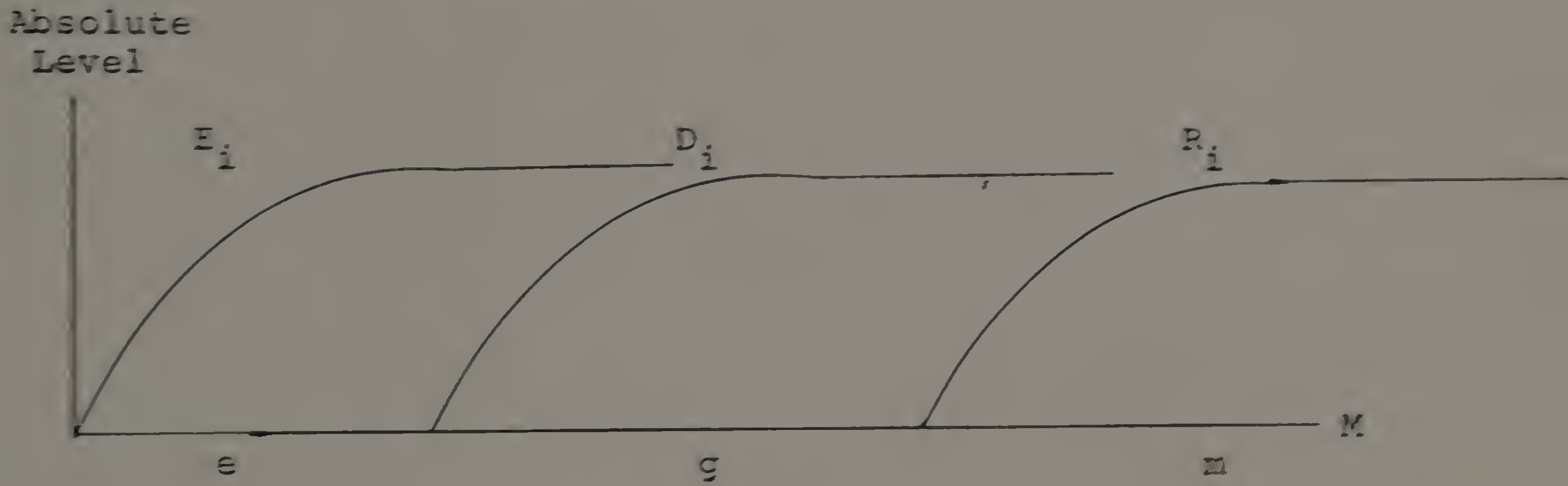
$$\frac{dE_i}{dM_e} > \frac{dE_i}{dM_g} > \frac{dE_i}{dM_m}$$

Here the graphical display of our analysis:

Graph 2-5

Absolute Level of Technology Imports

as a Function of M



Incorporating into equations (15) and (16) this latest part of our anlaysis, we write on the absolute level of T_i

$$\frac{dT_i}{dM} > 0 \qquad (16b)$$

<u>2.5. The balance of technology within the multinational corporation</u>. In Section 2.3. we described the behavior of technology exports, and imports were discussed in Section 2.4. Combining the two, we can arrive at the MNC's balance of technology. The basic issue here becomes whether an equilibrium position exists.

Based on Cases (1), (2), and (3) as described previously, a MNC will develop import capacity for technology over its development cycle. Imports will be growing with a lag required due to the start-up period of technological capacity abroad. We therefore state the following relationships:

$$E_x^e > E_i^e$$

$$D_x^g > D_i^g$$

$$R_x^m > R_i^m$$

where e = emergent MNC

g = growing MNC

m = mature MNC

x = exports

i = imports

In other words, while engineering transactions dominate in the emerging stage, engineering exports will be larger in absolute terms than engineering imports. The same holds true for development transactions in the growing stage and research transactions in the mature stage.

Consequently, if large exports of technology are initially required to build up the MNC's affiliates, and imports become possible only after such capacity has been developed, a MNC can be considered a net technology exporter at first and gradually move towards a balanced position when imports become possible in the mature stage.

Symbolically, we can write the following relationships:

$$T_x = k(M) \qquad \text{from (11)}$$

and

$$\frac{dT_x}{dM} > 0 \qquad \text{from (11a)}$$

Imports defined as

$$T_i = k(M) \qquad \text{from (16)}$$

and

$$\frac{dT_i}{dM} > 0 \qquad \text{from (16a)}$$

Combining we have

$$T_x - T_i = k(M) \qquad (17)$$

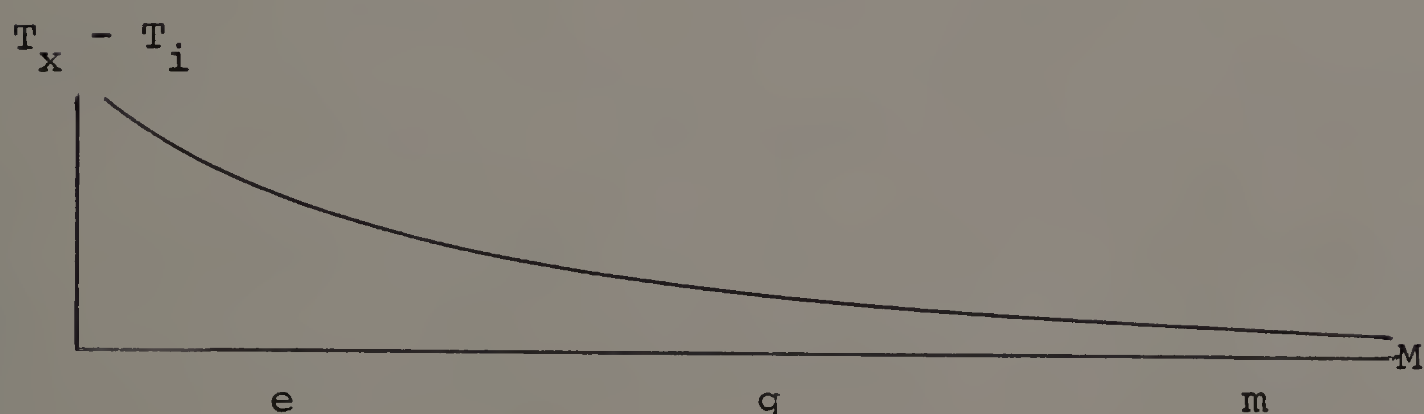
with

$$\frac{d(T_x - T_i)}{dM} < 0 \qquad (17a)$$

Graph 2-6 illustrates the relationship stipulated in 17 and 17a.

Graph 2-6

The Balance of Technology Within a MNC as a Function of M



We can extend this analysis to the three elements of technology likewise (R, D, and E). By now the reader will be able to follow this analysis without further elaboration.

Our main assumption is that a MNC reaches a balanced position after full development, i.e. $T_e = T_i$.

2.4. Data analysis.

2.4.1. Preparing collected data for quantitative analysis. In Appendix I we have described all the data collected from our sample of MNCs. All transactions have then been scored according to their level (R, E, or E respectively). For each MNC sampled, the relative span of observation with respect to the independent variable of multinationality (TIME, COUNTRIES, RESEARCH ORG.) was determined. Then, for each data point of the independent variable, the relative transfers have been entered. This procedure has been duplicated for both technology exports and imports. The results are shown in Appendix II for each company (see Section 1.1. Total transactions).

By comparing exports and imports in the above explained manner, most technology exports are counted repeatedly because a given technology could be exported to all countries within the MNC's subsidiary network. Imports, however, would only be counted once, the time the initial import to the US is made. To account for this discrepancy, all data has been adjusted to prevent duplication. This adjusted data actually no longer represents technology transactions, but technologies transferred. This adjustment is extremely important when the data is later used to analyze a balance of technology transactions where imports are subtracted from exports. The result of this data adjustment is shown in Appendix II, Section 1.2., for each MNC in the sample.

The data contained in Appendix II was then operationalized in a third step for the purpose of a quantitative data analysis. The following four transformations were made under this step:

(1) All transactions were scored according to their level

E=1
D=2
R=3

This scoring was necessary to trace the level of technology transactions through the sample and over the dimensions of multinationality.

(2) All data (transactions) was combined across the entire sample for any of the three given dimensions of multinationality.

(3) For each dimension of multinationality it was recorded how many MNCs have been observed for each data point along the independent variables.

Steps 1 through 3 have been separately performed for technology exports, imports, and total transfers (exports plus imports). In addition, this operation was performed separately for total transfers and adjusted transfers. The results are displayed in Appendix III and IV.

(4) Composing a data matrix by dividing data gathered under (2) by the number of MNCs observed as recorded under step (3).

Since there are three dimensions of multinationality and two sets of data, adjusted and non-adjusted, the results are

6 different data matrices as displayed in Appendix IV.

2.4.2. Method of data analysis. For all of the following computational analysis, a linear regression procedure has been selected. While in some instances curvilinear regressions might have provided a better fit, it was felt that due to the exploratory nature of this research linear regression would be the best method to start with. Furthermore, special curves could have been fitted with considerable success to the existing data, but it was felt meaningless to proceed with such a refined approach given the inherent errors in our data as well as given the fact that we do not have a probability sample. All computations have been performed using the Statistical Package For the Social Sciences (SPSS) subprogram REGRESSION.[15]

The model underlying the data analysis can be written as

$$Y = b_0 + b_1 X + e$$

where Y = R, D, E, T

R_x, D_x, E_x or T_x

R_i, D_i, E_i, or T_i depending on the specific equation,

b_0 is the intercept or constant,

b_1 is the rate of change (or slope), and

X denotes the degree of multinationality (M) corresponding to either TIME, COUNTRIES, or RESEARCH ORG.

---

[15] SPSS: Statistical Package for the Social Sciences, pp. 174-195, op. cit.

As an example, the model is used to test equation [1] at the beginning of the following chapter. The equation is written as:

$$R = f(M) \quad (1)$$

and

$$\frac{dR}{dM} > 0 \quad (1b)$$

The data used for this regression can be found in Appendix III and IV. The equation is tested for each of the three dimensions of multinationality as well as adjusted and non-adjusted data. The specific data to test equations [1] and [1b] for TIME as multinationality and using non-adjusted data base is found in Appendix III under the heading "Technology Transfers as a Function of Time: non-adjusted data." Variable 1, called "Time" at the top of the page, represents the independent variable for our regression equation. The dependent variable R, total research transactions, is found in row 5. This represents the raw score of all transactions for any given time (T = 0,1,.......,75) divided by the number of MNCs observed for each year (to be found in row 38, the bottom row of that page). Consequently, row 1 becomes the independent variable and row 38 the dependent variable.

Similarly, the other 5 sub-equations in Table 4-1 were derived from different data matrices, all part of Appendix III and IV. The dependent variable, R, was used all six times and can be found as Variable 5 in all the tables of the appendix. The independent variables have been changed and can always be found as Variable 1 in all of the tables of the appendix.

This results in a linear regression model of

$$R = b_0 + b_1(M) + e$$

Again, using the results as presented in Table 4-1, Chapter IV, the first row contains the result using TIME as the independent variable M. Including those results, the regression equation can be written as

$$R = b_0 + 0.00040M + e$$

For the purposes of this research, the constant has not been reported since it has no bearing on the test of the model's equations. The b_1 is equal to the "B" in all tables contained in Chapter IV.

The subprogram REGRESSION has been used despite the fact that actually a stepwise procedure or a multiple regression procedure were not needed. However, the SPSS program includes only those variables in its computation that are actually included in any one run, yet a whole set of variables can be specified at the outset. This resulted in a considerable savings both in computing time and preparation time. Furthermore, the selected program offers an additional feature (R^2, etc.) not available with a simple correlation program.

CHAPTER III

RESEARCH METHODOLOGY

1. Resource Restrictions

Due to limited resources it was not possible to carry out a complete test of the model involving a sample of all MNCs currently operating around the globe. This research was therefore restricted to US based MNCs only, and, more precisely, to a test using a small sample of US based MNCs.

2. Research Design

<u>2.1. Sample design</u>. Because of the complexity of the study, a convenience sample of MNCs located in the New England area was chosen. All companies were willing to cooperate. The adopted sample selection procedures has severe limitations with respect to a possible generalization beyond the sample. However, with a random sample the non-response error would have been so significant that, again, the study could not have been generalized beyond the sample of participating MNCs.

The cooperation of 11 MNCs located in New England was obtained. One company, consisting of four large and independent divisions in unrelated industries has been divided into four independent "MNCs." This was felt necessary due to the divisions and the decentralized management organizations allowing the divisions to operate similar to an independent MNC. This decision to split up the company was made before the data was collected. As will be pointed out later, a different way of accounting for the transfers (e.g. under one corporate umbrella) would have affected the outcome of the study to make it more favorable to the model. Consequently, data was collected on 14 MNCs from different industries and with different degrees of multinationality. The following industries are represented:

Scientific measurement instruments	1
Chemicals	3
Paper	1
Machinery	2
Aerospace	1
Fabricated metal products	1
Electronics	2
Stone, Clay, Glass products	1
Other manufactures	1

4 of the companies were in consumer products and 10 were active in industrial markets.

The sample also contained MNCs with various degrees of multinationality. Many of these companies have been observed over a timespan of 6 years, while others supplied data covering their first and their last foreign ventures. As of 1974, the companies in the sample can be classified as follows:[1]

---

[1]See Chapter II, Section 1.2., Table 1 for further definitions of above dimensions of multinationality.

Table 3-1

Type	Degree of Multinationality TIME	COUNTRIES	RESEARCH ORG.
Emerging	1	5	4
Growing	3	6	3
Mature	10	3	4
	14	14	14

However, this breakdown does not take into consideration the fact that many MNCs, particularly those classified as growing, have also been observed in their emerging state.

The following Table 3-2 gives a more detailed breakdown by individual companies. Most MNCs have asked us to disguise their names and to protect the often confidential data they have shared with us.

Table 3-2

Classification of MNCs in Sample According to Multinationality

Company	TIME	COUNTRIES	RESEARCH ORG.
1. Sprague Electric	3	3	3
2. New England Computer Co.*	2	1	1
3. Consumer Chemical Co.*	3	1	3
4. Industrial Supply Co.*	3	3	3
5. Office Supply Co.*	1	1	1
6. Aerospace International*	2	2	3
7. International Co.-Chemical Div.*	3	2	3
8. International Co.-Machinery D.*	3	2	3
9. International Co.-Heavy Mach.*	3	1	2
10. International Co.-Ind.Supplies*	3	2	3
11. Multinational Paper Co.*	3	2	1
12. Gillette Co.	3	3	1
13. International Photo Equipm.Co.*	2	1	1
14. International Instruments Co.*	3	2	2

*Name disguised 1=emerging MNC 2=growing MNC 3=mature MNC

Based upon the data presented in Table 3-2, Pearson correlation coefficients have been computed.[2] The results are contained in Table 3-3.

Table 3-3

Pearson Correlation Coefficients
Among Dimensions of Multinationality

Dimension	TIME	COUNTRIES	RESEARCH ORG.
TIME		0.5181 (.058)	0.5540 (.040)
COUNTRIES	0.5181 (.058)		0.4954 (.072)
RESEARCH ORG.	0.5540 (.040)	0.4954 (.072)	

level of significance in parentheses

As could be expected from the model, there is a strong and significant positive correlation among the three dimensions of multinationality. This is interpreted as an indication of the internal consistency of the method chosen to categorize the MNCs into three stages along our three dimensions.

2.2. Data collection. All data has been collected through personal interviews with executives of the partici-

---

[2]The PEARSON CORR program was used from Nie, Norman; Bent, Dale H.; and Hull, C. Hadlai, SPSS: Statistical Package for Social Sciences, McGraw-Hill, New York, 1970, pp. 145-153. Since the underlying data to each classification are ratio scaled, the Pearson program was selected rather than a non parametric program. E.g., it is possible to say that, using COUNTRIES as a dimension of multinationality, that a MNC ranked mature is 3 times a multinational as a company ranked emerging (1).

pating companies. The executives were mostly from high level staff positions or from the international divisions of the company. In some cases, the director of research and development was interviewed. All interviews took place in the period July 1974 to January 1975.

To facilitate the free exchange of information, no use of a questionnaire was made during the interview. However, during the course of our conversations, all required subjects were covered. In some cases, annual reports and other company material were used to supplement information by company executives.

During the interviews, the following data was collected on all companies:

(1) First Foreign Operation. The year of the first foreign operation (implies production facility) has been used to categorize the company along the dimension of time. In all but four companies exact data was available. For the others, the estimates made by the researcher are based on company informations and are accurate within 2 or 3 years. In no instance has this seriously affected the analysis.

(2) Countries with Production Facilities. The MNCs were asked to list all the countries where production operations are maintained. For each country, the MNCs were asked for the year of first entry. This was important since in many cases a company had more than one plant in a particular country.

In some cases where only the last few years of the company were observed, the years of entry of new, additional countries only were collected. For example, International Co.'s Industrial Supply Division has been observed over the last 7 years of its operations. Consequently, the 7 country-subsidiaries the division operated at the outset were not listed as to the year opened, but the new country added during the fifth year of the observation span is listed with the data.

Furthermore, all countries were given a technological rating as to their capabilities. Executives were asked whether subsidiaries were able to do their own research, development, and engineering. A country-subsidiary rated R (for research) has reached the highest level of technological capabilities and is automatically assumed to do also D and E level work. In many of these cases, the data reflects the best judgement of the respective executive where a certain country falls within the three types of technological capabilities.

(3) Research Organizations. The executives were asked to name those countries where their company maintains R and D level facilities. In some cases, judgement of both the executive and the researcher was used to estimate the year a particular subsidiary reached a given level of technology.

(4) Technology Exports. The next step amounted to a list of all technology exports of "some importance." The

data reflects dependence on the executives' perception of importance. That was required in those instances where whole product lines were transferred consisting of a multitude of small items. Also, insisting on "all" transactions would have included the small, continuous transactions that are extremely difficult to report. In addition, since all transactions were treated equally as far as their importance was concerned, the difference in importance among those reported could be minimized.

For all reported transactions data on the year effected was collected. Another important point of information consisted of the level at which the transfer was made. The assigned level, again, reflects the opinion of the executive interviewed given the model's definitions. In all instances, the country receiving the technology has also been listed.

(5) Technology Imports. All data on technology imports were collected using the same format as described under technology exports (4).

The complete set of data collected is contained in Appendix I for each participating MNC.

2.3. Experimental design. A combination of the cross-sectional and time series analysis has been chosen as the basis for our experimental design.[3] This design has been

---

[3] Wentz, Walter, Marketing Research: Management and Methods, Harper & Row, 1972, Chapter 18.

selected because it allows us to combine the short and limited time series of 14 MNCs to be combined into one single series. Using time series analysis for any of our MNCs at a time, we would have lacked the necessary number of observations in most instances.

Before using cross sectional analysis, the problem of heterogeneity in our data had to be solved. Primarily, one had to assume that one technological transaction of, e.g. Gillette, was equal to one of Sprague Electric. As long as one is interested in the number of transactions, or the technological level at which they occur, this is a reasonable assumption.

Furthermore, because we are pooling the data of 14 individual time series, we have to account for redundancy among observations. This occurred because we might have 5 MNCs observed in year 15 and only two in year 16. When comparing raw data, a correct conclusion cannot be made until such data has been normalized by the number of MNCs observed for each data point on the independent variable.

To justify the use of this type of analysis, one last, but crucial, assumption has to be made. We are assuming that the relationships between the variables are constant with respect to time and place. In some instances the actual time differences are substantial among the various observations reported for the same data point on the independent variable.

CHAPTER IV

RESULTS

4.1. The Degree of Multinationality and Technology Transfer

In this section, the relationships developed in Chapter II, Section 2.2. will be tested. The equation numbers correspond to those in the previous section.

Table 4-1

(1) $R = f(M)$ (1b) $\frac{dR}{dM} > 0$

Independent Variable	Correlation Coefficient	R^2	B	Degrees of Freedom	F	Level of Significance
non-adjusted						
TIME	.14681	.02155	0.00040	1,71	1.564	n.s.
COUNTRIES	.21882	.04788	0.00273	1,18	.905	n.s.
RESEARCH ORG.	-.27386	.075	-.00476	1,7	.568	n.s.
adjusted						
TIME	.14681	.02155	.0040	1,71	1.564	n.s.
COUNTRIES	.21882	.04788	.00273	1,18	.905	n.s.
RESEARCH ORG.	-.27386	.075	-.00476	1,7	.568	n.s.

Since there was only one observation of an R transfer none of the equations tested were significant. Furthermore, using RESEARCH ORG. as an independent variable, the correlation is negative instead of positive. This is due to the fact that the observation was recorded in a later stage along the first two variables but not so along RESEARCH ORG. Equations (1) and (1b) are not significantly supported by the data.

Table 4-2

$$(2)\ D = g(M) \qquad (2b)\ \frac{dD}{dM} > 0$$

Independent Variable	Correlation Coefficient	R^2	B	Degrees of Freedom	F	Level of Significance
non-adjusted						
TIME	.28450	.08094	.00566	1,71	6.253	.025
COUNTRIES	-.11360	.01291	-.02021	1,18	.235	n.s.
RESEARCH ORG.	.75352	.56779	.56300	1,7	9.196	.025
adjusted						
TIME	.30010	.09006	.00493	1,71	7.027	.01
COUNTRIES	-.20303	.04122	-.01544	1,18	.774	n.s.
RESEARCH ORG.	.74437	.55408	.43917	1,7	8.698	n.s.

