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COMPUTER TECHNOLOGY AND STANDARDIZATION IN U.S. TRADE AND PRODUCTION ABROAD; A CASE STUDY OF THE VERNON PRODUCT CYCLE MODEL

by

Benjamin Slome

A dissertation submitted to the Graduate Faculty in Economics in partial fulfillment of the requirements for the degree of Doctor of Philosophy, The City University of New York.

1972

This manuscript has been read and accepted for the Graduate Faculty in Economics in satisfaction of the dissertation requirement for the degree of Doctor of Philosophy.

May 9, 1972
date

Elliot Zupnick
Chairman of Examining Committee

May 12, 1972
date

Finis R. Welch
Executive Officer

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INTRODUCTION

Raymond Vernon in his article "International Investment and International Trade in the Product Cycle" links U.S. trade and direct foreign investment to the life cycle of a product.[1] Vernon's product cycle is developed primarily in terms of product standardization. Unfortunately, while the terms "standardized" and "standardization" are often used by economists, especially with respect to current research in international trade,[2] the topic of product standardization itself has not been subjected to rigorous analysis within the profession. Small wonder then that standardization is a topic of which it has been said: "Economists are almost unaware of its problems."[3] In analysing the Vernon model it will therefore prove necessary to review the product standardization literature, using sources which lie outside the profession. My integration of the insights offered by this literature is the major theoretical contribution of this dissertation. For the insights and hypotheses offered by the product standardization literature will prove to have important implications for the Vernon model.

In chapter II, "The Vernon Model," I present and analyse the model from the theoretical point of view. The initial analysis develops the firm orientation of the model, in addition to the important role played by product standardization concepts. I then perform the aforementioned review of the product standardization literature, and following that, a further analysis of the model. After completing the theoretical analysis, I perform an empirical study which encompasses both the Vernon model and the hypotheses suggested by the product standardization literature.

Despite the widespread acceptance and popularity of the Vernon model outside the profession,[4] the economics literature contains only one empirical study which attempts to encompass the product standardization aspects of the Vernon model. This empirical study was done by G. C. Hufbauer.[5] Unfortunately, as Hufbauer in performing the study mistakenly treated product standardization as the converse of product differentiation,[6] even this single attempt is unsuccessful. This absence of empirical work will be readily understood by the reader after reading the material in Chapter II. For to interpret the product standardization aspects of the Vernon model sufficiently to perform an empirical study, one is obliged to consider and work with unwieldy materials which would normally lie outside the purview of the economist.

As chapter II will also demonstrate, the structure of the Vernon model dictates that the empirical analysis take the form of a product case study. The product which is the subject of my case study of the Vernon model is the computer.

The major reason for my choosing the computer is a personal interest in this product caused by its present and growing role in modern society.[7] Economists attempting to place the computer in a historical perspective have likened it to the steam engine, calling it "the key to the second industrial revolution."[8]

The computer is well suited for an empirical case study of the Vernon model. For, as it is pointed out in section one of chapter II, the Vernon model deals only with labor saving and income elastic product innovations. Given the definition of a labor saving innovation with respect to the firm as one which raises capital-labor ratios for given rates of outputs at constant relative prices of capital and labor,[9] the computer product certainly qualifies as a labor-saving innovation. Empirical studies have shown this to be the case with regard to office data processing functions.[10] And with regard to the plant, the utilization of a computer to control production is the final step in fully automating the production process.[11]

The empirical portion of this dissertation begins with chapter III, "Computer Product Standardization." Discussion of the material covered in this chapter would at this point be premature, the model itself not having yet been presented. A similar condition holds true with respect to chapter IV, "The Computer Manufacturing Industry." I will therefore presently merely state that in this chapter I deal with those aspects of the industry that are relevant to the Vernon model.

In the remaining portion of this introductory chapter, I present two models which will prove helpful in analysing the Vernon model. The more important of the two for our purposes is a trade model which is an important intellectual forebear of the Vernon model. I have found that having this earlier work in juxtaposition to the Vernon model provokes insights which might otherwise have remained undiscerned. This earlier work to which I refer is Seev Hirsch's "International Competitiveness: The Production Function."[12]

The second work which I present in this introductory chapter is the industrial development model of Simon Kuznets. I was initially drawn to Kuznets' work solely because the Hirsch model is based upon it.[13] However, that portion of Kuznets' model which concerns product technological development will prove useful in our later analysis of Vernon's product cycle. For its discussion of the timing of product improvements is very similar to a discussion on the same subject found in the product standardization literature. I therefore precede my presentation of the Hirsch model with a brief presentation of the relevant subset of Kuznets' work.