Equations (2) and (2b) have been confirmed as being statistically significant in four of our six cases. Only with COUNTRIES as an independent variable was the relationship found to be nonsignificant. Similarly for the slopes. The reason for this discrepancy lies in the arrangement of our data. One MNC in our sample, the Heavy Equipment Division of International Co., accounts for a considerable level of D transactions with only two countries involved. Consequently, the company ranks as mature both in terms of TIME and

RESEARCH ORG. while with respect to COUNTRIES the observations occur in the emergent state.

Table 4-3

$$(3)\ E = k(M) \qquad (3b)\ \frac{dE}{dM} < 0$$

Independent Variable	Correlation Coefficient	R^2	B	Degrees of Freedom	F	Level of Significance
TIME	.05285	.00279	.00320	1,71	.199	n.s.
COUNTRIES	-.08962	.00803	-.03473	1,18	.146	n.s.
RESEARCH ORG.	-.29757	.08855	-.44700	1,7	.680	n.s.
<u>adjusted</u>						
TIME	-.13808	.01907	-.00302	1,71	1.380	n.s.
COUNTRIES	-.47685	.22739	-.07067	1,18	5.298	.05
RESEARCH ORG.	-.015890	.02525	-.08283	1,7	.181	n.s.

Engineering Transfers showed a mixed pattern. Statistically, only one equation was significant. However, the slopes were confirmed in all but one case. Here, the adjusted data (representing <u>technologies transferred</u>) are more significant than the non-adjusted data (representing <u>technology transfers</u>). This is primarily due to the fact that 3 MNCs (Sprague, Gillette, Industrial Supply Co.) continued to show transfers at the E level despite their mature stage.

Table 4-4

(6) T = k(M)

Independent Variable	Correlation Coefficient	R^2	B	Degrees of Freedom	F	Level of Significance
non-adjusted						
TIME	.15444	.02385		1,71	1.735	n.s.
COUNTRIES	-.12769	.01630		1,18	.298	n.s.
RESEARCH ORG.	.07571	.00573		1,7	.040	n.s.
adjusted						
TIME	.09417	.00887		1,71	.635	n.s.
COUNTRIES	-.42421	.17995		1,18	3.950	.10
RESEARCH ORG.	.53132	.28230		1,7	2.753	n.s.

The exact relationship of (6) could not be determined clearly. One of the six equations is statistically significant, while the others show the opposite slope.

With respect to technologies transferred (adjusted data), it appears that with the addition of further countries the MNCs are introducing new technologies at a considerably slower pace. As the MNC matures, countries are added faster than new technologies transferred. Furthermore, several overseas subsidiaries replace the headquarters as a source of new technologies to the whole system. This is supported by the results T non-adj. = k(COUNTIRES) where even the number of transactions is negatively correlated with the independent variable.

Another explanation for this behavior could be the speed at which new technologies are invented in the first place. While it might be possible to add production facilities in 15 to 20 countries over 10 to 15 years, it appears less feasible to introduce an equal amount of new technologies over the same period of time.

Table 4-5

$$(1a)\ \frac{R}{T} = f(M) \qquad \text{and} \qquad \frac{d\frac{R}{T}}{dM} > 0$$

Independent Variable	Correlation Coefficient	R^2	B	Degrees of Freedom	F	Level of Significance
non-adjusted						
TIME	.14681	.02155	.02622	1,71	1.564	n.s.
COUNTRIES	.21882	.04788	.10752	1,18	.905	n.s.
RESEARCH ORG.	-.27386	.07500	-.03333	1,7	.568	n.s.
adjusted						
TIME	.14681	.02155	.07946	1,71	1.564	n.s.
COUNTRIES	.21882	.04788	.11579	1,18	.905	n.s.
RESEARCH ORG.	-.27386	.07500	-.0333	1,7	.568	n.s.

As already explained under (1), the lack of observations prevented us from arriving at a definitive conclusion for equation (1a).

Table 4-6

$$(2a)\quad \frac{D}{T} = g(M) \quad \text{with} \quad \frac{d\frac{D}{T}}{dM_e} < \frac{d\frac{D}{T}}{dM_g} > \frac{d\frac{D}{T}}{dM_m}$$

Independent Variable	Correlation Coefficient	R^2	B	Degrees of Freedom	F	Level of Significance
<u>non-adjusted</u>						
TIME	.24026	.05772	.41072	1,71	4.349	.10
COUNTRIES	-.08390	.00704	-.31654	1,18	.128	n.s.
RESEARCH ORG.	.81370	.66211	10.650	1,7	13.717	.01
<u>adjusted</u>						
TIME	.20656	.04267	.34887	1,71	3.164	.10
COUNTRIES	-.08361	.00699	-.34361	1,18	.127	n.s.
RESEARCH ORG.	.77371	.59863	10.06667	1,7	10.440	.025

The difficulty encountered to prove relationship (2a) have already been explained under (2). It is interesting, however, that only those relationships that confirm our statement are significant. Generally, it has been confirmed that D transactions tend to comprise a larger share of the technological activity within MNCs as they mature.

Table 4-7

$$\frac{d\frac{D}{T}}{dM_e} < \frac{d\frac{D}{T}}{dM_g} > \frac{d\frac{D}{T}}{dM_m}$$

Independent Variable	EMERGING				GROWING				MATURE			
	Correl. Coeff.	B	d.o.f.	F	Correl. Coeff.	B	d.o.f.	F	Correl. Coeff.	B	d.o.f.	F
non-adjusted												
TIME	0	0			0	0			.06312	.14847	1,55	.220
COUNTRIES	-.13039	-1.37143	1,4	.070	-.03738	-.333	1,8	.011	0	0		
RESEARCH ORG.	tolerance level insufficient for further calculations											
adjusted												
TIME	0	0			0	0			.03632	.08496	1,55	.073
COUNTRIES	-.13093	-1.74286	1,4	.070	.04861	.44848	1,8	.019	tolerance level insufficient			
RESEARCH	tolerance level insufficient for further calculations											

Due to a lack of observations at the various stages of multinationality, a difference between the 3 stages could not be confirmed.

Table 4-8

$$(3a)\ \frac{E}{T} = h(M) \quad \text{with} \quad \frac{d\frac{E}{T}}{dM} < 0$$

Independent Variable	Correlation Coefficient	R^2	B	Degrees of Freedom	F	Level of Significance
non-adjusted						
TIME	-.25437	.06470	-.54326	1,71	4.912	.05
COUNTRIES	-.28950	.08381	-.74586	1,18	1.647	n.s.
RESEARCH ORG.	-.81218	.65964	-10.61667	1,7	13.567	.01
adjusted						
TIME	-.34676	.12024	-.78501	1,71	9.704	.01
COUNTRIES	-.48254	.23284	-3.50902	1,18	5.463	.05
RESEARCH ORG.	-.76525	.58561	-9.9667	1,7	9.892	.01

The percentage of E transactions with respect to all technology transfers has been confirmed as a function of multinationality. 5 out of 6 equations are statistically significant. All slopes are negative as postulated in (3a).

There is a difference, however, between the adjusted and non-adjusted data. Our model predicts better for the adjusted data, implying that as a MNC develops less technologies will be transferred at the E level. The non-adjusted data shows the same trend, but not as strongly. A possible explanation could be found in tracing what happens to technologies once exported at the E level. From our data, it appears that once a MNC starts to transfer a new technology at the E level it will continue to offer it at that level. New technologies, however, are more likely to be transferred at a higher level (D,R) from the outset.

The level of technology transfers. For each observation along the independent variable of multinationality, transactions have been scored such that

E = 1

D = 2

R = 3

and the average technology level has then been computed. According to equations (1a), (2a), and (3a), the average technology level should increase and consequently

$$\text{Level} = p(M) \quad \text{with} \quad \frac{d\ \text{Level}}{d\ M} > 0$$

Table 4-9

Independent Variable	Correlation Coefficient	R^2	B	Degrees of Freedom	F	Level of Significance
non-adjusted						
TIME	.31235	.09756	.00563	1,58	6.270	.025
COUNTRIES	.13838	.01915	.00720	1,14	.273	n.s.
RESEARCH ORG.	.81059	.65706	.10583	1,7	13.412	.01
adjusted						
TIME	.38981	.15195	.00833	1,47	8.421	.01
COUNTRIES	.17706	.03135	.00979	1,14	.453	n.s.
RESEARCH ORG.	.75724	.57341	.09850	1,7	9.409	.025

The results in Table 4-9 confirm the previous results from equations (1a), (2a), and (3a). The average level of technology transfer rises as the MNC develops. All slopes are positive, and 4 out of the 6 equations are statistically significant at the .025 level or better.

Overall, technology transfers have been found to be influenced by the degree of multinationality of a MNC. There are, however, some conflicting results. Of the 7 original equations of our model tested in this section, only 3 could be found statistically significant. This is based on the majority of the sub-equations (when e.g. at least 4 of the 6 subequations are found statistically significant). A total of 42 sub-equations were tested of which 14 were found to be statistically significant in support of our model. Only one of the 42 sub-equations was found to be statistically significant and negating our model.

For 6 of the 7 equations we also postulated slopes. Of these, all have shown a majority of the sub-equations with slopes as expected, and of the 36 sub-equations tested, only 5 had slopes with the opposite sign.

In general, adjusted transfers tended to be more significant with 8 of the 14 significant sub-equations. However, there are no conflicts between the two sets of data among the equations tested.

The three dimensions selected to predict technology transfers did not perform with the same reliability. The variables TIME and RESEARCH ORG. performed considerably better than COUNTRIES. However, as has been previously mentioned, this is primarily due to D level transfers. These results are detailed in Table 4-10.

Table 4-10

Reliability of Dimensions of Multinationality to Predict Total Technology Transfers

Dimension	Statistically Significant proving model	Statistically Significant negating model	Confirming Slope	Opposite Slope
TIME	6	0	11	1
COUNTRIES	2	1	6	6
RESEARCH ORG.	6	0	10	2
Total sub-equations tested	42	42	36	36
(per Dimension)	14	14	12	12

Throughout the analysis, the low R^2 scores for the sub-equations are apparent. RESEARCH ORG. consistently outperforms the other dimensions with respect to R^2. This points to a number of intervening variables that influence technology transfers and technologies transferred other than the dimensions of multinationality included in our model.

4.2. The Degree of Multinationality and Technology Exports

In this section, the relationships developed in Chapter II, Section 2.3. will be tested. The equation numbers in this section correspond to those used in Section 2.3.

$$(7)\ R_x = f(M) \text{ where } (7b)\ \frac{dR_x}{dM} > 0 \text{ with } \frac{dR_x}{dM_e} < \frac{dR_x}{dM_g} < \frac{dR_x}{dM_m}$$

There were no export transactions recorded at the R level. Therefore, these relationships could not be tested.

$$(8)\ D_x = g(M) \text{ where } (8b)\ \frac{dD_x}{dM_e} < \frac{dD_x}{dM_g} > \frac{dD_x}{dM_m}$$

Table 4-11

Independent Variable	Correlation Coefficient	R^2	B	Degrees of Freedom	F	Level of Significance
non-adjusted						
TIME	.09057	.00820	.00144	1,71	.587	n.s.
COUNTRIES	-.15860	.02515	-.02685	1,18	.464	n.s.
RESEARCH ORG.	.43852	.19230	.25600	1,7	1.667	n.s.
adjusted						
TIME	.05219	.00272	.00057	1,71	.194	n.s.
COUNTRIES	-.26206	.06868	-.01914	1,18	1.327	n.s.
RESEARCH ORG.	.53827	.28973	.13217	1,7	2.855	.10

Table 4-12

Independent Variable	EMERGING Correl. Coeff.	EMERGING B	EMERGING d.o.f.	EMERGING F	GROWING Correl. Coeff.	GROWING B	GROWING d.o.f.	GROWING F	MATURE Correl. Coeff.	MATURE B	MATURE d.o.f.	MATURE F
non-adjusted												
TIME	0	0			0	0			-.06344	-.00142	1,55	.222
COUNTRIES	-.13093	-.03943	1,4	.070	-.37211	-.16503	1,8	1.286	0	0		
RESEARCH ORG.	tolerance level insuff.											
adjusted												
TIME	0	0			0	0			-.12604	-.00193	1,55	.888
COUNTRIES	-.13093	-.03943	1,4	.070	-.43927	-.06352	1,8	1.913	0	0		
RESEARCH ORG.	tolerance level insufficient for further computations											

Export transactions at the D level are not significantly correlated with any of our dimensions of multinationality. Only one of our 6 sub-equations confirmed equation (8). In four of the six sub-equations, the slopes found correspond to our model, but the data did not contain enough observations to distinguish among the 3 stages of multinationality, emerging, growing, and mature.

Table 4-13

(9) $E_x = h(M)$ (9b) $\frac{dE_x}{dM} < 0$

Independent Variable	Correlation Coefficient	R^2	B	Degrees of Freedom	F	Level of Significance
non-adjusted						
TIME	.05366	.00288	.00324	1,71	.205	n.s.
COUNTRIES	-.08647	.00748	-.03305	1,18	.136	n.s.
RESEARCH ORG.	-.37963	.14412	-.57983	1,7	1.179	n.s.
adjusted						
TIME	-.13169	.01734	-.00285	1,71	1.253	n.s.
COUNTRIES	-.50364	.25365	-.06699	1,18	6.117	.025
RESEARCH ORG.	-.53702	.28839	-.21567	1,7	2.837	.10

Exports as a function of multinationality are not significant based on the non-adjusted data (technology transfers), they are, however, significant for the adjusted data (technologies transferred). In 5 out of 6 cases are the slopes as postulated, indicating that E exports tend to decline as a

MNC develops. Consequently, we can say that model equation (9) has been confirmed.

In all but one instance, the slopes agree with statement (9b). Differing slopes among the three stages are also confirmed (see Table 4-14) despite some discrepancies between non-adjusted and adjusted data. These discrepancies could be explained similarly to the comments offered under equation (3) and (3b). It appears that MNC continue to transfer existing technologies at the original level of the first transfer even if they have reached a mature level of development. It is primarily the new technology that tends to be transferred at a higher model. Since the adjusted data represents technologies transferred, it confirms our model better.

Table 4-14

Independent Variable	$\frac{dE_x}{dM_e}$ EMERGING Correl. Coeff.	B	Dof	F	>	$\frac{dE_x}{dM_g}$ GROWING Correl. Coeff.	B	dof	F	>	$\frac{dE_x}{dM_m}$ MATURE Correl. Coeff.	B	dof	F
non-adjusted														
TIME	-.61141	-.67512	1,6	3.582		.37853	.03107	1,6	1.004		.25333	.01629	1,55	3.772 (.10)
COUNTRIES	-.62389	-.90914	1,4	2.549		-.35354	-.27255	1,8	1.218		.15394	.25	1,2	.049
RESEARCH ORG.	tolerance level insufficient for further calculations													
adjusted														
TIME	-.68865	-.28619	1,6	5.412 (.10)		-.42390	-.02048	1,6	1.314		.14697	.00301	1,55	1.214
COUNTRIES	-.72514	-.39857	1,4	4.436		-.57657	-.13958	1,8	3.984 (.10)		-.89443	-.200	1,2	8.000

( ) level of significance

Table 4-15

$$(11)\quad T_x = k(M) \quad \text{with} \quad (11a)\quad \frac{dT_x}{dM} > 0$$

Independent Variable	Correlation Coefficient	R^2	B	Degrees of Freedom	F	Level of Significance
non-adjusted						
TIME	.07812	.00610	.00475	1,71	.436	n.s.
COUNTRIES	-.14730	.02170	-.05981	1,18	.399	n.s.
RESEARCH ORG.	-.20144	.04058	-.32383	1,7	.296	n.s.
adjusted						
TIME	-.10079	.01016	-.00227	1,71	.729	n.s.
COUNTRIES	-.54844	.30079	-.08692	1,18	7.743	.025
RESEARCH ORG.	-.19265	.03711	-.8350	1,7	.270	n.s.

Equations (11) and (11a) have only been found significant in one case with COUNTRIES as an independent variable. However, the slopes in all but one case negate our model (11a) indicating that the overall technology export activity will decline as the MNC develops. This is more so for technologies exported than it is the case for technology transfers in general. The findings do not support our original assumption as contained in (11a). It appears that the MNC's headquarters contributes less technologies as the MNC's system of subsidiaries grows. Other foreign subsidiaries could become major suppliers of technologies to newly formed subsidiaries, or, because of the higher level of local competence, transfers of technology are not as crucial any more to the survival of a local subsidiary.

$$\text{(7a)} \quad \frac{R_x}{T_x} = f(M) \quad \text{where} \quad \frac{d\frac{R_x}{T_x}}{dM} > 0$$

All coefficients for this relationship turned out to be zero for this relationship since no R exports have been observed in the sample.

$$\text{(8a)} \quad \frac{D_x}{T_x} = g(M) \quad \text{where} \quad \frac{dD_x}{dM} > 0$$

Table 4-16

Independent Variable	Correlation Coefficient	R^2	B	Degrees of Freedom	F	Level of Significance
<u>non-adjusted</u>						
TIME	.06651	.00442	.09709	1,71	.316	n.s.
COUNTRIES	-.13884	.01928	-.46466	1,18	.354	n.s.
RESEARCH ORG.	.86530	.74875	11.56667	1,7	20.861	.01
<u>adjusted</u>						
TIME	F level insufficient for further computations					n.s.
COUNTRIES	-.16254	.02642	-.67594	1,18	4.88	.05
RESEARCH ORG.	.83809	.70240	10.800	1,7	16.521	.01

Our calculations tend to confirm that D exports as a percentage of all exports are determined by the level of multinationality. 3 of our 6 sub-equations are statistically significant. Equation (8a) appears to be even more applicable for technologies transferred.

The slopes, however, are positive only in three out of six cases and no significant differences between the three stages could be observed (see Table 4-17).

The results based on adjusted data are conflicting. While both dimensions of multinationality, COUNTRIES and RESEARCH ORG., show significant coefficients, the percentage of D level transactions with respect to total exports is negatively correlated with COUNTRIES but correlates positively with RESEARCH ORG. This result is caused by our classification of MNCs as discussed in the previous section. One MNC, International Co.'s Heavy Equipment Div., is characterized by large D level exports. That same MNC is classified as emerging using COUNTRIES as an independent variable, growing using RESEARCH ORG. as an independent variable, and mature based on TIME as the independent variable of multinationality.

While the overall results point towards a confirmation of (8a) the findings are not statistically significant.

Table 4-17

$$(8a) \quad \frac{d \frac{D_x}{T_x}}{dM_e} < \frac{d \frac{D_x}{T_x}}{dM_g} > \frac{d \frac{D_x}{T_x}}{dM_m}$$

Independent Variable	EMERGING Correl. Coeff.	B	dof	F	GROWING Correl. Coeff.	B	dof	F	MATURE Correl. Coeff.	B	dof	F
non-adjusted												
TIME	0	0			0	0			-.14065	-.28642	1,55	1.110
COUNTRIES	-.13093	-1.25714	1,4	.070	-.17420	-1.39394	1,8	.250	0	0		
RESEARCH ORG.	F level not sufficient for further computations											
adjusted												
TIME	0	0			0	0			-.24178	-.52554	1,55	3.415
COUNTRIES	-.13093	-1.97143	1,4	.070	-.15475	-1.38182	1,8	.196	0	0		
RESEARCH ORG.	F level not sufficient for further computations											

Table 4-18

$$(9a)\quad \frac{E_x}{T_x} = k(M) \quad \text{and} \quad \frac{d\,\frac{E_x}{T_x}}{dM} < 0$$

Independent Variable	Correlation Coefficient	R^2	B	Degrees of Freedom	F	Level of Significance
non-adjusted						
TIME	-.26877	.07224	-.58754	1,71	5.528	.025
COUNTRIES	-.25999	.06759	-1.49023	1,18	1.305	n.s.
RESEARCH ORG.	-.86530	.74875	-11.5667	1,7	20.861	.01
adjusted						
TIME	-.32415	.10508	-.73556	1,71	8.336	.01
COUNTRIES	-.43469	.18896	-3.08346	1,18	4.194	.10
RESEARCH ORG.	-.83809	.70240	-.10800	1,7	16.521	.01

Equation (9a) of our model can be considered confirmed. Exports decline at the E level as a MNCs becomes more multinational. Not only has the relationship been found significant 5 out of 6 times but also all slopes are negative.

The level of technology exports as a function of multinationality. For each observation along the independent variable of multinationality, transactions have been scored with

E = 1

D = 2

R = 3

The total score has then been divided by the number of transactions observed. According to equations (7a), (8a), and (9a) the average technology level will increase, and consequently

$$\text{Export Level} = p(M) \quad \text{with} \quad \frac{d\ \text{Export Le.}}{dM} > 0$$

with the results displayed in Table 4-19.

Table 4-19

Independent Variable	Correlation Coefficient	R^2	B	Degrees of Freedom	F	Level of Significance
non-adjusted						
TIME	.15838	.02508	.00267	1,52	1.338	n.s.
COUNTRIES	F-level insufficient for further computations					
RESEARCH	.87682	.76882	.11333	1,7	23.280	.01
adjusted						
TIME	.15833	.02507	.00315	1,39	1.003	n.s.
COUNTRIES	-.04053	.00164	-.00202	1,14	.023	n.s.
RESEARCH	.83923	.70430	.10430	1,7	16.673	.01

The level of exports is also found to be a function of multinationality, even though only 2 out of 6 sub-equations are significant (in both instances with RESEARCH ORG. as the independent variable. The results suggest that, as a MNC develops, its exports tend to be composed of higher level technology, particularly if the MNC has added several research organizations abroad.

Generally, of the 7 major equations on export of technology ((7) and (7a), (8) and (8a), (9) and (9a), (11) and (11a), (7b), (8b), and (9b)) only 5 could be tested since there was no data on R exports. Of the 5 equations, only one could be statistically confirmed. In two of the equations, the majority of the slopes were directing towards the opposite direction.

It has been confirmed that E_x will decline in relation to all other technology exports. However, the absolute amount of both technology transfers and technologies transferred will decline just as the overall amount of transfers and technolgies exported will decline also (T_x). These results are contrary to what was originally postulated in the model. However, given the overall decline for all exports a decline in E level exports is consistent within our results. It appears that our original model would have to be modified with respect to the amounts of technology transferred.

Since there were 6 sub-equations for each major equation, a total of 30 sub-equations were tested. Of these, 13 were found to be significant. Among those, however, 4 sub-equations resulted in signs contrary to those stipulated in the model. For reasons explained above, only 15 of the 30 sub-equations confirmed our slopes as specified in the model. These results are further displayed in Table 4-20.

Regressions based on adjusted data were more likely to be significant than those based on non-adjusted data. Of the 30 sub-equations with statistically significant correlations, 9 are based on adjusted data. This further suggests that our model is better supported by data based on new technolgies (adjusted) exported. Often, older technologies continue to be exported at the lower level since such transfers are usually made to countries with lower technological sophistication. This is particularly the case for MNCs that tend to add developing countries during the later stages of their expansion to their network of subsidiaries. Consequently, while newer technologies are transferred at a higher level to the advanced countries, considerable amounts of transfers at lower levels are still made to developing countries by MNC who traditionally have moved into these latter countries after having entered the developed countries.

The 3 dimensions for multinationality do not correlate equally with technology exports. As can be seen from Table 4-20, RESEARCH ORG. outperforms the other dimensions with respect to significance.

R^2 scores are consistently higher for RESEARCH ORG. compared to the other dimensions. Nevertheless, the average low R^2 for the regressions implies that other factors not contained in the model intervene over the development cycle of the MNC.

It has not been possible to show differences between the three stages of development of a MNC because the intervals selected over the independent variables are often too narrow and therefore do not contain a large enough number of observations to perform an analysis.

Table 4-20

Reliability of Dimensions of Multinationality

Dimension	Statistically Significant proving model	Statistically Significant disproving model	Confirming Slope	Opposite Slope
TIME	2	0	8	2
COUNTRIES	1	3	1	8
RESEARCH ORG.	6	1	6	4
Total sub-equations per dimension	30 (10)	30 (10)	30 (10)	30 (10)

4.3. The Degree of Multinationality and Technology Imports

In this section, the relationships developed in Chapter II, Section 2.4., will be tested. The equation numbers in this section correspond to those used in Section 2.4.

Due to the nature of import data, no adjustments had to be made. While exports from the US headquarters could have been made to a number of countries, and therefore could have been counted several times, imports have always been recorded for one transaction only. Consequently, there is no difference between our adjusted or non-adjusted data on technology imports. For this reason, we report only one set of results in this section.

Table 4-21

$$(12)\ R_i = f(M) \quad \text{and} \quad (12b)\ \frac{dR_i}{dM} > 0$$

Independent Variable	Correlation Coefficient	R^2	B	Degrees of Freedom	F	Level of Significance
TIME	.14681	.02155	.00040	1,71	1.564	n.s.
COUNTRY	.21882	.04788	.00273	1,18	.905	n.s.
RESEARCH ORG.	-.27386	.07500	-.00467	1,7	.568	n.s.

Because of a lack of observation, the underlying assumptions of (12) and (12b) could not be reliably estimated. There was only one R import throughout the entire sample. Consequently, all regressions are insignificant with 2 of the 3 slopes of opposite signs.

Table 4-22

Independent Variable	$\frac{dR_i}{dM_e}$ EMERGING Correl. Coeff.	B	dof	F	< $\frac{dR_i}{dM_g}$ GROWING Correl. Coeff.	B	dof	F	< $\frac{dR_i}{dM_m}$ MATURE Correl. Coeff.	B	dof	F
TIME	0	0			0	0			.14722	-.00057	1,55	1.218
COUNTRIES	0	0			.52223	.0180	1,8	3.000	0	0		
RESEARCH ORG.	0	0			F-level insufficient for further computations							

Again, as for equations (12) and (12b), a lack of obsertations in various stages of multinationality prevented a conclusion whether the slopes of (12b) differ according to the development stage of the MNC.

Table 4-23

$$(13)\ D_i = g(M) \quad \text{and} \quad (13b)\ \frac{dD_i}{dM} > 0$$

Independent Variable	Correlation Coefficient	R^2	B	Degrees of Freedom	F	Level of Significance
TIME	.38576	.14881	.00423	1,71	12.413	.01
COUNTRIES	.17162	.02945	.00874	1,18	.546	n.s.
RESEARCH ORG.	.63612	.40465	.30700	1,7	4.758	.10

Equations (13) and (13b) can be considered confirmed since two of the three regressions are significant and all slopes are positive. This confirms the growth of D level imports as the MNC develops. As before, no reliable estimates can be made as to the differences among slopes of the various stages. For results see Table 4-24.

Table 4-24

$$\frac{dD_i}{dM_e} < \frac{dD_i}{dM_g} > \frac{dD_i}{dM_m}$$

Independent Variable	EMERGING				GROWING				MATURE			
	Correl. Coeff.	B	dof	F	Correl. Coeff.	B	dof	F	Correl. Coeff.	B	dof	F
TIME	0	0			0	0			.40589	.00630	1,55	10.848 (.01)
COUNTRIES	-.13093	-.00714	1,4	.070 n.s.	.53486	.07406	1,8	3.206	0	0		
RESEARCH ORG.	0	0			F-level insufficient for further calculations							

( ) = level of significance

Table 4-25

$$(14)\ E_i = h(M) \quad \text{and} \quad (14b)\ \frac{dE_i}{dM} > 0$$

Independent Variable	Correlation Coefficient	R^2	B	Degrees of Freedom	F	Level of Significance
TIME	-.03879	.00150	-.00018	1,71	.107	n.s.
COUNTRIES	-.00379	.01256	-.00379	1,18	.229	n.s.
RESEARCH ORG.	.37102	.13766	.13283	1,7	1.117	n.s.

Imports of technologies at the E level are not significantly dependent on the degree of multinationality of the MNC. Two of the regressions have opposite slopes. Just as the overall regressions so are the partial regressions for each stage of multinationality insignificant (see Table 4-26 for results). Therefore, the data failed to support equations (14) and (14b) of our model.

Table 4-26

$$\frac{dE_i}{dM_e} > \frac{dE_i}{dM_e} > \frac{dE_i}{dM_m}$$

Independent Variables	EMERGING Correl. Coeff.	B	dof	F	GROWING Correl. Coeff.	B	dof	F	MATURE Correl. Coeff.	B	dof	F
TIME	0	0			-.37115	-.01286	1,6	.959 (n.s.)	.14722	.11397	1,55	1.218 (n.s.)
COUNTRIES	.65465	.03571	1,4	3.000 (n.s.)	-.44618	-.03788	1,8	1.988 (n.s.)	0	0		
RESEARCH ORG.	0	0			F-level insufficient for further computations							

( ) = significance level

Table 4-27

$$(16)\ T_i = k(M) \quad \text{and} \quad (16b)\ \frac{dT_i}{dM} > 0$$

Independent Variable	Correlation Coefficient	R^2	B	Degrees of Freedom	F	Level of Significance
TIME	.38987	.15200	.00459	1,71	12.726	.01
COUNTRIES	.10818	.01170	.00768	1,18	.213	n.s.
RESEARCH ORG.	.71185	.50673	.43517	1,7	7.191	.05

The results show that technology imports are significantly and positively correlated with 2 of the three dimensions of multinationality. Furthermore, all slopes are positive confirming our model in the assumption that as a MNC develops it becomes dependent on foreign technology.

Table 4-28

$$(12a)\ \frac{R_i}{T_i} = f(M) \quad \text{and} \quad \frac{d\frac{R_i}{T_i}}{dM} > 0$$

Independent Variable	Correlation Coefficient	R^2	B	Degrees of Freedom	F	Level of Significance
TIME	.14681	.02155	.07946	1,71	1.564	n.s.
COUNTRIES	.21882	.04788	.16541	1,18	.905	n.s.
RESEARCH ORG.	-.27386	.07500	-.83333	1,7	.568	n.s.

With only one observation as a basis for the above 3 sub-equations, it is not surprising that the correlations are all non-significant. Furthermore, one of the slopes carries the opposite sign. We therefore conclude that the data failed to support equation (12a). Furthermore, data suggests that there are only very few transfers at the R level. If this is true across a large number of MNCs, this separate category for R ought to be abolished and merged into D level transfers. The reason for this absence of R transfers could be justified by the relative immaturity of our sample. In other words, the emergence of R as a distinct category lies beyond the range of our data.

Table 4-29

$$(13a)\ \frac{D_i}{T_i} = g(M)$$

Independent Variable	Correlation Coefficient	R^2	B	Degrees of Freedom	F	Level of Significance
TIME	.34733	.12064	.41626	1,71	9.740	.025
COUNTRIES	-.08650	.00748	-.40977	1,18	.136	n.s.
RESEARCH ORG.	.49099	.24107	6.2500	1,7	2.224	n.s.

The share of D technologies imported as compared to all imported technologies is only significantly correlated with TIME. The slopes are positive in 2 of the 3 sub-equations, including the significant one.

Table 4-30

(13a) $\frac{d\frac{D_i}{T_i}}{dM_e}$ EMERGING $<$ $\frac{d\frac{D_i}{T_i}}{dM_g}$ GROWING $>$ $\frac{d\frac{D_i}{T_i}}{dM_m}$ MUTUAL

Independent Variable	EMERGING				GROWING				MUTUAL			
	Correl. Coeff.	B	dof	F	Correl. Coeff.	B	dof	F	Correl. Coeff.	B	dof	F
TIME	0	0			0	0			.34428	.58412	1,55	7.396 (.01)
COUNTRIES	-.13093	-2.85714	1,4	.070 (n.s.)	.53290	4.51515	1,8	3.173 (n.s.)	0	0		
RESEARCH ORB.	0	0			F-level not sufficient for further computations							

( ) = level of significance

The attempt to find differences between the three stages of multinationality failed for all dimensions as displayed in Table 4-30.

Table 4-31

$$\text{(14a)}\quad \frac{E_i}{T_i} = h \qquad \text{and} \qquad \frac{d\frac{E_i}{T_i}}{dM} < 0$$

Independent Variable	Correlation Coefficient	R^2	B	Degrees of Freedom	F	Level of Significance
TIME	-.12921	.01670	-.17925	1,71	1.205	n.s.
COUNTRIES	-.22756	.05178	-1.63534	1,18	.983	n.s.
RESEARCH ORG.	.07596	.00577	1.2500	1,7	.041	n.s.

The number of imported technologies is not significantly related to any of our 3 independent variables. Nevertheless, 2 of our 3 sub-equations carry a negative slope. However, equation (14a) is not supported by our data.

The level of technology imports as a function of multinationality. For each observation along the independent variable of multinationality, transactions have been scored as follows:

E = 1

D = 2

R = 3

The total score has then been divided by the number of transactions observed. According to equations (12a), (13a), and (14a), the average technology import level will increase but not at a rate that is statistically significant. We can therefore write

$$\text{Import Level} = i(M) \quad \text{with} \quad \frac{d\ \text{Imp.Level}}{dM} > 0$$

The results of this test are displayed in Table 4-32.

Table 4-32

Independent Variable	Correlation Coefficient	R^2	B	Degrees of Freedom	F	Level of Significance
TIME	.66146	.43753	.01676	1,12	9.334	.025
COUNTRIES	.28961	.08388	.03584	1,5	.458	n.s.
RESEARCH ORG.	.17909	.03207	.03545	1,3	.099	n.s.

The level of imports is significantly correlated with TIME only, but all 3 slopes are positive as expected. Consequently, the postulate that imports show a rise with respect to technological level is weakly supported. The results in Table 4-32 confirm earlier results reported in Tables 4-28 through 4-31.

In this section, the following model equations on technology imports were tested:

12, 12b
13, 13b
14, 14b
16, 16b
12a
13a
14a

For each of these 7 major equations, 3 sub-equations were tested leaving a total of 21 regressions. Only two of the major equations and 5 of the 21 regressions were statistically significant. However, 16 of the 21 slopes were confirmed as far as their sign was concerned. While none of the equations of the model was disproved, the results nevertheless show weak support for our model.

Overall, technology imports correlate well with our model, but it is its components (R_i, D_i, and E_i respectively) that the model fails to accurately, or at least reliably, describe. Part of this is due to the small number of imports observed which are then distributed over the full range of our independent variables.

It is interesting to note that imports do not mainly consist of E transactions. Probably due to the already advanced capabilities of the headquarters country, new technologies are more likely to be imported at higher levels from the beginning.

As the following Table 4-33 shows, TIME was the most reliable predictor of technology imports. It was RESEARCH ORG. on the other hand, that showed the highest R^2 scores. This suggests that some of our equations, particularly the stipulated slopes, might have to be revised.

Table 4-33

Reliability of Dimensions

of Multinationality

Dimension	Statistical Significance proving model	Statistical Significance negating model	Confirming Slope	Negating Slope
TIME	3	0	7	0
COUNTRIES	0	0	6	1
RESEARCH ORG.	2	0	3	4
Total Sub-equations	21	21	21	21
(per dimensions)	(7)	(7)	(7)	(7)

4.4 The Balance of Technology Within the Multinational Corporations as a Function of Multinationality

In the previous sections, we analyzed both the export and import patterns independently as well as the total transactions by combining exports and imports. For many researchers, however, the balance of technological transactions, technology exports minus imports, is really the important issue. Are MNCs primarily technology exporters, or are they importers? What will happen to the pattern of their transactions in the future?

To answer these questions, our data from the previous sections was used as a base. Throughout Sections 4.1 to 4.3, all transactions were equal in technological "worth" and they were only differentiated by their level (R, D, or E respectively). For the purpose of arriving at a balance of technology for our MNCs, we felt one could not simply subtract import transactions from export transactions without any adjustment for their relative technological importance. Consequently, all data was weighted using data from the National Science Foundation.[1]

The ideal weight would have been the number of engineering man/time spent on the transferred technology. Unfortunately, this information was not available for most of our MNCs in our sample. Therefore, <u>the number of R and D scientists and engineers per 1000 employees for each industry</u> was judged to be the most appropriate weight under the circumstances. Others have used these weights for similar reasons earlier.[2] The National Science Foundation publishes this information as an annual series for each industry.

At Worcester Polytechnical Institute, two reports have been submitted to the Project Center on measuring the technology intensity on any given industry.[3] In these reports,

---

[1]National Science Foundation, NSF 73-305, <u>Research and Development in Industry 1971</u>.

[2]Gruber W., Metha, D., and Vernon, R., "The R&D Factor in International Trade and International Investment of United States Industries," and Keesing, D.B., "The Impact of Research and Development on United States Trade," both in <u>Journal of Political Economy</u>, February 1967, pp. 20.

[3]R.D. Cibulski, <u>et. al</u>., <u>Technology Indicators</u>, Worcester Polytechnical Institute, Project Center, October 1974.

the NSF data are termed unreliable and a new set of data is suggested, termed "technology indicators." However, these indicators are presently only available for 3 isolated industries. Furthermore, they contain indices on managerial as well as manufacturing technology. A comparison between these technology indicators and NSF data shows that relative relationships are preserved for the three industries where data was available. For this research, the 1971 figures by the National Science Foundation have been selected. The respective weights for each MNC in our sample are presented in Table 4-34.

Table 4-34

Weights Assigned for Technology Transfers for each MNC

	MNC	Weight
1.	Sprague Electric	43
2.	New England Computer Co.	43
3.	Consumer Chemical Co.	34
4.	Industrial Supply Co.	11
5.	Office Supply Co.	9
6.	Aerospace International	76
7.	International Co./Chemical Div.	34
8.	/Machinery Div.	28
9.	/Heavy Mach. Div.	28
10.	/Indust.Suppl. Div.	10
11.	Multinational Paper Co.	7
12	Gillette Co.	10
13.	International Photo Equipment Co.	34
14.	International Instruments Co.	29

For those MNCs where the entire corporate history was made available this system of weights is used for all and not just the current transactions. We are assuming the 1971 weights are appropriate for the entire development of these MNCs in our sample.

As a next step, the data contained in Appendix II was scored using the weights from Table 4-34 as the appropriate weight for each transaction. Only the adjusted data was used for the analysis since the non-adjusted data would put undue emphasis on technology exports. The results of this scoring are displayed in Appendix V.

These raw scores (Appendix V) were then normalized by the number of MNCs observed at any point on the independent variable. Furthermore, it became necessary to add 100 to each of the balance values (R_{x-i}, D_{x-i}, E_{x-i}, T_{x-i}) because some values had a minus sign (indicating an import surplus) which could not be entered into the computer program. The complete set of data matrices is displayed in Appendix V.

The results are presented using the same format as in the previous sections. Where applicable, the equation numbers correspond to those of Section 2.5 in Chapter II.

(17) $T_x - T_i = k(M)$ with (17a) $\frac{dT_x - T_i}{dM} < 0$ and $\frac{dT_x - T_i}{dm}$

$= 0$ as $M \rightarrow M_{max}$

Table 4-35

Independent Variable	Correlation Coefficient	R^2	B	Degrees of Freedom	F	Level of Significance
TIME	-.50756	.25761	-.26912	1,71	24.637	.01
COUNTRIES	-.60671	.36809	-2.32980	1,18	10.485	.01
RESEARCH ORG.	-.73431	.53921	-17.2475	1,7	8.191	.025

Equations (17) and (17a) are both significant at the .025 level or better, and the slopes correspond as well. We can therefore conclude that the balance of technology is significantly related to the dimensions of multinationality. The data strongly suggest that a MNC heavily exports technologies at its earlier stages and starts to import larger amounts as the MNC matures.

Table 4-36

(18) $R_x - R_i = f\ (M)$ with (18a) $\frac{dR_x - R_i}{dM} < 0$

Independent Variable	Correlation Coefficient	R^2	B	Degrees of Freedom	F	Level of significance
TIME	-.14681	.02155	-.00397	1,71	1.564	n.s.
COUNTRIES	-.21882	.04788	-.02680	1,18	.905	n.s.
RESEARCH ORG.	.27386	.07500	.04767	1,7	.568	n.s.

Due to the lack of observations of R level transfers, all regressions are non-significant. Two of the three slopes correspond to (18a). Overall, however, equations (18) and (18a) are only weakly supported by our data.

Table 4-37

$$(19)\quad D_x - D_i = g(M) \text{ and } (19a)\ \frac{dD_x - D_i}{dM} < 0$$

Independent Variable	Correlation Coefficient	R^2	B	Degrees of Freedom	F	Level of significance
TIME	-.32047	.10270	-.11858	1,71	8.126	.01
COUNTRIES	-.40204	.16164	-.72511	1,18	3.470	.10
RESEARCH ORG.	-.51953	.26991	-6.39467	1,7	2.588	n.s.

Our data supports equations (19) and (19a). The results show that the D surplus declines with an increase in the degree of multinationality. Two out of the three regressions are significant, and all three show a negative regression coefficient.

Table 4-38

$$(20)\quad E_x - E_i = h(M) \text{ and } (20a)\ \frac{dE_x - E_i}{dM} < 0$$

Independent Variable	Correlation Coefficient	R^2	B	Degrees of Freedom	F	Level of Significance
TIME	-.37711	.14221	-.14645	1,71	11.771	.01
COUNTRIES	-.61355	.37644	-1.88918	1,18	10.866	.01
RESEARCH ORG.	-.65140	.42432	-10.90050	1,7	5.160	.10

Again, the results clearly support the relationships stated under (20) and (20a) at levels of statistical significance of .10 or better. Accordingly, the surplus of the technology balance at the E level will decline as the MNC develops. This supports again the thesis that a MNC is only a heavy technology exporter during its early stages of development.

In this section, we have tested four major equations, each with three sub-equations. Of the four major equations, three have been found to be statistically sifniciant, and all four slopes have been confirmed. Among the 12 sub-equations, 8 have been found statistically significant, and 11 of the slopes have been confirmed. Consequently, this section of our model has been well supported by our data.

Of the three dimensions of M, all three performed well, particularly TIME and COUNTRIES. Despite smaller significance level, R^2 of RESEARCH ORG. continuously outperformed the other two variables. For more details see Table 4-39.

Table 4-39

Reliability of Dimensions of Multinationality

Dimension	Statistical Significance proving model	negating model	Confirming Slope	Negating Slope
TIME	3	0	4	0
COUNTRIES	3	0	4	0
RESEARCH ORG.	2	0	3	1
Total sub-equations	12	12	12	12
(per dimension)	(4)	(4)	(4)	(4)

CHAPTER V

CONCLUSIONS

1. Review of General Findings

1.1. The model. Generally, the model has been supported by our data. It has been shown that technology exports decline over the development cycle of a MNC. Also, exports tend to be at a higher technological level among mature MNC since more exports occur at the D level.

Technology imports have shown a strong tendency to rise for MNCs in the mature stage. The rise is particularly strong for imports at the D level. It appears that many MNCs will not transfer technologies back to their home office as improvements on previously exported technology. There is a strong tendency to bring back new developments in fields not previously exploited by the parent company.

The balance between technology exports and imports is changed significantly as a MNC develops. Emerging MNCs are heavy exporters, and a MNC shifts gradually to depend more on imports as a source of technologies.

The results on total technology transfers (6) point towards a decreased intensity of technology transfers as a MNC develops, particularly with COUNTRIES as an independent variable. This is contrary to the opinions of many executives interviewed. However, our data does not include small transfers or technical exchanges that go on a continuous basis.

It is precisely those continuous transfers that have shown the largest increase according to executives' opinions.

1.2. Elements of technology. For the purpose of this research, all transactions have been categorized as either R, D, or E level transactions. The results show that, because of a lack of observations, equations based on R level transfers were generally not significant. D equations tended to negate the model more often than those of the other elements. The reason for this behavior, has been explained in section 4.1. of Chapter IV, and can be attributed to classification of one MNC of our sample. E transfers have tended to confirm our model with the exception of E imports.

Overall, the differences between the elements of technology with respect to amounts transferred have been confirmed. Consequently, we feel that dividing technology into these categories is a useful tool to explain the phenomena under investigation. However, the lack of occurrences of R level transfers suggest that R and D level transfers could be combined in one category.

1.3. Dimensions of multinationality. RESEARCH ORG. was the most reliable dimension of multinationality. Of the 35 sub-equations tested for each dimension, 50 percent were found statistically significant with RESEARCH ORG., compared to 40 percent for TIME and 29 percent for COUNTRIES. With respect to R^2, RESEARCH ORG. turned out to be by far the superior variable, also. However the slopes of TIME sub-equations were more often in agreement with our model than those using other dimensions as the independent variable. The results are contained in Table 5-1.

Table 5-1

Reliability of Dimensions of Multinationality for the Model as a Whole

Dimension	Sub-equations with Statistical Significance confirming model	Sub-equations with Statistical Significance negating model	Confirming Slope	Negating Slope
TIME	14	0	30	3
COUNTRIES	6	4	17	15
RESEARCH ORG.	16	1	22	11
	36	5	69	29

total sub-equations 105
35 for each dimension

As apparent from Table 5-1, COUNTRIES as a dimension has a strong tendency to negate the model. The signs of the slopes point towards the opposite direction and often conflict with the other dimensions. Consequently, the three dimensions cannot be considered substitutes for each other. The model could be improved by treating COUNTRIES separately. It appears that we cannot state relationships between technology transfers and the three dimensions of multinationality simultaneously.

TIME as a dimension of multinationality. Generally, the model has been confirmed with respect to TIME. The results show that over time the technology export surplus decreases considerably (Table 4-35) with some MNCs turning into net importers of technology, while the technology exports show mixed results (Table 4-15). The shift to a higher level of technology, particularly for imports, has also been demonstrated (Table 4-32) clearly indicating that the foreign subsidiaries increase their capabilities over time.

Based on these results, a forecast of future flows of technology can be made. At least for the sample under investigation, the forecast calls for a decrease in technology exports in the future. The mature MNCs in the sample that demonstrated such a strong trend reached a balanced or net importing position over a time span of 75 years. The majority of the emerging and growing MNCs in the sample can be expected to reach such a position earlier, perhaps after 40 to 50 years. With many MNCs having moved abroad in the '40s, a strong trend would become apparent within a decade.

This trend can be extended to all US based MNCs. Since a large number of these have been abroad for 30 to 40 years, a trend to more exports will most likely become noticeable at an earlier stage than for our sample.

Such a shift in the flows of technology could not have occurred without a technological maturity of the MNCs' local subsidiary. Consequently, this trend can be interpreted as a strong indication that MNCs do in fact contribute to the diffusion of new technology and are a prime mover in economic development. However, it should be noted, and the reader can judge for himself by inspecting Appendix I - Imports, that MNCs import primarily from subsidiaries in the highly developed countries of Western Europe.

The results show, however, that the United States has a strong interest in the free flow of technology in order to receive the dividends of heavy exports in the past two decades.

COUNTRIES as a dimension of multinationality. At first, the results appear contradictory with TIME and RESEARCH ORG. positively correlated with technology transfers and COUNTRIES negatively. From the data presented in Appendix I it becomes clear that MNCs have added new countries in rapid succession to their networks, often at a pace of 2 or 3 a year (Gillette). Major new technologies, however, have not been created at the same pace. Particularly, countries added only recently have received technologies that have been transferred at least once before. This explains the contradiction between the adjusted and non-adjusted data (Tables 4-4, 4-15).

With respect to technology imports (Table 4-27) and the balance of technological transactions (4-35), COUNTRIES as an independent variable shows the same results as the other two dimensions. Here, both of these flows are highly confounded with time and this has influenced the outcome.

The results strongly suggest that the number of technologies exported are not affected by the number of countries in which a MNC maintains a subsidiary. The results further support a policy of maintaining no restrictions to the future growth of MNCs. It appears that the first few subsidiaries have a far greater effect on the flow of technology transfers than the following 10 or 15 new subsidiaries.

RESEARCH ORG. as a dimension of multinationality. Since the dimension of RESEARCH ORG. has proven to be the most reliable indicator of technology flows with respect to R^2, no specific conclusions could be drawn with respect to total technology transfers (T) as indicated in Table 4-4 and T_x (Table 4-15). However, Table 4-19 demonstrates that in order to increase the level of which transfers occur, a number of research organizations must exist. Similarly, T_i is clearly related to the RESEARCH ORG. as indicated in Table 4-27.

RESEARCH ORG. as a variable is more highly correlated with TIME than with COUNTRIES (Table 3-3). This suggests that over time MNCs have a tendency to increase the technological capability of their subsidiaries. But due to the importance of this variable of the flow of technology, future research should concentrate on the reasons MNCs have to open research facilities abroad.

1.4. Stages of multinational development. For many sub-equations an attempt has been made to test for differences between the three stages of multinational development (emerging, growing, and mature stages). However, due to a limited number of observations in several stages no conclusive test could be performed. Furthermore, our categorization by stage for the three dimensions of multinationality left us with too narrow a range over the independent variable.

This was particularly true for RESEARCH ORG. Consequently, while the concept of different development stages is conceptually sound, for the purpose of data analysis a less rigid categorization should be employed.

1.5. Proposed model changes. Based on the results reported in Chapter IV, we propose the following changes for our model of technology transfer:

Equations: The relationship between technology transfers (T) and multinationality has been defined as

$$T = k\ (M) \qquad (6)$$

At first, no first order relationship has been stated, but our results show that for the dimensions TIME and RESEARCH ORG. the equation can be further defined as

$$\frac{dT}{dM} > 0 \qquad (6b)$$

and for COUNTRIES

$$\frac{dT}{dC} < 0 \qquad (6c)$$

Technology transfers increase over time and as a MNC creates research centers abroad, but such transactions are negatively correlated with the number of countries a MNC maintains production facilities in. This fact points towards the existence of a 2-step flow of technological communications. Some of the MNCs in our sample export new technologies at first to a select number of countries, usually those with the highest technological capabilities. Often, further transfers to other subsidiaries are then made by that first subsidiary and the

MNC's headquarters office is not directly involved. Such a development could be observed for Sprague Electric Co. Furthermore, as some subsidiaries become specialists in certain product lines they often absorb the burden of transferring new technology to newly formed subsidiaries. Such is the case for Gillette where the UK subsidiary is responsible for many small scale operations (mini-plants) added in recent years. This further reinforces the assumption that subsidiaries of a MNC tend to decrease their technological dependence on the headquarters country as the MNC matures.

Equation (9b) will also be revised as follows:

$$\frac{dE_x}{dM} < 0 \qquad (9b)$$

From the data presented we conclude that E level exports do not only decrease in relative but also in absolute terms. Partially, this is also caused by the 2-step communications hypothesis.

Technology exports tend to decrease in absolute terms rather than increase, again explained by the 2-step flow hypothesis as well as the increased sophistication of the local subsidiaries. Consequently, we are amending Equation (11a):

$$\frac{dT_x}{dM} < 0 \qquad (11a)$$

<u>Observational units (elements of technology)</u>: To simplify further analysis and tests, we propose to abandon the 3-way categorization of technology elements into R, D, and E technology. Presently, it appears that R level transfers are

occurring only rarely and could therefore be combined with D level transfers into an R & D category. This would also simplify the data collection since it is often difficult to distinguish between R and D type work.

Stages of development: While a general distinction between emerging, growing, and mature MNCs can be conceptually useful, we propose to abandon the fixed, and often arbitrary, classification along the dimensions of multinationality. The ranges for each stage tend to be too narrow for the purpose of a data analysis.

2. Limitations of Research

2.1. Limitations based on sample. Primarily because of our non-probability sample, the results of this research cannot be generalized without caution. However, due to the data collection required on the part of the cooperating MNCs, a probability sample would not have been feasible in the first place. To further substantiate our results, a similar effort with other MNCs would have to be undertaken.

2.2. Response errors. The data concentrates on "large" discontinuous transfers as perceived by the executive interviewed. It is unlikely that our data is complete for each MNC. Continuous transfers or "small" transfers have been excluded from our analysis. Furthermore, in some cases an executive's experience was limited to certain aspects of the company, resulting in additional bias of our data. However, we feel that these limitations are inherent to field research and do not invalidate our findings.

2.3. Limitation of experimental design. The basic assumptions underlying our experimental design have been laid out in Chapter III. From the results, however, it is apparent that only a small portion of the variations have been explained by our model. This is particularly true for equations based on TIME and COUNTRIES as independent variables.

The cross-section time series combination was selected to combine our often sparse company data into an overall series that would allow us to apply a regression analysis to our data base. As a result, several variables other than multinationality have been confounded. The following confounded variables have been isolated:

Time: Due to combining various time series, transactions from MNCs dated from 1910 to 1930 have been combined with emerging MNCs that listed their first transfers as late as 1963. It is quite possible that during this time period the initial decision as to at what level to transfer has been altered. Furthermore, the nature of international business has undergone tremendous changes since World War II.

Type of industry: We have treated all companies equally regardless of their industry. Interviews with executives have shown however, that the level of technology transferred is also dependent on the maturity level of the technology or industry itself. Mature industries can be considered those who have not been subject to extensive innovative activity. An example would be the technology to produce heavy machinery, while the design of the machinery has changed, the basis production technology is stable.

Therefore, subsidiaries abroad are allowed to completely assimilate heavy machinery production technology, and transfers tend to occur at the design (D) level. The Electronic Industry would be an example for a production technology still subject to change. Under such circumstances, a foreign subsidiary is always a step behind its parent company and transfers are more likely to occur at the E level.

Ownership policy: No distinction has been made between subsidiaries acquired or those started from the beginning. Subsidiaries acquired could be expected to have a higher level of technology and due to their experience might be able to absorb D transfers at an earlier time.

Managerial philosophy: MNCs striving for a large degree of decentralization are more likely to delegate research and development work to their subsidiaries. One MNC in our sample, the International Co., has even transferred two of their division headquarters abroad, the Chemical and Industrial Supply Divisions. This has led to a larger emphasis of foreign research and, consequently, more imports of technology.

Human variables: For many technical employees at headquarters it is difficult to accept new concepts from foreign subsidiaries particularly when the foreign subsidiary has only limited experience with technology concerned. These problems have been mentioned explicitly by two of the executives interviewed. Consequently, a MNC with a strong ethnocentric orientation among its technical staff would emphasize technology exports and minimize imports.

Market factors: The subject of our investigation was technology transfers within MNCs. As a result, we have excluded arrangements made outside the systems of a MNC's subsidiaries. Certain economic and marketing factors force a MNC to engage in technology transfers outside its subsidiary system. One such factor, the existence of a "club," concerns the competitive climate in certain countries. Here, the government or industry in general has done business with an established group of domestic companies. A foreign entrant is often prevented from establishing a production facility, or if he does, government orders are channeled to domestic firms. Under these circumstances, the only avenue open to enter the market is through a contractual arrangement with a member of the "club." As a result, technology transfers occur outside the subsidiary system. In our situation, the existence of "clubs" reduces the amount of technology recorded as exports.[1]

Sourcing strategy: Sourcing strategy can influence technology transfers in two ways. First, a company can follow a

[1]The term "club" was used by one of the executives interviewed who asked to remain anonymous.

policy of centralized production for each product. Each subsidiary could be assigned responsibility for one product line with respect to production. This would lead to reduced transfers of technology, both imports and exports, since all subsidiaries would have to strive for technological autonomy. The opposite strategy, producing products near their markets, could lead to a high intensity of technology transfers among all subsidiaries.

All of the above mentioned variables influence technology transfers to some extent yet have been excluded for the purpose of our study. They could eventually be considered with a large enough sample of MNCs that would allow blocking along these variables. But only the existence of a significant number of MNCs for each category would allow us to isolate these factors. Such a sample is beyond the objectives of this study.

3. Contribution to The Field of International Business

This research is intended as a contribution to the field of international business. As such it represents the first approach of a systematic analysis of intra-MNC transfers of technology. The results have shown that MNCs clearly raise the technological standards of their subsidiaries. The study contributes to four areas of interest to the researcher in international business.

3.1. Knowledge of MNCs. The study adds to the knowledge of operations of MNCs in an area where data is sparse. Previous studies as detailed in Chapter I, have concentrated on case studies or industry data, and an integrative concept has been lacking.

3.2. Research methodology. One of the major contributions of this research is in the area of research methodology. First, a systematic approach to collect data on technology transfer has been outlined. Technology has been divided into R, D, and E level technology components. Similarly, all subsidiaries have been classified according to their level of technological capabilities. This same approach can easily be adopted by other researchers and data across many MNCs could be pooled. Second, MNCs cannot be considered as one homogeneous group any more. Instead, companies are considered to differ along the dimensions of multinationality. This new approach allows us to forecast future developments by isolating emerging from mature MNCs. As such this approach can be used for other investigations on MNCs. Therefore, we believe that this study contains a conceptual methodology beyond the context of technology transfer that could be extended to investigate the transfer of other resources by MNCs. Particularly, an extension of this research into transfers of managerial technology is now a real possibility.

3.3. Policy implications for MNCs. Many students of MNCs have suggested that a MNC constantly appraise its contribution to a host country.[2] Traditionally, such an apprais-

---

[2] Robinson, Richard D., International Business Policy, Holt, Rinehart and Winston, New York, 1966, Chapter 3.

al focused on the contribution to the host country's economy in monetary terms and, in particular, on the host country's balance of payment. However, MNCs have long maintained that they contribute substantially to a host country's technological development. This fact is confirmed by the results of this study. To control and substantiate such technological contributions, however, a MNC could effectively employ a technological reporting system as developed for the purpose of this study. Such a system would serve to monitor technology flows for internal control as well as to document contributions to host countries.

3.4. Policy implications for government agencies. Governments are increasingly concerned about the activities of MNCs within their boundaries. One particular area of concern has been technology. The research methodology employed for this study can be extended for the purpose of a national technological accounting system. Part of this system would be the development of a balance of technology to monitor flows across national borders. Governments have made attempts to motivate MNCs to increase local technological capability. Such actions could be based on data collected through a reporting system similar to the one employed here.

Since all MNCs of the sample are US based, the research findings can more likely be generalized for US based MNCs than for foreign based MNCs. The trend, demonstrated with TIME as an independent variable, leads to a further shift from exporting to importing of technology. This has important policy implications for the United States. Critics have generally assailed MNCs for their export of technology that will lead to a loss of US preeminance in modern technology. A sudden stop to such transfers would result in a stop of the inflows as well representing the benefits of having exported technologies earlier. At a time when an ever larger number of US MNCs are moving into a mature state, the companies will depend to a considerable degree on their foreign affiliates for technological inputs. Since with the growing concentration in US industry the MNCs account for a considerable share of total output, such a flow becomes critical to the further development of the industrial base in the US. MNCs have, in the past, fought for free trade to exploit their US invented technology abroad. With the new realities pointing towards higher imports, MNCs could be faced with a situation where they are fighting to be able to import technologies from their foreign subsidiaries.

The results of this research partially support and explain the work done by Boretsky.[3] Boretsky is concerned about a slowdown in the US' technological effort which might lead to slow growth in productivity and a loss in the US' technological leadership. Furthermore, he points out the

---

[3]Boretsky, Michael, US Technology: Trends and Policy Issues, Program of Policy Studies in Science and Technology, The George Washington University, Washington, D.C., 1973.

tremendous growth in US exports of technology.[4] Of the three causes Boretsky cites for the loss of US technological advantage, two relate directly to this study. In his report, Boretsky writes:

> "Relatively smaller in volume and rate of growth investment in economically relevant R&D in the United States than in other industrialized countries."

has been one of the major causes of the US' loss in technological leadership. He points towards a high concentration of US technological effort in defense related industries with little fall out for the commercial industries.[5] The results of this study can partly be used as an explanation of the cause Boretsky cites. MNCs have expanded new facilities for R&D abroad and naturally, the incremental contribution to growth in R&D in the various foreign countries has been larger than growth in the US. MNCs have spread their efforts over several countries rather than one (the United States) and have contributed significantly to R&D in many nations. Dunning,[6] Brash,[7] and Safarian[8] have all underlined the sub-

---

[4] Ibid., p. 66.

[5] Ibid., p. 77.

[6] Dunning, John H., The Role of American Investment in the British Economy, PEP Broadsheet No. 507, 1969.

[7] Brash, Donald T., American Investment in Australian Industry, Harvard University Press, Cambridge, Mass., 1966.

[8] Safarian, A.E., Foreign Ownership of Canadian Industry, McGraw-Hill of Canada, Toronto, 1966.

stantial contributions US MNCs have made to R&D in the UK, Australia, and Canada. Furthermore, they support the opinion that the research intensity of US owned foreign affiliates exceeds that of local companies. US industry with defense contracts has not had the option of expanding abroad resulting in a growing defense oriented R&D effort combined with a shift of non-defense R&D abroad. This trend has lead to an over-concentration of US funded R&D on defense. Yet such an interpretation of the data is only superficial. A considerable portion of foreign, economically-relevant, R&D is actually funded and controlled by US based MNCs. This technology can be transferred back to the US and should, at least in part, be considered a US contribution. The results presented in this research clearly show that new technologies are imported by US based MNCs at an increasing rate. Consequently, this development allows MNCs to deemphasize US based R&D. It is this author's judgement that for the development of the US industry, the source of the technology is of a lesser importance than the speed at which new knowledge is made available.

As a second major cause of the deterioration of the US technological leadership, Boretsky names the export of "naked" technology.[9] Under naked Boretsky means "sales of this technology in the form of patent rights and licenses, together

---

[9]Boretsky, op. cit., p. 97.

with appropriate instructions, blueprints and other technical assistance on the part of the seller to assure exploitation of the know how, for a fixed or 'running' fee rather than the export of such technology embodied in products manufactured in the United States."[10] Boretsky demonstrates a faster growth for exports over the 1960 to 1970 period.[11]

The results of this research are in direct contradiction with Boretsky's data. The reason for this difference lies in the research methodology that does not separate mature from emerging MNCs. Consequently, in the 1960's when US MNCs expanded at a tremendous pace, the emerging companies were by far in the majority. But projections for the future cannot be made based on data concentrating on emerging MNCs. Such forecasts need to be done with the development of mature MNCs in mind. Thus, while Boretsky concludes that such a sell-out of US technology will undermine the standing of the United States, the author of this study concludes that such a heavy export emphasis is only temporary and is bound to subside once the initial rush abroad has passed.

The results of this research showed a development similar to Vernon's trade cycle.[12] In Vernon's article, results

---

[10] Ibid.

[11] Ibid., p. 105.

[12] Vernon, Raymond, "International Investment and International Trade in the Product Cycle," Quarterly Journal of Economics, Vol. 80, May 1966.

are based on various product groups and reported separately. In this study, however, no disaggregate data is presented that could lead to a direct comparison of the results. However, there appears a strong resemblance in the two hypotheses and an argument can be made that the results of this model of technology transfer are a further proof of Vernon's trade cycle hypothesis. To arrive at a definitive conclusion, however, each industry that has been analyzed by Vernon would have to be subject of a study such as the one presented here.

4. Future Research

This research is intended to be exploratory. Consequently, to gain further insights into the determinants of technology transfers this research should be extended over a large number of MNCs, United States and foreign based. An enlarged sample would allow us to considerably narrow the observation span for each MNC and therefore better control confounding variables.

Once a reliable data base has been assembled, investigations with regard to the variables mentioned in Section 2. of this chapter can be undertaken. The results of this study are not definitive and need further confirmation.

BIBLIOGRAPHY

Abramovitz, Moses. "Resource and Output Trends in the United States since 1870," American Economic Review, Vol. 46, No. 2, May 1956.

Aharoni, Yair. "On the Definition of a Multinational Corporation," Quarterly Review of Economics and Business, Vol. II, Autumn 1971.

Anshen, Melvin, and Bach, George L., eds., Management and Corporations, New York, McGraw-Hill, 1960.

Arrow, Kenneth J., "The Economic Implications of Learning by Doing," Review of Economic Studies, June 1962.

Baranson, Jack, Industrial Technologies for Developing Economies, Praeger, New York, 1969.

Baranson, Jack, International Transfer of Automotive Technology to Developing Countries, Unitar Research Report No. 8, United Nations Institute for Training and Research, New York, 1971.

Behrman, Jack N., Some Patterns in the Rise of the Multinational Enterprise, Graduate School of Business Administration, University of North Carolina at Chapel Hill, 1969.

Bhagwati, J., "The Pure Theory of International Trade: A Survey," Surveys of Economic Development, Vol. II, 1965.

Bhagwati, J., Trade, Tariffs and Growth, Cambridge, 1969.

Boretsky, Michael, US Technology: Trends and Policy Issues, Program of Policy Studies in Science and Technology, The George Washington University, Washington, D.C., 1973.

Brash, Donald T., American Investment in Australian Industry, Harvard University Press, Cambridge, Mass., 1966.

Bruck, J.K. and Lees, F.A., "Foreign Content of US Corporate Activities," Financial Analysis Journal, September-October 1966.

Bruck, J.K. and Lees, F.A., "Foreign Investments, Capital Control, and the Balance of Payments," The Bulletin, New York University Institute of Finance, April 1968.

Campbell, Donald T. and Stanley, Julian C., Experimental and Quasi-Experimental Designs for Research, Rand McNally, Chicago, 1963.

Chang, U.S., The Transfer of Technology: Economics of Offshore Assembly, The Case of Semiconductor Industry. Unitar Research Report No. 11, United Nations Institute for Training and Research, New York, 1971.

Chipman, John, "A Survey of the Theory of International Trade," Part 1, Econometrica, 23, No. 3, July 1965, pp. 477-519.

Chipman, John, "A Survey of the Theory of International Trade," Part 2, Econometrica, No. 4, October 1965, pp. 685-760.

Cibulskis, R.D., et. al., Technology Indicators, Worcester Polytechnic Institute, Project Center, unpublished report, 1974.

Croxton, Frederick E. and Cowden, Dudley T., Practical Business Statistics, Prentice-Hall, N.J., Englewood Cliffs, 1960.

Denison, Edward F., The Sources of Economic Growth in the United States and the Alternatives Before Us, Supplementary Paper No. 13, Committee for Economic Development, New York, 1962.

Draper, N.R. and Smith, H., Applied Regression Analysis, John Wiley & Sons, New York, 1966.

Drucker, Peter F., The Concept of the Corporation, The New American Library, New York, 1964.

Duerr, Michael G., R&D in the Multinational Company, The Conference Board, Ottawa, 1970.

Dunning, John H., The Role of American Investment in the British Economy, PEP Broadsheet No. 507, 1969.

Dunning, John, ed., The Multinational Enterprise, George Allen Unwin, London, 1971.

Dunning, John and Steuer, M., The Effects of US Investment on UK Technology, Moorgate and Wall Street, 1969.

Franko, L.G., European Business Strategies in the US, Business International, Geneva, 1971.

Goldberger, Arthur S., Econometric Theory, John Wiley & Sons, New York, 1964.

Green, Paul E. and Tull, Donald S., Research for Marketing Decisions, 2nd ed., Prentice-Hall, N.J., 1970.

Gruber, William; Metha, Dileep; and Vernon, Raymond, "The R&D Factor in International Trade and International Investment of United States Industries," Journal of Political Economy, February 1967, pp. 20-37.

Hahlo, H.R.; Smith, J. Graham; and Wright, Richard W., Nationalism and the Multinational Enterprise, Oceana Publications, Dobbs Ferry, N.Y., 1973.

Hanson, W.T. Jr., "Multinational R&D in Practice - Two Case Studies," Research Management, January 1971.

Hawthorne, Edward P., The Transfer of Technology, OECD, Paris, 1971.

Hufbauer, Garry C., Synthetic Materials and the Theory of International Trade, Harvard University Press, Cambridge, 1966.

Jacoby, Neil H., "The Multinational Corporation," The Center Magazine, Vol. III, No. 1, May 1970.

Keesing, Donald B., "The Impact of Research and Development on United States Trade," Journal of Political Economy, February 1967, pp. 45.

Kapoor, A. and Grub, Phillip D., The Multinational Enterprise in Transition, The Darwin Press, Princeton, N.J., 1972.

Kerlinger, Fred N., Foundations of Behavioral Research, Holt, Rinehart and Winston, New York, 1964.

Kindleberger, Ch.P., ed., The International Corporation, The MIT Press, Cambridge, 1970.

Kujawa, Duane, ed., American Labor and the Multinational Corporation, Praeger Publishers, New York, 1973.

Mansfield, Edwin, Economics of Technical Change, W.W. Norton & Co., New York, 1968.

Mansfield, Edwin, Industrial Research and Technological Innovation, W.W. Norton, New York, 1968.

Martyn, Howe, Multinational Business Management, Heath & Co., Lexington, Mass., 1970.

National Academy of Sciences, US International Firms and R, D, & E in Developing Countries, Washington, 1973.

National Science Foundation, NSF 73-305, Research and Development in Industry 1971.

Nelson, Richard, ed., The Rate and Direction of Inventive Activity, National Bureau of Economic Research, Princeton University Press, Princeton, 1962.

Nelson, Richard R.; Peck, Merton J.; and Kalacheck, Edward P., Technology, Economic Growth and Public Policy, The Brookings Institutions, Washington, 1967.

Nie, Norman H.; Bent, Dale H.; Hull, C. Hadlai, SPSS: Statistical Package For the Social Sciences, McGraw-Hill Book Company, New York, 1970.

OECD, Gaps in Technology, Paris, 1970.

Papo, Maurice, "How to establish and operate multinational labs," Research Management, January 1971.

Perlmutter, Howard V., Three Conceptions of a World Enterprise," Revue Economique et Sociale, May 1965.

Perlmutter, Howard V., "The Tortuous Evolution of the Multinational Corporation," Columbia Journal of World Business, January-February 1969.

Perlmutter, Howard V., "The Multinational Firm and the Future," The Annals, September 1972.

Phatak, Arvind V., Evolution of World Enterprises, American Management Association, 1971.

Polk, Judd. "The New World Economy," Columbia Journal of World Business, January-February 1968.

Quinn, James B., Harvard Business Review, "Technology Transfer by Multinational Companies," November-December 1969, pp. 147-161.

Robinson, Richard D., International Business Policy, Holt, Rinehart and Winston, New York, 1966.

Robinson, Richard D., International Management, Holt, Rinehart and Winston, New York, 1967.

Robinson, Richard D., International Management, Holt, Rinehart and Winston, New York, 1973.

Robock, Stefan; and Simmonds, Kenneth, "International Business: How big is it? The Missing Measurements," Columbia Journal of World Business, May-June 1970.

Russell, Peter, ed., Nationalism in Canada, McGraw-Hill, Toronto, 1966.

Safarian, A.E., Foreign Ownership of Canadian Industry, McGraw-Hill of Canada, Toronto, 1966.

Salera, Virgil, Multinational Business, Boston, Houghton Mifflin, 1969.

Sametz, Arnold W., "The Foreign Multinational Company in the US," Salamon Brothers Center for the Study of Financial Institutions, New York University, Working Paper No. 9, 1973.

Schmookler, Jacob, Invention and Economic Growth, Harvard University Press, Cambridge, Mass., 1966.

Servan-Schreiber, J.J., Le défi américain, Editions Denoël, Paris, 1967.

Solow, Robert M., "Technical Change and the Aggregate Production Function," Review of Economics and Statistics, 39, 1957.

Solow, Robert M., "Technical Progress, Capital Formation, and Economic Growth," American Economic Review, Vol. 52, No. 2, May 1962.

Stanford Research Institute, Long Range Planning Report No. 198, 1963.

Stobaugh, Robert B., The International Transfer of Technology in the Establishment of the Petrochemical Industry in Developing Countries, Unitar Research Report No. 12, United Nationals Institute for Training and Research, New York, 1971.

Task Force on the Structure of Canadian Industry, Foreign Ownership and the Structure of Canadian Industry, Queens Printer, Ottawa, 1968.

Unesco, The Role of Science and Technology in Economic Development, Paris, 1970.

US Department of Commerce, Foreign Affiliate Survey, 1967-1968.

US Senate Committee on Finance, "Implications of Multinational Firms for World Trade and Investment and for US Trade and Labor," US Government Printing Office, Washington, 1973.

Vaupel, James W. and Curhan, Joan P., _The Making of Multinational Enterprise_, Graduate School of Business Administration, Harvard University, Boston, 1969.

Vernon, Raymond, "International Investment and International Trade in the Product Cycle," _Quarterly Journal of Economics_, Vol. 80, May 1966.

Vernon, Raymond, ed., _The Technology Factor in International Trade_, National Bureau of Economic Research, New York, 1970.

Vernon, Raymond, _Sovereignty at Bay_, Basic Books, New York, 1971.

Wells, Louis T. Jr., "A Product Life Cycle for International Trade," _Journal of Marketing_, Vol. 32, July 1968, pp. 1-6.

Wentz, Walter, _Marketing Research: Management & Methods_, Harper & Row, 1972.

Williams, Bruce R., _Technology, Investment and Growth_, Chapman and Hall, London, 1967.

Wortzel, Lawrence H., _Technology Transfer in the Pharmaceutical Industry_, Unitar Research Report No. 14, United Nations Institute for Training and Research, New York, 1971.

APPENDIX I

APPENDIX I

Data Base Collected from Participating MNCs

1. Sprague Electric Company

First Foreign Operation: 1956

Countries with Production Facilities (12)

Year of Entry	Country	Present Technology level
1956	Italy	D
1960	Hong Kong	E
	Belgium	D
	Mexico	E
1962	Canada	D
1965	Spain	E
1967	France	D
1969	Taiwan	E
1970	England	D
	Germany	D
	Japan	E
1974	Malaysia	E

Research Organizations (6)

Year D Level Reached (estimates)	Country	Present Level
1956	Italy	D
1960	Belgium	D
1962	Canada	D
1967	France	D
1970	England	D
	Germany	D

Technology Exports

Year	Country	Content	Level
1956	Italy	Aluminum Electrolytic Capacitator	E
1960	Hong Kong	Aluminum Electr. Cap.	E
	Belgium	Magnetic Components	E
	Mexico	Aluminum Electr. Cap.	E
1962	Canada	Aluminum Electr. Cap.	E
1963	Italy	Solid Tantalum Cap.	E
	Belgium	Metanets	E

1967	Italy	Wet Tantalum Cap.	E
	Canada	Solid Tantalum Cap.	E
	France	Resistors	E
1968	Hong Kong	Solid Tantalum Cap.	E
1969	Taiwan	Magnetic Comp.	E
	Mexico	Aluminum Electrolytics	E
	Mexico	Semiconductors	E
1970	Belgium	Aluminum Substrates	E
	Mexico	Solid Tantalum Cap.	E
	England	Aluminum Electr. Cap.	E
	Japan	Solid Tantalum Cap.	E
1971	Belgium	Ceramic Monolytic Cap.	E
1971	France	Wet Tantalum Cap.	E
	Taiwan	Paper Film Cap.	E
1972	Taiwan	Ceramic Monolytic Cap.	E
	England	Wet Tantalum Cap.	E
1974	Malaysia	Solid Tantalum Cap.	E

Not included here are exports made by subsidiaries to third countries.

Technology Imports

Year (estimates)	Originating Country	Content	Level
1964	Italy	Solid Tantalum Cap.	E
1965	Belgium	Metanets	E
1969	Italy	Wet Tantalum Cap.	E

2. New England Computer Company

First Foreign Operation: 1963

Countries with Manufacturing Operations (4)

Year	Country	Level
1963	Canada	E
1971	Ireland	E
1972	Taiwan	E
1974	Hong Kong	E

Puerto Rico, where the company maintains a plant, is not considered a foreign country.

Research Organizations (0)
None at present

Technology Exports

Year	Country	Content	Level
1963	Canada	Wire Wrap Panels (final assembly)	E
1971	Ireland	Final assembly, test	E
1972	Taiwan	Memory Stack System	E
1974	Hong Kong	Memory Stack System	E

Technology Imports
None reported

3. Consumer Chemical Company

First Foreign Operation: 1944 (estimate)

Countries with Production Facilities (3)

Year	Country	Level
1964	Mexico	E
1967	England	E

Research Organizations (1)

1950's (estimate)	Canada	D

Technology Exports

Year	Country	Content	Level
1944	Canada	Inks, Adhesives, Carbons, Ribbons	E
1962	Canada	Markers	E (est.)
1964	Mexico	Inks, Adhesives, Markers	E
1967		Inks, Adhesives, Markers	E

Technology Imports
None recorded

4. Industrial Supply Company

First Foreign Operation: 1909

Countries with Production Facilities (17)

Year	Country	Level
1909	Germany	E
1919	Canada	R
1920	France	D
1930	England	E

1935	Italy	E
1938	Australia	D
1951	South Africa	D
1956	Argentina	E
	Brazil	E
1962	Luxembourg	E
	Mexico	E
1965	Norway	E
1966	Spain	E
1967	New Zealand	E
	India	E
1968	Japan	E
1972	Malaysia	E

Research Organizations (4)

Year (est.)	Country	Level
1950	France	D
1950	Australia	D
1960	South Africa	D
1960 (separate) (organi- zation)	Canada	R

Technology Exports

Year	Country	Content	Level
1909	Germany	Bonded Products	E
1919	Canada	Bonded Products	E
1920	France	Bonded Products	E
1930	England	Bonded Products	E
1935	France	Refractories	E
	Germany	Refractories	E
	Italy	Bonded Products	E
1938	Australia	Bonded Products	E
1950	England	Refractories	E
1951	Australia	Coated Products	E
	Canada	Coated Products	E
	Canada	Crude Products	E
	France	Coated Products	E
	South Africa	Refractories	E
	South Africa	Bonded Products	E
1952	England	Coated Products	E
1956	Argentina	Coated Products	E
	Brazil	Bonded Products	E
	Brazil	Coated Products	E
	Brazil	Crude Products	E
1958	England	Crude Alum. Products	E

1962	Luxembourg	Clipper Machine	E
	Mexico	Bonded Products	E
	Mexico	Coated Products	E
1965	Norway	Crude Silicone Products	E
1966	Spain	Bonded Products	E
1967	India	Bonded Products	E
	New Zealand	Tapes	E
1968	Japan	Bonded Products	E
1969	Japan	Crude Alum. Products	E
1970	Canada	Diamond Tools	E
	Japan	Coated Products	E
	England	Refractories	E
1972	India	Crude Carbide Products	E
	Japan	Bonded Products	E
	Malaysia	Tapes	E

Technology Imports
None

Comments
No major imports from subsidiaries have been listed. This reflects the immature nature of the company's product line. A continuous flow of information is maintained among all foreign plants mostly dealing in production problems (E Level).

5. Office Supply Company

First Foreign Operation: No Production Facilities Abroad

Countries with Licensing Agreements
1950 Germany
1950 England
1954 France
1958 Japan

Research Organizations (0)
None

Technology Exports (major licensing agreements)

Year	Country	Content	Level
1950	Germany	Barry Line	E (est.)
	England	Barry Line	E
1954	France	Visirecord Line	E
1958	Japan	Barry Line	E
1955	France	Barry Line	E (est.)
1970	Germany	Wright Line	E (est.)
1971	France	Wright Line	E
No Date	England	Visirecord Line	E

Comments

This represents the activities of a small producer of office supplies that, up to now, does not have any direct foreign investment abroad other than a marketing subsidiary in Italy. By including such a company, we are able to collect data on MNCs from zero foreign involvement to a mature state.

6. Aerospace International

First Foreign Operation: 1956

Countries with Production Facilities (6)

Year	Country	Level
1956	Canada	E
1959	Switzerland	D
1960	Italy	-
1961	England	E
	India	E
	Japan	E
1973	West Germany	D
	divested Italy	

Research Organizations (3)

Year (author estimated)	Country	Level
1959	Switzerland	D
1961	England	D
1973	Germany	D

Technology Exports

Year	Country	Content	Level
1956	Canada	Electronic Tubes	E
1960	Italy	Radar A	E
1961	Japan	Components	E
1962	India	Components	E
1963	Switzerland	Power Supply	E
1965	Italy	Missile B	E
1967	England	Display A	E
1973	NATO (entered because some subsidiaries would be affected by this transfer)	Missile C	D
1974	England	Display B	E

Technology Imports

1969	from England	Radio B	E

7. International Company - Chemical Division

Period of Observation: 1969-1974

First Foreign Operation: 1922 (no exact date could be determined, actual date could be earlier)

Countries with Production Facilities (12)
All these countries had facilities prior to 1969. During the observation period of 1969-1974, no new facilities in other countries were added.

Sweden	D
Australia	D
Portugal	E
Germany	R
Ireland	E
Japan	E
England	D
New Zealand	E
France	D
Spain	E
South Africa	D

Research Organizations

1971	Germany	R
	Sweden	D
	Australia	D
	Germany	D
	England	D
	France	D
	South Africa	D

All organizations with D capabilities are assumed to have reached that stage prior to 1969.

Technology Exports

1972	Germany	Aircraft Paint	E
1972	Australia	Weather Stripping	D

Technology Imports

	From		
1972	Germany	Polyester Process	E
1973	Germany	Adhesive	D
1973	Germany	Film Adhesive	E
1974	Germany	Adhesives	E

Comments
Since all subsidiaries of the division have free access to the technology of each other, there is a constant flow of exchanges averaging about 5 to 6 exports and imports monthly at the D level.

8. <u>International Company - Machinery Division</u>

Period of Observation: 1969-1974

First Foreign Operation: 1899

Countries with Production Facilities (15)
During the 1969-1974 period, the number of countries with production facilities remained constant.

Australia	E
New Zealand	E
South Africa	E
England	R
Brazil	E
Germany	R
Japan	E
Ireland	E
Spain	E
Sweden	E
France	E
Italy	E
Portugal	E
Argentina	E
Netherlands	

Research organizations (8)

All in existence before 1969

Germany	1 at R level 2 at D level
England	1 at R level 4 at D level

Technology Exports

1969	England	Machine Brushes	D

Technology Imports

	From		
1969	England	Unidec (joint US-UK development)	D
1970	England	Pattern Grader	D
1971	England/Germany	Pulling & Lashing Machine	D
1973	England	Unifast Machinery	D

9. International Company - Heavy Machinery Division

Period of Observation 1969-1974

Frist Foreign Operation: 1947

Countries with Production Facilities (2)

England	D
Italy	D

Both set up prior to 1969.

Research Organizations: (2)

England	D
Italy	D

Both are assumed to have reached that level prior to 1969.

Technology Exports

1969	Italy	75 Ton Machine	D
	England	75 Ton Machine	D
	Italy	125 Ton Machine	D
	England	125 Ton Machine	D
1970	Italy	Molding Machine	D
	England	Mixer	D
1971	Italy	Mixer	D
	England	Molding Machine	D
1972	Italy	Mixer (redesigned)	D
	England	Molding Machine (redesigned)	D
1973	England	Extruder	D

Technology Imports

	From		
1974	England	Cooler	D
1974	England	Pelletizer	D

10. International Company - Industrial Supplies Division

Period of Observation: 1969-1974

First Foreign Operation: 1925 (estimate)

Countries with Production Facilities (8)

Prior to 1969	France	D
	Japan	D
	England	R
	Australia	D
	Germany	D
	Sweden	D
	Brazil	E

1972	Spain		E

Research Organizations (6)

Prior to 1969	France	D
	England	R
	Australia	D
	Germany	D
	Sweden	
1971(est.)	Japan	D

Technology Exports

1969	Japan	Warren System	E
1970	France	Bolts	D
	Australia	Patch	D
1971	England	Bolts	D
	England	Nuts	D
1972	France	Screws	D
	Germany	Welding Equipment	D
	Australia	Welding Equipment	D
	France		D
	Japan		D
	Spain	Slips	D
	England		D
	Sweden	Fasteners	D
	Australia	Fasteners	D
1973	Sweden	Patch	D
1974	Japan	Screws	D
	Brazil		E
	Japan	Bolts	D
	Australia		D

Technology Imports
None reported

11. Multinational Paper Company

First Foreign Operation: 1912

Countries with Production Facilities (6)

1912	England	E
1922	Canada	E
1969	Australia	E
1972	Denmark	E
	Belgium	E
1974	France	E

Research Organizations (0)
None outside the United States

Technology Exports (only major, discrete transfers)

1912	England	Paper Products	E
1922	Canada	Paper Products	E
1969	Australia	Paper Products	E
1972	Denmark	Paper Products	E
1972	Belgium	Paper Products	E
1974	France	NBB Products	E

Technology Imports
None reported

12. Gillette Corporation (excluding Brown AG, Germany)

Period of Observation: 1967-1974

First Foreign Operation: 1908

Countries with Production Facilities (19)

Prior to 1967	Germany	E
	France	E
	Spain (1967)	E
	Brazil	E
	England	R
	Argentina	E
	Mexico	E
	Australia	E
	Canada	E
	Colombia	E
1968	South Africa	E
1969	Venezuela	E
1970	Malaysia	E
1971	Jamaica	E
	Phillippines	E
1972	Indonesia	E
	Iran	E
1973	Puerto Rico	E
	Yugoslavia	E

Research Organizations (2)

England (2 organizations)	1R 1D

Technology Exports

1967	Colombia	Pens	E
	England (est.)	Pens	E
	Australia "	Pens	E
	Germany	Techmatic	E
	England	Techmatic	E
	Argentina	Techmatic	E
	Mexico	Razors Techmatic	E
	Spain	Blades	E
1968	South Africa	Blades	E
1969	Venezuela	Blades	E
1970	Germany/France		E/E
	Spain		E
	Brazil		E
	England	Platinum Plus	E
	Argentina		E
	Mexico		E
	Australia		E
	Canada		E
	Colombia		E
	Venezuela	Pens	E
1972	Germany	TracII Blades	E
	Iran	Blades	E
	Brazil	Lighters	E
	Mexico	Lighters	E
1973	Puerto Rico	Lighters	E
	Brazil	TracII Blades	E
	Canada	G2 Assembly	E
	Yugoslavia	Blades	E

Technology Imports

1971	England	TracII Technology (partially)	R

13. International Photo Equipment Company

First Foreign Operation: 1965

Countries with Production Facilities (2)

1965	England	E
1965	Netherlands	E

Research Organizations
None abroad

Technology Exports

1965	England	Roll Film	E
	Netherlands		E
1967	England	Pack Film	E
	Netherlands		E
1970	England	Black & White Film	E
	Netherlands		E
1974	England	Camera Parts	E
	Netherlands	Camera Parts	E
	Netherlands	Special Film	E

Technology Imports

14. International Instruments Company

Period of Observation: 1968-1974

First Foreign Operation: 1934 (estimate)

Countries with Production Facilities (7)

1934	England	R
1947	Canada	E
1961	Netherlands	D
1962	Mexico	E
1964	France	E
1965	Australia	E
1970	Argentina	E

Research Organizations (2)

England	R
Netherlands	D

Both estimated to have reached this capability prior to 1968 when our period of observation started.

Technology Exports

1968	England	Cons 100	E
	Canada	Cons 100	E
	Netherlands	Cons 100	E
1970	Argentina	Assembly Technology	E
1971	England		E,E
	Canada	Motion-type Transmitter & Valves	E,E
	Mexico		E
	France	Transmitters	E
	Australia		E

	Argentina	Valves	E
1972	England	System I	E
	Netherlands	System I	E
1973	England	System II	E
	Netherlands	System II	E

<u>Technology Imports</u>

	From		
1971	England	Transmitter	E

APPENDIX II

APPENDIX II

Score Sheets for MNCs in Sample

1. Sprague Electric Company

1.1 Total Transactions

Exports

Range	Time (1-18)	Countries (1-12)		Research Org. (1-6)	
1	E	1	E	1	E
5	3E	4	3E	2	3E
7	E	5	3E	3	3E
8	2E	6	-	4	7E
12	3E	7	4E	6	10E
13	E	8	3E		
14	3E	11	9E		
15	4E	12	E		
16	3E				
17	2E				
18	E				

Imports

	Time (1-18)	Countries (1-12)		Research Org. (1-6)	
8	E	5	E	3	2E
9	E	6	E	4	E
13	E	8	E		
All others none		All others none		All others none	

1.2 Adjusted Transactions

A technology is only included when transferred the first time.

Exports

	Time	Countries		Research Org.	
1	E	1	E	1	E
5	E	4	E	2	E
8	E	5	2E	3	2E
12	E	7	2E	4	3E
14	E	8	E	6	3E
15	E	11	3E		
16	E	12	0		

Imports

Same data as 1.1

2. New England Computer Company

2.1 Total Transactions

Exports

Time (1-11)		Countries (1-4)		Research Org. (0)	
1	E	1	E	0	4E
8	E	2	E		
9	E	3	E		
11	E	4	E		

Imports

Time (1-11)	Countries (1-4)	Research Org. (0)
zero	zero	zero

2.2 Adjusted Transactions

Exports

Time (1-11)		Countries (1-4)		Research Org. (0)	
1	E	1	E	0	2E
9	E	3	E		

Imports

Same as in section 2.1

3. Consumer Chemical Company

3.1 Total Transactions

Exports

Time (1-30)		Countries (1-3)		Research Org. (0-1)	
1	2E	1	3E	0	2E
18	E	2	2E	1	4E
20	2E	3	2E		
23	2E				

Imports

Time (1-30)	Countries (1-3)	Research Org. (0-1)
zero	zero	zero

3.2 Adjusted Transactions

Exports

Time (1-30)		Countries (1-3)		Research Org. (0-1)	
1	2E	1	3E	0	2E
18	E			1	E

Imports

Same as in section 3.1

4. Industrial Supply Company

4.1 Total Transactions

Exports

Time (1-63)	
1	E
10	E
11	E
21	E
26	3E
29	E
41	E
42	6E
43	E
47	E
49	E
53	3E
56	E
57	E
58	2E
59	E
60	E
61	3E
63	3E

Countries (1-17)	
1	E
2	E
3	E
4	E
5	3E
6	2E
7	7E
9	5E
11	3E
12	E
13	E
15	2E
16	6E
17	3E

Research Org. (0-4)	
0	8E
2	12E
4	16E

Imports

Time (1-63)	Countries (1-17)	Research Org. (0-4)
zero	zero	zero

Adjusted Transactions

Exports

Time (1-63)	
1	E
26	E
42	2E
49	E
53	E
57	E
61	E

Countries (1-17)	
1	E
5	E
7	2E
9	E
11	E
15	E
16	E

Research Org. (0-4)	
0	2E
2	3E
4	3E

Imports

Same as in Section 4.1

5. Office Supply Company

5.1 Total Transactions

Exports

Time	Countries	Research Org.
0 8E	0 8E	0 8E

Imports

Time	Countries	Research Org.
zero	zero	zero

5.2 Adjusted Transactions

Exports

Time	Countries	Research Org.
0 3E	0 3E	0 3E

Imports

Same as in Section 5.1

6. Aerospace International

6.1 Total Transactions

Exports

Time (1-18)		Countries (1-6)		Research Org. (0-3)	
1	E	1	E	0	E
4	E	2	-	1	E
5	E	3	E	2	5E
6	E	6	6E,D	3	E,D
7	E				
9	E				
11	E				
17	D				
18	E				

Imports

Time (1-18)		Countries (1-6)		Research Org. (0-3)	
17	E	6	E	3	E

6.2 Adjusted Transactions

Exports

Time (1-18)		Countries (1-6)		Research Org. (0-3)	
1	E	1	E	0	E
4	E	2	-	1	E
5	E	3	E	2	4E
7	E	6	5E,D	3	E,D
9	E				
11	E				
17	E				
18	E				

Imports

Same as in Section 6.1

7. International Company - Chemical Division

7.1 Total Transactions

Exports

	Time (47-52)	Countries (11)		Research Org. (6-7)	
50	E,D	11	E,D	7	E,D

Imports

	Time (47-52)	Countries (11)		Research Org. (6-7)	
50	E	11	3E,D	7	3E,D
51	D,E				
52	E				

7.2 Adjusted Transactions

Same as under section 7.1

8. International Company - Machinery Division

8.1 Total Transactions

Exports

	Time (70-75)	Countries (15)		Research Org. (8)	
70	D	15	D	8	D

Imports

	Time (70-75)	Countries (15)		Research Org. (8)	
70	D	15	4D	8	4D
71	D				
72	D				
74	D				

8.2 Adjusted Transactions

Same as under Section 8.1

9. International Company - Heavy Machinery Division

9.1 Total Transactions

Exports

	Time (22-27)	Countries (2)		Research Org. (2)	
22	4D	2	11D	2	11D
23	D,D				
24	D,D				
25	D,D				
26	D				

Imports

	Time (22-27)	Countries (2)		Research Org. (2)	
27	D,D	2	D,D	2	D,D

9.2 Adjusted Transactions

Same as under section 9.1

10. International Company - Industrial Supplies Division

10.1 Total Transactions

Exports

	Time (44-49)	Countries (7-8)		Research Org. (5-6)	
44	E	7	E,4D	5	E,2D
45	2D	8	E,13D	6	E,15D
46	2D				
47	9D				
48	D				
49	3D,E				

Imports

Time (44-49)	Countries (7-8)	Research Org. (5-6)
zero	zero	zero

10.2 Adjusted Transactions

Exports

	Time (44-49)	Countries (7-8)		Research Org. (5-6)	
44	E	7	E,3D	5	E,2D
45	2D	8	4E	6	5D
46	D				
47	4D				

Imports

Same as in section 10.1

11. Multinational Paper Company

11.1 Total Transactions

Exports

Time (1-62)		Countries (1-6)		Research Org. (0)	
1	E	1	E	0	6E
10	E	2	E		
57	E	3	E		
60	2E	4	E		
62	E	5	E		
		6	E		

Imports

Time (1-62)	Countries (1-6)	Research Org. (0)
zero	zero	zero

11.2 Adjusted Transactions

Exports

Time (1-62)		Countries (1-6)		Research Org. (0)	
1	E	1	E	0	2E
62	E	6	E		

Imports

Same as in section 11.1

12. Gillette

12.1 Total Transactions

Exports

Time (59-66)		Countries (10-19)		Research Org. (2)	
59	8E	10	8E	2	30E
60	E	11	E		
61	E	12	E		
62	11E	13	11E		
64	4E	15	-		
65	4E	17	4E		
66	E	19	5E		

Imports

Time (59-66)		Countries (10-19)		Research Org. (2)	
63	R	15	R	2	R

12.2 Adjusted Transactions

Exports

Time (59-66)		Countries (10-19)		Research Org. (2)	
59	3E	10	3E	2	7E
60	E	11	E		
62	E	13	2E		
64	2E	17	E		

Imports

Same as in section 12.1

13. International Photo Equipment

13.1 Total Transactions

Exports

	Time (1-10)	Countries (2)		Research Org. (0)	
1	2E	2	9E	0	9E
3	2E				
6	2E				
10	3E				

Imports

Time (1-10)	Countries (2)	Research Org. (0)
zero	zero	zero

13.2 Adjusted Transactions

Exports

	Time (1-10)	Countries (2)		Research Org. (0)	
1	E	2	5E	0	5E
3	E				
6	E				
10	2E				

Imports

Same as in section 13.1

14. International Instruments Company

14.1 Total Transactions

Exports

Time (34-40)		Countries (6-7)		Research Org. (2)	
34	3E	6	3E	2	19E
36	E	7	16E		
37	11E				
38	2E				
39	E				

Imports

Time (34-40)		Countries (6-7)		Research Org. (2)	
37	E	7	E	2	E

14.2 Adjusted Transactions

Exports

Time (34-40)		Countries (6-7)		Research Org. (2)	
34	E	6	E	2	5E
37	2E	7	4E		
38	E				
39	E				

Imports

Same as in section 14.1

APPENDIX III

Exhibit IIIa

Technology Transfers as a Function of COUNTRIES

Data Matrix - Nonadjusted Data

No.	Variable																				
1	Countries	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
2	Total Transactions	8	8	27	6	6	8	15	33	18	5	8	19	3	12	0	8	6	7	0	5
3	/MNCs	8	1.14	3.38	1	1.2	2	3	8.25	6	2.5	2.66	4.75	1	6	0	2.66	3	3.5	0	5
4	T Des Trans	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
5	/MNCs	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	.33	0	0	0	0
6	T Dev Trans	0	0	13	0	0	0	3	4	13	0	0	2	0	0	0	5	0	0	0	0
7	/MNCs	0	0	1.63	0	0	0	.6	1	4.33	0	0	.5	0	0	0	1.66	0	0	0	0
8	T Eng Trans	8	8	14	6	6	8	12	29	5	5	8	17	3	12	0	2	6	7	0	5
9	/MNCs	8	1.14	1.75	1	1.2	2	2.4	7.25	1.66	2.5	2.66	4.25	1	6	0	.66	3	3.5	0	5
10	Percent Res	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	13	0	0	0	0
11	Percent Dev	0	0	48	0	0	0	20	12	72	0	0	11	0	0	0	62	0	0	0	0
12	Percent Eng	100	100	52	100	100	100	80	88	28	100	100	89	100	100	0	25	100	100	0	100
13	Level	1	1	1.48	1	1	1	1.2	1.12	1.72	1	1	1.10	1	1	0	1.87	1	1	0	1
14	Total Export Tr.	8	8	25	6	6	7	13	32	17	5	8	15	3	12	0	3	6	7	0	5
15	/MNCs	8	1.14	3.13	1	1.2	1.75	2.6	8	5.66	2.5	2.66	3.75	1	6	0	1	3	3.5	0	5
16	T Res Exp	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
17	/MNCs	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
18	T Dev Exp	0	0	11	0	0	0	1	4	13	0	0	1	0	0	0	1	0	0	0	0
19	/MNCs	0	0	1.38	0	0	0	.2	1	4.33	0	0	.25	0	0	0	.33	0	0	0	0
20	T Eng Exp	8	8	14	6	6	7	12	28	4	5	8	14	3	12	0	2	6	7	0	5
21	/MNCs	8	1.14	1.75	1	1.2	1.75	2.4	7	1.33	2.5	2.66	3.5	1	6	0	.66	3	3.5	0	5
22	Percent Res Exp	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
23	Percent Dev Exp	0	0	44	0	0	0	7	13	76	0	0	7	0	0	0	33	0	0	0	0

Exhibit IIIa (Cont.)

24	Percent Eng Exp	100	100	56	100	100	100	93	87	24	100	100	93	100	100	0	67	100	100	0	100
25	Level	1	1	1.44	1	1	1	1.08	1.13	1.76	1	1	1.06	1	1	0	1.33	1	1	0	1
26	Total Import Tr.	0	0	2	0	0	1	2	1	1	0	0	4	0	0	0	5	0	0	0	0
27	/MNCs	0	0	.25	0	0	.25	.4	.25	.33	0	0	1	0	0	0	1.66	0	0	0	0
28	T Res Imp	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
29	/MNCs	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	.33	0	0	0	0
30	T Dev Imp	0	0	2	0	0	0	0	0	0	0	0	1	0	0	0	4	0	0	0	0
31	/MNCs	0	0	.25	0	0	0	0	0	0	0	0	.25	0	0	0	1.33	0	0	0	0
32	T Eng Imp	0	0	0	0	0	1	2	1	1	0	0	3	0	0	0	0	0	0	0	0
33	/MNCs	0	0	0	0	0	.25	.4	.25	.33	0	0	.75	0	0	0	0	0	0	0	0
34	Percent Res Imp	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	20	0	0	0	0
35	Percent Dev Imp	0	0	100	0	0	0	0	0	0	0	0	25	0	0	0	80	0	0	0	0
36	Percent Eng Imp	0	0	0	0	0	100	100	100	100	0	0	75	0	0	0	0	0	0	0	0
37	Level	0	0	2	0	0	1	1	1	1	0	0	1.25	0	0	0	2.2	0	0	0	0
38	Number of MNCs	1	7	8	6	5	4	5	4	3	2	3	4	3	2	2	3	2	2	1	1

Exhibit IIIb

Technology Transfers as a Function of Research Organizations

Variable No.	Data Matrix - Non-adjusted Data								
1	0	1	2	3	4	5	6	7	8
2	38	6	82	6	24	5	26	6	5
3	5.43	1.5	11.71	1.5	12	2.5	8.66	6	5
4	0	0	1	0	0	0	0	0	0
5	0	0	.14	0	0	0	0	0	0
6	0	0	13	0	0	3	15	2	5
7	0	0	1.86	0	0	1.5	5	2	5
8	38	6	68	6	24	2	11	4	0
9	5.43	1.5	9.71	1.5	12	1	3.66	4	0
10	0	0	1	0	0	0	0	0	0
11	0	0	16	0	0	60	56	33	100
12	100	100	83	100	100	40	44	67	0
13	1	1	1.18	1	1	1.6	1.56	1.33	2
14	38	6	78	3	23	5	26	2	1
15	5.43	1.5	11.14	.75	11.5	2.5	8.66	2	1
16	0	0	0	0	0	0	0	0	0
17	0	0	0	0	0	0	0	0	0
18	0	0	11	0	0	3	15	1	1
19	0	0	1.57	0	0	1.5	5	1	1
20	38	6	67	3	23	2	11	1	0
21	5.43	1.5	9.57	.75	11.5	1	3.66	1	0
22	0	0	0	0	0	0	0	0	0
23	0	0	14	0	0	60	56	50	100
24	100	100	86	100	100	40	44	50	0
25	1	1	1.14	1	1	1.6	1.56	1.5	2
26	0	0	4	3	1	0	0	4	4
27	0	0	.57	.75	.5	0	0	4	4
28	0	0	1	0	0	0	0	0	0
29	0	0	.14	0	0	0	0	0	0
30	0	0	2	0	0	0	0	1	4
31	0	0	.29	0	0	0	0	1	4
32	0	0	1	3	1	0	0	3	0
33	0	0	.14	.75	.5	0	0	3	0
34	0	0	25	0	0	0	0	0	0
35	0	0	50	0	0	0	0	25	100
36	0	0	25	100	100	0	0	75	0
37	0	0	2	1	1	0	0	1.25	2
38	7	4	7	4	2	2	3	1	1

Exhibit IIIc

Technology Transfers as a Function of Time

Non-adjusted Data

Variables
Time

1	0	1	2	3	4	5	6	7	8
2	8	9	0	2	1	4	3	2	4
3	8	1.29	0	.29	.14	.57	.43	.29	.57
4	0	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0	0	0
7	0	0	0	0	0	0	0	0	0
8	8	9	0	2	1	4	3	2	4
9	8	1.29	0	.29	.14	.57	.43	.29	.57
10	0	0	0	0	0	0	0	0	0
11	0	0	0	0	0	0	0	0	0
12	100	100	0	100	100	100	100	100	100
13	1	1	0	1	1	1	1	1	1
14	8	9	0	2	1	4	3	2	3
15	8	1.29	0	.29	.14	.57	.43	.29	.43
16	0	0	0	0	0	0	0	0	0
18	0	0	0	0	0	0	0	0	0
19	0	0	0	0	0	0	0	0	0
20	0	0	0	0	0	0	0	0	0
21	8	9	0	2	1	4	3	2	3
22	8	1.29	0	.29	.14	.57	.43	.29	.43
23	0	0	0	0	0	0	0	0	0
24	0	0	0	0	0	0	0	0	0
25	100	100	0	100	100	100	100	100	100
25	1	1	0	1	1	1	1	1	1
26	0	0	0	0	0	0	0	0	1
27	0	0	0	0	0	0	0	0	.14
28	0	0	0	0	0	0	0	0	0
29	0	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0	0
31	0	0	0	0	0	0	0	0	0
32	0	0	0	0	0	0	0	0	1
33	0	0	0	0	0	0	0	0	.14
34	0	0	0	0	0	0	0	0	0
35	0	0	0	0	0	0	0	0	0
36	0	0	0	0	0	0	0	0	100
37	0	0	0	0	0	0	0	0	1
38	1	7	7	7	7	7	7	7	7

Exhibit IIIc (Cont.)

Variables
Time

1	9	10	11	12	13	14	15	16	17
2	3	5	3	3	2	3	4	3	4
3	.43	.71	.5	.6	.4	.6	.8	.6	.8
4	0	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0	0	1
7	0	0	0	0	0	0	0	0	.2
8	3	5	3	3	2	3	4	3	3
9	.43	.71	.5	.6	.4	.6	.8	.6	.6
10	0	0	0	0	0	0	0	0	0
11	0	0	0	0	0	0	0	0	25
12	100	100	100	100	100	100	100	100	75
13	1	1	1	1	1	1	1	1	1.25
14	2	5	3	3	1	3	4	3	3
15	.29	.71	.5	.6	.2	.6	.8	.6	.6
16	0	0	0	0	0	0	0	0	0
17	0	0	0	0	0	0	0	0	0
18	0	0	0	0	0	0	0	0	0
19	0	0	0	0	0	0	0	0	.2
20	2	5	3	3	1	3	4	3	2
21	.29	.71	.5	.6	.2	.6	.8	.6	.4
22	0	0	0	0	0	0	0	0	0
23	0	0	0	0	0	0	0	0	33
24	100	100	100	100	100	100	100	100	66
25	1	1	1	1	1	1	1	1	1.33
26	1	0	0	0	1	0	0	0	1
27	.14	0	0	0	.2	0	0	0	.2
28	0	0	0	0	0	0	0	0	0
29	0	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0	0
31	0	0	0	0	0	0	0	0	0
32	1	0	0	0	1	0	0	0	1
33	.4	0	0	0	.2	0	0	0	.2
34	0	0	0	0	0	0	0	0	0
35	0	0	0	0	0	0	0	0	0
36	100	0	0	0	100	0	0	0	100
37	1	0	0	0	1	0	0	0	1
38	7	7	6	5	5	5	5	5	5

Exhibit IIIc (Cont.)

Variables Time									
1	18	19	20	21	22	23	24	25	26
2	3	0	2	1	4	4	2	2	4
3	.6	0	.67	.33	1	1	.5	.5	1
4	0	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0	0
6	0	0	0	0	4	2	2	2	1
7	0	0	0	0	1	.5	.5	.5	.25
8	3	0	2	1	0	2	0	0	3
9	.6	0	.67	.33	0	.5	0	0	.75
10	0	0	0	0	0	0	0	0	0
11	0	0	0	0	100	50	100	100	25
12	100	0	100	100	0	50	0	0	75
13	1	0	1	1	2	1.5	2	7	1.25
14	3	0	2	1	4	4	2	2	4
15	.6	0	.67	.33	1	1	.5	.5	1
16	0	0	0	0	0	0	0	0	0
17	0	0	0	0	0	0	0	0	0
18	0	0	0	0	4	2	2	2	1
19	0	0	0	0	1	.5	.5	.5	.25
20	3	0	2	1	0	2	0	0	3
21	.6	0	.67	.33	0	.5	0	0	.75
22	0	0	0	0	0	0	0	0	0
23	0	0	0	0	100	50	100	100	25
24	100	0	100	100	0	50	0	0	75
25	1	0	1	1	2	1.5	2	2	1.25
26	0	0	0	0	0	0	0	0	0
27	0	0	0	0	0	0	0	0	0
28	0	0	0	0	0	0	0	0	0
29	0	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0	0
31	0	0	0	0	0	0	0	0	0
32	0	0	0	0	0	0	0	0	0
33	0	0	0	0	0	0	0	0	0
34	0	0	0	0	0	0	0	0	0
35	0	0	0	0	0	0	0	0	0
36	0	0	0	0	0	0	0	0	0
37	0	0	0	0	0	0	0	0	0
38	5	3	3	3	4	4	4	4	4

Exhibit IIIc (Cont.)

Variables
Time

1	27	28	29	30	31	32	33	34	35
2	2	0	1	0	0	0	0	3	0
3	.5	0	.33	0	0	0	0	1	0
4	0	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0	0
6	2	0	0	0	0	0	0	0	0
7	.5	0	0	0	0	0	0	0	0
8	0	0	1	0	0	0	0	0	3
9	0	0	.33	0	0	0	0	0	1
10	0	0	0	0	0	0	0	0	0
11	100	0	0	0	0	0	0	0	0
12	0	0	100	0	0	0	0	0	100
13	2	0	1	0	0	0	0	0	1
14	0	0	1	0	0	0	0	3	0
15	0	0	.33	0	0	0	0	1	0
16	0	0	0	0	0	0	0	0	0
17	0	0	0	0	0	0	0	0	0
18	0	0	0	0	0	0	0	0	0
19	0	0	0	0	0	0	0	0	0
20	0	0	1	0	0	0	0	3	1
21	0	0	.33	0	0	0	0	1	0
22	0	0	0	0	0	0	0	0	0
23	0	0	0	0	0	0	0	0	0
24	0	0	100	0	0	0	0	100	0
25	0	0	1	0	0	0	0	1	0
26	2	0	0	0	0	0	0	0	0
27	.5	0	0	0	0	0	0	0	0
28	0	0	0	0	0	0	0	0	0
29	0	0	0	0	0	0	0	0	0
30	2	0	0	0	0	0	0	0	0
31	.5	0	0	0	0	0	0	0	0
32	0	0	0	0	0	0	0	0	0
33	0	0	0	0	0	0	0	0	0
34	0	0	0	0	0	0	0	0	0
35	100	0	0	0	0	0	0	0	0
36	0	0	0	0	0	0	0	0	0
37	0	0	0	0	0	0	0	0	0
38	4	3	3	3	3	3	3	3	3

Exhibit IIIc (Cont.)

Variables
Time

1	36	37	38	39	40	41	42	43	44
2	1	12	2	2	0	1	6	1	1
3	.33	4	.67	.67	0	.5	33	.5	.33
4	0	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0	0	0
7	0	0	0	0	0	0	0	0	0
8	1	12	2	2	0	1	6	1	1
9	.33	4	.67	.67	0	.5	3	.5	.33
10	0	0	0	0	0	0	0	0	0
11	0	0	0	0	0	0	0	0	0
12	100	100	100	100	0	100	100	100	100
13	1	1	1	1	0	1	1	1	1
14	1	11	2	2	0	1	6	1	1
15	.33	3.66	.67	.67	0	.5	3	.5	.33
16	0	0	0	0	0	0	0	0	0
17	0	0	0	0	0	0	0	0	0
18	0	0	0	0	0	0	0	0	0
19	0	0	0	0	0	0	0	0	0
20	1	11	2	2	0	1	6	1	1
21	.33	3.66	.67	.67	0	.5	3	.5	.33
22	0	0	0	0	0	0	0	0	0
23	0	0	0	0	0	0	0	0	0
24	100	100	100	100	0	100	100	100	100
25	1	1	1	1	0	1	1	1	1
26	0	1	0	0	0	0	0	0	0
27	0	.33	0	0	0	0	0	0	0
28	0	0	0	0	0	0	0	0	0
29	0	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0	0
31	0	0	0	0	0	0	0	0	0
32	0	1	0	0	0	0	0	0	0
33	0	.33	0	0	0	0	0	0	0
34	0	0	0	0	0	0	0	0	0
35	0	0	0	0	0	0	0	0	0
36	0	100	0	0	0	0	0	0	0
37	0	1	0	0	0	0	0	0	0
38	3	3	3	3	3	2	2	2	3

Exhibit IIIc (Cont.)

Variables Time									
1	45	46	47	48	49	50	51	52	53
2	2	2	13	1	5	3	2	1	3
3	.67	.67	3.25	.25	1.25	1	.67	.33	1.5
4	0	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0	0
6	2	2	9	1	3	1	1	0	0
7	.67	.67	2.25	.25	.75	.33	.33	0	0
8	0	0	4	0	2	2	1	1	3
9	0	0	1	0	.5	.66	.33	.33	1.5
10	0	0	0	0	0	0	0	0	0
11	100	100	69	100	60	33	50	0	0
12	0	0	31	0	40	67	50	100	100
13	2	2	1.69	2	1.6	1.33	1.5	1	1
14	2	2	13	1	5	2	0	0	3
15	.67	.67	3.25	.25	1.25	.67	0	0	1.5
16	0	0	0	0	0	0	0	0	0
17	0	0	0	0	0	0	0	0	0
18	2	2	9	1	3	1	0	0	0
19	.67	.67	2.25	.25	.75	.33	0	0	0
20	0	0	4	0	2	1	0	0	3
21	0	0	1	0	.5	.33	0	0	1.5
22	0	0	0	0	0	0	0	0	0
23	100	100	69	100	60	50	0	0	0
24	0	0	31	0	40	50	0	0	100
25	2	2	1.69	2	1.6	1.5	0	0	1
26	0	0	0	0	0	1	2	1	0
27	0	0	0	0	0	.33	.67	.33	0
28	0	0	0	0	0	0	0	0	0
29	0	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	1	0	0
31	0	0	0	0	0	0	.33	0	0
32	0	0	0	0	0	1	1	1	0
33	0	0	0	0	0	.33	.33	.33	0
34	0	0	0	0	0	0	0	0	0
35	0	0	0	0	0	0	50	0	0
36	0	0	0	0	0	100	50	100	0
37	0	0	0	0	0	1	1.5	1	0
38	3	3	4	4	4	3	3	3	2

Exhibit IIIc (Cont.)

Variables
Time

1	54	55	56	57	58	59	60	61	62
2	0	0	1	2	2	9	4	4	12
3	0	0	.5	1	1	3	1.33	1.33	4
4	0	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0	0	0
7	0	0	0	0	0	0	0	0	0
8	0	0	1	2	2	9	4	4	12
9	0	0	.5	1	1	3	1.33	1.33	4
10	0	0	0	0	0	0	0	0	0
11	0	0	0	0	0	0	0	0	0
12	0	0	100	100	100	100	100	100	100
13	0	0	1	1	1	1	1	1	1
14	0	0	1	2	2	9	4	4	12
15	0	0	.5	1	1	3	1.33	1.33	4
16	0	0	0	0	0	0	0	0	0
17	0	0	0	0	0	0	0	0	0
18	0	0	0	0	0	0	0	0	0
19	0	0	0	0	0	0	0	0	0
20	0	0	1	2	2	9	4	4	12
21	0	0	.5	1	1	3	1.33	1.33	4
22	0	0	0	0	0	0	0	0	0
23	0	0	0	0	0	0	0	0	0
24	0	0	100	100	100	100	100	100	100
25	0	0	1	1	1	1	1	1	1
26	0	0	0	0	0	0	0	0	0
27	0	0	0	0	0	0	0	0	0
28	0	0	0	0	0	0	0	0	0
29	0	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0	0
31	0	0	0	0	0	0	0	0	0
32	0	0	0	0	0	0	0	0	0
33	0	0	0	0	0	0	0	0	0
34	0	0	0	0	0	0	0	0	0
35	0	0	0	0	0	0	0	0	0
36	0	0	0	0	0	0	0	0	0
37	0	0	0	0	0	0	0	0	0
38	2	2	2	2	2	3	3	3	3

Exhibit IIIc (Cont.)

Variables
Time

1	63	64	65	66	67	68	69	70	71
2	4	4	4	1	0	0	0	2	1
3	2	4	4	1	0	0	0	2	1
4	1	0	0	0	0	0	0	0	0
5	.5	0	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0	2	1
7	0	0	0	0	0	0	0	2	1
8	3	4	4	1	0	0	0	0	0
9	1.5	4	4	1	0	0	0	0	0
10	33	0	0	0	0	0	0	0	0
11	0	0	0	0	0	0	0	100	100
12	67	100	100	100	0	0	0	0	0
13	1.5	1	1	1	0	0	0	2	2
14	3	4	4	1	0	0	0	1	0
15	1.5	4	4	1	0	0	0	1	0
16	0	0	0	0	0	0	0	0	0
17	0	0	0	0	0	0	0	0	0
18	0	0	0	0	0	0	0	1	0
19	0	0	0	0	0	0	0	1	0
20	3	4	4	1	0	0	0	0	0
21	1.5	4	4	1	0	0	0	0	0
22	0	0	0	0	0	0	0	0	0
23	0	0	0	0	0	0	0	100	0
24	100	100	100	100	0	0	0	0	0
25	1	1	1	1	0	0	0	2	0
26	1	0	0	0	0	0	0	1	1
27	.5	0	0	0	0	0	0	1	1
28	1	0	0	0	0	0	0	0	0
29	.5	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	1	1
31	0	0	0	0	0	0	0	1	1
32	0	0	0	0	0	0	0	0	0
33	0	0	0	0	0	0	0	0	0
34	100	0	0	0	0	0	0	0	0
35	0	0	0	0	0	0	0	100	100
36	0	0	0	0	0	0	0	0	0
37	3	0	0	0	0	0	0	2	2
38	2	1	1	1	0	0	0	1	1

Exhibit IIIc (Cont.)

Variables
Time

1	72	73	74	75
2	1	0	1	0
3	1	0	1	0
4	0	0	0	0
5	0	0	0	0
6	1	0	1	0
7	1	0	1	0
8	0	0	0	0
9	0	0	0	0
10	0	0	0	0
11	100	0	100	0
12	0	0	0	0
13	2	0	2	0
14	0	0	0	0
15	0	0	0	0
16	0	0	0	0
17	0	0	0	0
18	0	0	0	0
19	0	0	0	0
20	0	0	0	0
21	0	0	0	0
22	0	0	0	0
23	0	0	0	0
24	0	0	0	0
25	0	0	0	0
26	1	0	1	0
27	1	0	1	0
28	0	0	0	0
29	0	0	0	0
30	1	0	1	0
31	1	0	1	0
32	0	0	0	0
33	0	0	0	0
34	0	0	0	0
35	100	0	100	0
36	0	0	0	0
37	2	0	2	0
38	1	1	1	1

APPENDIX IV

Exhibit IVa

Technology Transfers as a Function of Countries

Adjusted Data

No. I	Countries 0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
2	3	7	18	2	1	4	10	13	6	1	3	11	0	2	0	7	1	1	0	0
3	3	1	2.25	.33	.2	1	2	3.25	2	.5	1	2.75	0	1	0	2.33	.5	.5	0	0
4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	.33	0	0	0	0
6	0	0	11	0	0	0	1	3	4	0	0	2	0	0	0	5	0	0	0	0
7	0	0	1.38	0	0	0	.2	.75	1.33	0	0	.5	0	0	0	.71	0	0	0	0
8	3	7	5	2	1	4	9	10	2	1	3	9	0	2	0	1	1	1	0	0
9	3	1	.62	.33	.2	1	1.8	2.5	.66	.5	1	2.25	0	1	0	.33	.5	.5	0	0
10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	14	0	0	0	0
11	0	0	61	0	0	0	10	24	67	0	0	19	0	0	0	72	0	0	0	0
12	100	100	39	100	100	100	90	76	23	100	100	81	0	100	0	14	100	100	0	0
13	1	1	1.5	1	1	1	1.10	1.23	1.66	1	1	1.18	0	1	0	2	1	1	0	0
14	3	7	16	2	1	3	8	12	5	1	3	7	0	2	0	2	1	1	0	0
15	3	1	2	.33	.2	.75	1.6	3	1.66	.5	1	1.75	0	1	0	.66	.5	.5	0	0
16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
17	0	0	00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
18	0	0	11	0	0	0	1	3	4	0	0	1	0	0	0	1	0	0	0	0
19	0	0	1.38	0	0	0	.2	.75	1.33	0	0	.25	0	0	0	.33	0	0	0	0
20	3	7	5	2	1	3	7	9	1	1	3	6	0	1	0	1	1	1	0	0
21	3	1	.63	.33	.2	.75	1.4	2.25	.33	.5	1	1.5	0	2	0	.33	.5	.5	0	0
22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
23	0	0	69	0	0	0	13	25	80	0	0	14	0	0	0	50	0	0	0	0
24	100	100	31	100	100	100	87	75	20	100	100	86	0	100	0	50	100	100	0	0
25	1	1	1.69	1	1	1	1.29	1.25	1.8	1	1	1.14	0	1	0	1.5	1	1	0	0
26	0	0	2	0	0	1	2	1	1	0	0	4	0	0	0	5	0	0	0	0
27	0	0	.25	0	0	.25	.4	.25	.33	0	0	1	0	0	0	1.66	0	0	0	0
28	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
29	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	.33	0	0	0	0

Exhibit IVa (Cont.)

No.	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
30	0	0	2	0	0	0	0	0	0	0	0	1	0	0	0	4	0	0	0	0
31	0	0	.25	0	0	0	0	0	0	0	0	.25	0	0	0	1.33	0	0	0	0
32	0	0	0	0	0	1	2	1	1	0	0	3	0	0	0	0	0	0	0	0
33	0	0	0	0	0	.25	.4	.25	.33	0	0	.75	0	0	0	0	0	0	0	0
34	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	20	0	0	0	0
35	0	0	100	0	0	0	0	0	0	0	0	25	0	0	0	80	0	0	0	0
36	0	0	0	0	0	100	100	100	100	0	0	75	0	0	0	0	0	0	0	0
37	0	0	2	0	0	1	1	1	1	0	0	1.25	0	0	0	2.2	0	0	0	0
38	1	7	8	6	5	4	5	4	3	2	3	4	3	2	2	3	2	2	1	1

Exhibit IVb

<u>Technology Transfers as a Function of Research Organizations</u>

Adjusted Data

1	0	1	2	3	4	5	6	7	8
2	17	3	35	7	7	3	8	6	5
3	2.43	.75	5	1.75	3.5	1.5	2.66	6	5
4	0	0	1	0	0	0	0	0	0
5	0	0	.14	0	0	0	0	0	0
6	0	0	13	1	0	2	5	2	5
7	0	0	1.86	.25	0	1	1.66	2	5
8	17	3	21	6	7	1	3	4	0
9	2.43	.75	3	1.5	3.5	.5	1	4	0
10	0	0	3	0	0	0	0	0	0
11	0	0	37	14	0	67	63	33	100
12	100	100	60	86	100	33	37	67	0
13	1	1	1.43	1.14	1	1.66	1.63	1.33	2
14	17	3	31	4	6	3	8	2	1
15	2.43	.75	4.43	1	3	1.5	2.66	2	1
16	0	0	0	0	0	0	0	0	0
17	0	0	0	0	0	0	0	0	0
18	0	0	11	1	0	2	5	1	1
19	0	0	1.57	.25	0	1	1.66	1	1
20	17	3	20	3	6	1	3	1	0
21	2.43	.75	2.86	.75	3	.5	1	1	0
22	0	0	0	0	0	0	0	0	0
23	0	0	35	25	0	67	63	50	100
24	100	100	65	75	100	33	37	50	0
25	1	1	1.35	1.25	1	1.66	1.63	1.5	2
26	0	0	4	3	1	0	0	4	4
27	0	0	.57	.75	.5	0	0	4	4
28	0	0	1	0	0	0	0	0	0
29	0	0	.14	0	0	0	0	0	0
30	0	0	2	0	0	0	0	1	4
31	0	0	.29	0	0	0	0	1	4
32	0	0	1	3	1	0	0	3	0
33	0	0	.14	.75	.5	0	0	3	0
34	0	0	25	0	0	0	0	0	0
35	0	0	50	0	0	0	0	25	100
36	0	0	25	100	100	0	0	75	0
37	0	0	2	1	1	0	0	1.25	2
38	7	4	7	4	2	2	3	1	1

Exhibit IVc

Technology Transfers as a Function of Time

Adjusted Data

Variables

1	0	1	2	3	4	5	6	7	8
2	3	8	0	1	1	2	1	1	3
3	3	1.14	0	.14	.25	.29	.14	.14	.43
4	0	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0	0	0
7	0	0	0	0	0	0	0	0	0
8	3	8	0	1	1	2	1	1	3
9	3	1.14	0	.14	.25	.29	.14	.14	.43
10	0	0	0	0	0	0	0	0	0
11	0	0	0	0	0	0	0	0	0
12	100	100	0	100	100	100	100	100	100
13	1	1	0	1	1	1	1	1	1
14	3	8	0	1	1	2	1	1	2
15	3	1.14	0	.14	.25	.29	.14	.14	.29
16	0	0	0	0	0	0	0	0	0
17	0	0	0	0	0	0	0	0	0
18	0	0	0	0	0	0	0	0	0
19	0	0	0	0	0	0	0	0	0
20	3	8	0	1	1	2	1	1	2
21	3	1.14	0	.14	.25	.29	.14	.14	.29
22	0	0	0	0	0	0	0	0	0
23	0	0	0	0	0	0	0	0	0
24	100	100	0	100	100	100	100	100	100
25	1	1	0	1	1	1	1	1	1
26	0	0	0	0	0	0	0	0	1
27	0	0	0	0	0	0	0	0	.14
28	0	0	0	0	0	0	0	0	0
29	0	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0	0
31	0	0	0	0	0	0	0	0	0
32	0	0	0	0	0	0	0	0	1
33	0	0	0	0	0	0	0	0	.14
34	0	0	0	0	0	0	0	0	0
35	0	0	0	0	0	0	0	0	0
36	0	0	0	0	0	0	0	0	100
37	0	0	0	0	0	0	0	0	1
38	7	7	7	7	7	7	7	7	7

Exhibit IVc (Cont.)

Variables

1	9	10	11	12	13	14	15	16	17
2	3	2	1	2	1	1	1	2	2
3	.43	.29	.17	.4	.2	.2	.2	.4	.4
4	0	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0	0	1
7	0	0	0	0	0	0	0	0	.2
8	3	2	1	2	1	1	1	2	1
9	.43	.29	.17	.4	.2	.2	.2	.5	.2
10	0	0	0	0	0	0	0	0	0
11	0	0	0	0	0	0	0	0	50
12	100	100	100	100	100	100	100	100	50
13	1	1	1	1	1	1	1	1	1.5
14	2	2	1	2	0	1	1	2	1
15	.29	.29	.17	.4	0	.2	.2	.4	.2
16	0	0	0	0	0	0	0	0	0
17	0	0	0	0	0	0	0	0	0
18	0	0	0	0	0	0	0	0	1
19	0	0	0	0	0	0	0	0	.2
20	2	2	1	2	0	1	1	2	0
21	.29	.29	.17	.4	0	.2	.2	.4	0
22	0	0	0	0	0	0	0	0	0
23	0	0	0	0	0	0	0	0	100
24	100	100	100	100	0	100	100	100	0
25	1	1	1	1	0	1	1	1	2
26	1	0	0	0	1	0	0	0	1
27	.14	0	0	0	.2	0	0	0	.2
28	0	0	0	0	0	0	0	0	0
29	0	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0	0
31	0	0	0	0	0	0	0	0	0
32	1	0	0	0	1	0	0	0	1
33	.14	0	0	0	.2	0	0	0	.2
34	0	0	0	0	0	0	0	0	0
35	0	0	0	0	0	0	0	0	0
36	100	0	0	0	100	0	0	0	100
37	1	0	0	0	1	0	0	0	1
38	7	7	6	5	5	5	5	5	5

Exhibit IVc (Cont.)

Variables

1	18	19	20	21	22	23	24	25	26
2	2	0	0	0	4	2	2	2	2
3	.4	0	0	0	1	.5	.5	.5	.5
4	0	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0	0
6	0	0	0	0	4	2	2	2	1
7	0	0	0	0	1	.5	.5	.5	.25
8	2	0	0	0	0	0	0	0	1
9	.4	0	0	0	0	0	0	0	.25
10	0	0	0	0	0	0	0	0	0
11	0	0	0	0	100	100	100	100	50
12	100	0	0	0	0	0	0	0	50
13	1	0	0	0	2	2	2	2	1.5
14	2	0	0	0	4	2	2	2	2
15	.4	0	0	0	1	.5	.5	.5	.5
16	0	0	0	0	0	0	0	0	0
17	0	0	0	0	0	0	0	0	0
18	0	0	0	0	4	2	2	2	1
19	0	0	0	0	1	.5	.5	.5	.25
20	2	0	0	0	0	0	0	0	1
21	.4	0	0	0	0	0	0	0	.25
22	0	0	0	0	0	0	0	0	0
23	0	0	0	0	100	100	100	100	50
24	100	0	0	0	0	0	0	0	50
25	1	0	0	0	2	2	2	2	1.5
26	0	0	0	0	0	0	0	0	0
27	0	0	0	0	0	0	0	0	0
28	0	0	0	0	0	0	0	0	0
29	0	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0	0
31	0	0	0	0	0	0	0	0	0
32	0	0	0	0	0	0	0	0	0
33	0	0	0	0	0	0	0	0	0
34	0	0	0	0	0	0	0	0	0
35	0	0	0	0	0	0	0	0	0
36	0	0	0	0	0	0	0	0	0
37	0	0	0	0	0	0	0	0	0
38	5	3	3	3	4	4	4	4	4

Exhibit IVc (Cont.)

Variables

1	27	28	29	30	31	32	33	34	35
2	2	0	0	0	0	0	0	1	0
3	.5	0	0	0	0	0	0	.33	0
4	0	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0	0	0
7	0	0	0	0	0	0	0	0	0
8	2	0	0	0	0	0	0	1	0
9	.5	0	0	0	0	0	0	.33	0
10	0	0	0	0	0	0	0	0	0
11	0	0	0	0	0	0	0	0	0
12	100	0	0	0	0	0	0	100	0
13	1	0	0	0	0	0	0	1	0
14	0	0	0	0	0	0	0	1	0
15	0	0	0	0	0	0	0	.33	0
16	0	0	0	0	0	0	0	0	0
17	0	0	0	0	0	0	0	0	0
18	0	0	0	0	0	0	0	0	0
19	0	0	0	0	0	0	0	0	0
20	0	0	0	0	0	0	0	1	0
21	0	0	0	0	0	0	0	.33	0
22	0	0	0	0	0	0	0	0	0
23	0	0	0	0	0	0	0	0	0
24	0	0	0	0	0	0	0	100	0
25	0	0	0	0	0	0	0	1	0
26	2	0	0	0	0	0	0	0	0
27	.5	0	0	0	0	0	0	0	0
28	0	0	0	0	0	0	0	0	0
29	0	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0	0
31	0	0	0	0	0	0	0	0	0
32	2	0	0	0	0	0	0	0	0
33	.5	0	0	0	0	0	0	0	0
34	0	0	0	0	0	0	0	0	0
35	0	0	0	0	0	0	0	0	0
36	100	0	0	0	0	0	0	0	0
37	1	0	0	0	0	0	0	0	0
38	4	3	3	3	3	2	2	3	3

Exhibit IVc (Cont.)

Variables

1	36	37	38	39	40	41	42	43	44
2	0	3	1	1	0	0	2	0	1
3	0	1	.33	.33	0	0	1	0	.33
4	0	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0	0	0
7	0	0	0	0	0	0	0	0	0
8	0	3	1	1	0	0	2	0	1
9	0	1	.33	.33	0	0	1	0	.33
10	0	0	0	0	0	0	0	0	0
11	0	0	0	0	0	0	0	0	0
12	0	100	100	100	0	0	100	0	100
13	0	1	1	1	0	0	1	0	1
14	0	2	1	1	0	0	2	0	1
15	0	.67	.33	.33	0	0	1	0	.33
16	0	0	0	0	0	0	0	0	0
17	0	0	0	0	0	0	0	0	0
18	0	0	0	0	0	0	0	0	0
19	0	0	0	0	0	0	0	0	0
20	0	2	1	1	0	0	2	0	1
21	0	.67	.33	.33	0	0	1	0	.33
22	0	0	0	0	0	0	0	0	0
23	0	0	0	0	0	0	0	0	0
24	0	100	100	100	0	0	100	0	100
25	0	1	1	1	0	0	1	0	1
26	0	1	0	0	0	0	0	0	0
27	0	.33	0	0	0	0	0	0	0
28	0	0	0	0	0	0	0	0	0
29	0	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0	0
31	0	0	0	0	0	0	0	0	0
32	0	1	0	0	0	0	0	0	0
33	0	.33	0	0	0	0	0	0	0
34	0	0	0	0	0	0	0	0	0
35	0	0	0	0	0	0	0	0	0
36	0	100	0	0	0	0	0	0	0
37	0	1	0	0	0	0	0	0	0
38	3	3	3	3	3	2	2	2	3

Exhibit IVc (Cont.)

Variables

1	45	46	47	48	49	50	51	52	53
2	2	1	4	0	1	3	2	1	1
3	.67	.33	1	0	.25	1	.67	.33	.5
4	0	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0	0
6	2	1	4	0	0	1	1	0	0
7	.67	.33	1	0	0	.33	.33	0	0
8	0	0	0	0	1	2	1	1	1
9	0	0	0	0	.25	.67	.33	.33	.5
10	0	0	0	0	0	0	0	0	0
11	100	100	100	0	0	33	50	0	0
12	0	0	0	0	100	67	50	100	100
13	2	2	2	0	1	1.33	1.5	1	1
14	2	1	4	0	1	.2	0	0	1
15	.67	.33	1	0	.25	.67	0	0	.5
16	0	0	0	0	0	0	0	0	0
17	0	0	0	0	0	0	0	0	0
18	2	1	4	0	0	1	0	0	0
19	.67	.33	1	0	0	.33	0	0	0
20	0	0	0	0	1	1	0	0	1
21	0	0	0	0	.25	.33	0	0	.5
22	0	0	0	0	0	0	0	0	0
23	100	100	100	0	0	50	0	0	0
24	0	0	0	0	100	50	0	0	100
25	2	2	2	0	1	1.5	0	0	1
26	0	0	0	0	0	1	2	1	0
27	0	0	0	0	0	.33	.67	.33	0
28	0	0	0	0	0	0	0	0	0
29	0	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	1	0	0
31	0	0	0	0	0	0	.33	0	0
32	0	0	0	0	0	1	1	1	0
33	0	0	0	0	0	.33	.33	.33	0
34	0	0	0	0	0	0	0	0	00
35	0	0	0	0	0	0	50	0	0
36	0	0	0	0	0	100	50	100	0
37	0	0	0	0	0	1	1.5	1	0
38	3	3	4	4	4	3	3	3	2

Exhibit IVc (Cont.)

Variables

1	54	55	56	57	58	59	60	61	62
2	0	0	0	1	0	3	1	1	2
3	0	0	0	.5	0	1	.33	.33	.67
4	0	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0	0	0
7	0	0	0	0	0	0	0	0	0
8	0	0	0	1	0	3	1	1	2
9	0	0	0	.5	0	1	.33	.33	.67
10	0	0	0	0	0	0	0	0	0
11	0	0	0	0	0	0	0	0	0
12	0	0	0	100	0	100	100	100	100
13	0	0	0	1	0	1	1	1	1
14	0	0	0	1	0	3	1	1	2
15	0	0	0	.5	0	1	.33	.33	.67
16	0	0	0	0	0	0	0	0	0
17	0	0	0	0	0	0	0	0	0
18	0	0	0	0	0	0	0	0	0
19	0	0	0	0	0	0	0	0	0
20	0	0	0	1	0	3	1	1	2
21	0	0	0	.5	0	1	.33	.33	.67
22	0	0	0	0	0	0	0	0	0
23	0	0	0	0	0	0	0	0	0
24	0	0	0	100	0	100	100	100	100
25	0	0	0	1	0	1	1	1	1
26	0	0	0	0	0	0	0	0	0
27	0	0	0	0	0	0	0	0	0
28	0	0	0	0	0	0	0	0	0
29	0	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0	0
31	0	0	0	0	0	0	0	0	0
32	0	0	0	0	0	0	0	0	0
33	0	0	0	0	0	0	0	0	0
34	0	0	0	0	0	0	0	0	0
35	0	0	0	0	0	0	0	0	0
36	0	0	0	0	0	0	0	0	0
37	0	0	0	0	0	0	0	0	0
38	2	2	2	2	2	3	3	3	3

Exhibit IVc (Cont.)

Variables

1	63	64	65	66	70	71	72	73	74	75
2	1	2	0	0	2	1	1	0	1	0
3	.5	2	0	0	2	1	1	0	1	0
4	1	0	0	0	0	0	0	0	0	0
5	.5	0	0	0	0	0	0	0	0	0
6	0	0	0	0	2	1	1	0	1	0
7	0	0	0	0	2	1	1	0	1	0
8	0	2	0	0	0	0	0	0	0	0
9	0	2	0	0	0	0	0	0	0	0
10	100	0	0	0	0	0	0	0	0	0
11	0	0	0	0	100	100	100	0	100	0
12	0	100	0	0	0	0	0	0	0	0
13	3	1	0	0	2	2	2	0	2	0
14	0	2	0	0	1	0	0	0	0	0
15	0	2	0	0	1	0	0	0	0	0
16	0	0	0	0	0	0	0	0	0	0
17	0	0	0	0	0	0	0	0	0	0
18	0	0	0	0	1	0	0	0	0	0
19	0	0	0	0	1	0	0	0	0	0
20	0	2	0	0	0	0	0	0	0	0
21	0	2	0	0	0	0	0	0	0	0
22	0	0	0	0	0	0	0	0	0	0
23	0	0	0	0	100	0	0	0	0	0
24	0	100	0	0	0	0	0	0	0	0
25	0	1	0	0	2	0	0	0	0	0
26	1	0	0	0	1	1	1	0	1	0
27	.5	0	0	0	1	1	1	0	1	0
28	1	0	0	0	0	0	0	0	0	0
29	.5	0	0	0	0	0	0	0	0	0
30	0	0	0	0	1	1	1	0	1	0
31	0	0	0	0	1	1	1	1	1	0
32	0	0	0	0	0	0	0	1	0	0
33	0	0	0	0	0	0	0	0	0	0
34	100	0	0	0	0	0	0	0	0	0
35	0	0	0	0	100	100	100	0	100	0
36	0	0	0	0	0	0	0	0	0	0
37	3	0	0	0	2	2	2	0	2	0
38	2	1	1	1	1	1	1	1	1	1

APPENDIX V

Exhibit Va

<u>Weighted Technologies Transferred as a Function of Research Organizations</u>

Adjusted Data - normalized by Number of MNCs observed

Research Org.	0	1	2	3	4	5	6	7	8
R_x	0	0	0	0	0	0	0	0	0
R_i	0	0	1.43	0	0	0	0	0	0
R_{x-i} (+100)	100	100	98.57	100	100	100	100	100	100
D_x	0	0	44	19	0	10	16.66	34	28
D_i	0	0	8	0	0	0	0	34	112
D_{x-i} (+100)	100	100	136	119	100	110	116.66	100	16
E_x	66.14	38.25	85	40.5	81	5	43	34	0
E_i	0	0	4.14	40.5	21.5	0	0	102	0
E_{x-i} (+100)	166.14	138.25	180.86	100	159.5	105	143	32	100
T_x	66.14	38.25	129	59.5	81	15	59.66	68	28
T_i	0	0	13.57	40.5	21.5	0	0	136	112
T_{x-i} (+100)	166.14	138.25	215.43	119	159.5	115	159.66	32	16

For all x-i, to facilitate computation 100 was added. This prevented negative numbers in the data matrix. Consequently, a figure of less than 100 on those four rows indicates net inflow, and a figure of greater than 100 indicates a net technology outflow.

Exhibit Vb

<u>Weighted Technologies Transferred as a Function of Countries</u>

Adjusted Data - Normalized by Number of MNCs Observed

Variables											
Countries	0	1	2	3	4	5	6	7	8	9	10
R_x	0	0	0	0	0	0	0	0	0	0	0
R_i	0	0	0	0	0	0	0	0	0	0	0
R_{x-i} (+100)	100	100	100	100	100	100	100	100	100	100	100
D_x	0	0	38.5	0	0	0	15.2	7.5	13.33	0	0
D_i	0	0	7	0	0	0	0	0	0	0	0
D_{x-i} (+100)	100	100	131.5	100	100	100	115.2	107.5	113.33	100	100
E_x	27	40.29	21.25	19.83	8.6	24.25	83.2	58.5	14.33	5.5	10
E_i	0	0	0	0	0	10.75	23.8	8.5	14.33	0	0
E_{x-i} (+100)	127	140.29	121.25	119.83	108.6	113.50	159.4	150.5	100	105.5	110
T_x	27	40.29	59.75	19.83	8.6	24.25	98.4	66	27.33	5.5	10
T_i	0	0	31.5	0	0	10.75	23.8	8.5	14.33	0	0
T_{x-i} (+100)	127	140.29	128.25	119.83	108.6	113.50	174.6	157.5	113.33	105.5	110

Exhibit Vb (Cont.)

Countries	11	12	13	14	15	16	17	18	19
R_x	0	0	0	0	0	0	0	0	0
R_i	0	0	0	0	3.33	0	0	0	0
R_{x-i} (+100)	100	100	100	100	96.67	100	100	100	100
D_x	8.5	0	0	0	9.33	0	0	0	0
D_i	8.5	0	0	0	37.33	0	0	0	0
D_{x-i} (+100)	100	100	100	100	72	100	100	100	100
E_x	46	0	10	0	3.66	0	0	0	0
E_i	25.5	0	0	0	0	0	0	0	0
E_{x-i} (+100)	120.5	100	110	100	103.66	100	100	100	100
T_x	54.5	0	10	0	12.99	0	0	0	0
T_i	29	0	0	0	40.66	0	0	0	0
T_{x-i} (+100)	125.5	100	110	100	72.33	100	100	100	100

Exhibit Vc

Weighted Technologies Transferred as a Funtion of Time

Based on Adjusted Data Normalized by MNCs Observed

Time		0	1	2	3	4	5	6	7	8	9
R_x		0	0	0	0	0	0	0	0	0	0
R_i		0	0	0	0	0	0	0	0	0	0
R_{x-i}	(+100)	100	100	100	100	100	100	100	100	100	100
D_x		0	0	0	0	0	0	0	0	0	0
D_i		0	0	0	0	0	0	0	0	0	0
D_{x-i}	(+100)	100	100	100	100	100	100	100	100	100	100
E_x		27	40.29	0	4.86	10.86	17	4.86	10.86	12.86	17
E_i		0	0	0	0	0	0	0	0	6.43	6.43
E_{x-i}	(+100)	127	140.29	100	104.86	110.86	117	104.86	110.86	106.43	110.57
T_x		27	40.29	0	4.86	10.86	17	4.86	10.86	12.86	17
T_i		0	0	0	0	0	0	0	0	6.43	6.43
T_{x-i}	(+100)	127	140.29	100	104.86	110.86	117	104.86	110.86	106.43	110.57

Exhibit Vc (Cont.)

Time		10	11	12	13	14	15	16	17	18	19
R_x		0	0	0	0	0	0	0	0	0	0
R_i		0	0	0	0	0	0	0	0	0	0
R_{x-i}	(+100)	100	100	100	100	100	100	100	100	100	100
D_x		0	0	0	0	0	0	0	15.2	0	0
D_i		0	0	0	0	0	0	0	0	0	0
D_{x-i}	(+100)	100	100	100	100	100	100	100	115.2	100	100
E_x		9.72	12.67	17.2	0	8.6	8.6	17.2	0	22	0
E_i		0	0	0	8.6	0	0	0	15.2	0	0
E_{x-i}	(+100)	109.72	112.67	117.2	91.4	108.6	108.6	117.2	84.8	122	100
T_x		9.72	12.67	17.2	0	8.6	8.6	17.2	15.2	22	0
T_i		0	0	0	8.6	0	0	0	15.2	0	0
T_{x-i}	(+100)	109.72	112.67	117.2	91.4	108.6	108.6	117.2	100	122	100

Exhibit Vc (Cont.)

Time		20	21	22	23	24	25	26	27	28	29
R_x		0	0	0	0	0	0	0	0	0	0
R_i		0	0	0	0	0	0	0	0	0	0
R_{x-i}	(+100)	100	100	100	100	100	100	100	100	100	100
D_x		0	0	28	14	14	14	7	0	0	0
D_i		0	0	0	0	0	0	0	14	0	0
D_{x-i}	(+100)	100	100	128	114	114	114	107	86	100	100
E_x		0	0	0	0	0	0	2.75	0	0	0
E_i		0	0	0	0	0	0	0	0	0	0
E_{x-i}	(+100)	100	100	100	100	100	100	102.75	100	100	100
T_x		0	0	28	14	14	14	9.75	0	0	0
T_i		0	0	0	0	0	0	0	14	0	0
T_{x-i}	(+100)	100	100	128	114	114	114	109.75	86	100	100

Exhibit Vc (Cont.)

Time		30	31	32	33	34	35	36	37	38	39
R_x		0	0	0	0	0	0	0	0	0	0
R_i		0	0	0	0	0	0	0	0	0	0
R_{x-i}	(+100)	100	100	100	100	100	100	100	100	100	100
D_x		0	0	0	0	0	0	0	0	0	0
D_i		0	0	0	0	0	0	0	0	0	0
D_{x-i}	(+100)	100	100	100	100	100	100	100	100	100	100
E_x		0	0	0	0	9.67	0	0	19.33	9.67	9.67
E_i		0	0	0	0	0	0	0	9.67	0	0
E_{x-i}	(+100)	100	100	100	100	109.67	100	100	109.66	109.67	109.67
T_x		0	0	0	0	9.67	0	0	19.33	9.67	9.67
T_i		0	0	0	0	0	0	0	9.67	0	0
T_{x-i}	(+100)	100	100	100	100	109.67	100	100	109.66	109.67	109.67

Exhibit Vc (Cont.)

Time		40	41	42	43	44	45	46	47	48	49
R_x		0	0	0	0	0	0	0	0	0	0
R_i		0	0	0	0	0	0	0	0	0	0
R_{x-i}	(+100)	100	100	100	100	100	100	100	100	100	100
D_x		0	0	0	0	0	6.67	3.33	10	0	0
D_i		0	0	0	0	0	0	0	0	0	0
D_{x-i}	(+100)	100	100	100	100	100	106.67	103.33	110	100	100
E_x		3.33	0	11	0	0	0	0	0	0	2.25
E_i		0	0	0	0	0	0	0	0	0	0
E_{x-i}	(+100)	103.33	100	111	100	100	100	100	100	100	102.25
T_x		3.33	0	11	0	0	6.67	3.33	10	0	2.25
T_i		0	0	0	0	0	0	0	0	0	0
T_{x-i}	(+100)	103.33	100	111	100	100	106.67	103.33	110	100	102.25

Exhibit Vc (Cont.)

Time		50	51	52	53	54	55	56	57	58	59
R_x		0	0	0	0	0	0	0	0	0	0
R_i		0	0	0	0	0	0	0	0	0	0
R_{x-i}	(+100)	100	100	100	100	100	100	100	100	100	100
D_x		11.33	0	0	0	0	0	0	0	0	0
D_i		0	11.33	0	0	0	0	0	0	0	0
D_{x-i}	(+100)	111.33	88.67	100	100	100	100	100	100	100	100
E_x		11.33	0	0	5.5	0	0	0	5.5	0	10
E_i		11.33	11.33	11.33	0	0	0	0	0	0	0
E_{x-i}	(+100)	100	88.67	88.67	105.5	100	100	100	105.5	100	110
T_x		22.66	0	0	5.5	0	0	0	5.5	0	10
T_i		11.33	22.66	11.33	0	0	0	0	0	0	0
T_{x-i}	(+100)	111.33	77.34	88.67	105.5	100	100	100	105.5	100	110

Exhibit Vc (Cont.)

Time		60	61	62	63	64	65	66	70	71	72
R_x		0	0	0	0	0	0	0	0	0	0
R_i		0	0	0	5	0	0	0	0	0	0
R_{x-i}	(+100)	100	100	100	95	100	100	100	100	100	100
D_x		0	0	0	0	0	0	0	28	0	0
D_i		0	0	0	0	0	0	0	28	28	28
D_{x-i}	(+100)	100	100	100	100	100	100	100	100	72	72
E_x		3.33	3.67	5.67	0	20	0	0	0	0	0
E_i		0	0	0	0	0	0	0	0	0	0
E_{x-i}	(+100)	103.33	103.67	105.67	100	120	100	100	100	100	100
T_x		3.33	3.67	5.67	0	20	0	0	28	0	0
T_i		0	0	0	5	0	0	0	28	28	28
T_{x-i}	(+100)	103.33	103.67	105.67	95	120	100	100	100	72	72

Exhibit Vc (Cont.)

Time		73	74	75
R_x		0	0	0
R_i		0	0	0
R_{x-i}	(+100)	100	100	100
D_x		0	0	0
D_i		0	28	0
D_{x-i}	(+100)	100	72	100
E_x		0	0	0
E_i		0	0	0
E_{x-i}	(+100)	100	100	100
T_x		0	0	0
T_i		0	28	0
T_{x-i}	(+100)	100	72	100