Kuznets

Kuznets investigated the tendency of mature industry growth rates to decline following a preceding period of very rapid growth.[14] He used the S shaped Gompertz and logistic curves to statistically demonstrate this secular growth pattern of industry outputs.[15] Kuznets attributed this growth pattern to four primary causes. These are:

I. Technical progress slackens.
II. The slower growing industries exercise a retarding influence upon the faster growing complementary branches. The rapidly growing industries exercise a similar influence upon competitive branches.
III. The funds available for the expansion of an industry decrease in relative size as the industry grows.
IV. An industry in one country may be retarded by the competition of the same industry in a younger country.[16]

Technical progress slackens within an industry because of the exhaustion of areas for technological advance.[17] In this regard, of particular relevance to the subsequent analysis of Vernon's product cycle are Kuznets' thoughts concerning the technological development of the steam engine. Kuznets believes that the development of this product illustrates certain general characteristics concerning the technological development of product innovations. Improvements, for example, came rapidly during the early period of development, even though certain improvements had to await technological advance in other industries and were therefore delayed. The contemporary steam engine product had thus achieved "comparative perfection" by 1850, post 1850 improvements being minor in nature. This early exhaustion of areas for steam engine technological advance served to retard subsequent industry growth.[18]

Kuznets' thoughts concerning the development of product technology will prove highly compatible with those which will be later drawn from the product standardization literature.

Hirsch

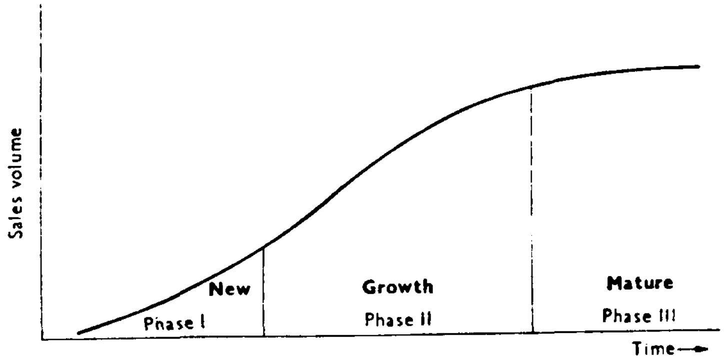
Expanding upon Kuznets' industry growth concepts, Hirsch links international trade to a product cycle which is described in terms of three market growth phases.

> The phases through which many products typically pass are illustrated in Figure 1. Time is indicated on the horizontal axis and sales volume is shown on the vertical axis. As new products are first introduced into the market, sales tend to be low. While the rate at which sales rise may be increasing, total volume remains relatively modest throughout the first phase. A sharp increase in volume characterizes the second phase. Growth rate, which is comparatively high at the beginning of the second phase, tends to slacken towards its latter part. The curve flattens out in the third phase, and may either continue on a plateau or decline, depending on whether the product in question is replaced or continues to be bought[19]

As it is the Vernon model which is the subject of this dissertation, of special interest is Hirsch's use of product standardization concepts. The characteristics of the production process in the new and mature stages stem from the degree of product standardization. In the new product phase "product specifications are loose."[20] This causes the production process to use low levels of capital and

Figure 1

Hirsch's Product Cycle



highly skilled labor inputs capable of adapting to frequently changing product specifications. In the mature phase "product specifications are by now quite standardized."[21] The production process can therefore be relatively capital intensive. It also no longer requires the highly skilled labor inputs capable of adapting to the frequently changing product specifications of the unstandardized product.

Of primary importance during the second phase is the sharp increase in the volume of sales. This, although inevitably later followed by a slackening of the growth rate, spurs the initial utilization of mass production techniques with the result that the production process becomes more capital intensive. The need to "combine mass production methods with non-uniform outputs" in turn accounts for management having a critical role in production during this phase.[22]

Hirsch links his product cycle concepts to international trade in the following manner. He believes that comparative advantage in manufactured goods is determined by the relative abundance of five factors of production: capital, unskilled labor, management, scientific and engineering know-how, and external economies. He also believes that the relative importance of each of these factors varies systematically during a product's life cycle.[23]

For example, the management skills which are crucial for producing growth phase products are relatively abundant and cheap in the United States. This relative abundance of management in fact overshadows that of capital. Hirsch therefore believes that the comparative advantage of the United States tends to lie in growth phase products, rather than in the more highly capital intensive mature phase of the product.[24]

In discussing mature products Hirsch points out that the manufacture of mature capital intensive goods in the less-developed nations does occur, e.g., steel in India. Hirsch avoids any claim that the less-developed nations will also tend to have a comparative advantage in mature goods. Although he does believe that "the mere fact that they exist whereas numerous less capital intensive industries do not, supports the premises of the product-cycle approach."[25]

In discussing new products Hirsch distinguishes between two broad types. The first type is comprised of those new products whose development and manufacture are more dependent on external economies, i.e., "easy access to . . . independent supply services and communication facilities."[26] The second type is more dependent on scientific and engineering skills. Comparative advantage in the former type of new product will lie with the leading industrialized nations such as the United States where the domestic economy offers abundant external economies. However, given the relative abundance and cheapness of scientific and engineering labor, the smaller developed economies, e.g., Switzerland, Holland, Sweden and Israel, may have a comparative advantage in the latter type of new product.[27]

As Hirsch himself acknowledges, his product cycle model of international trade is an "extension of the Heckscher-Ohlin model."[28]

Footnotes to Chapter I

[1] Vernon, Raymond, "International Investment and International Trade in the Product Cycle," Quarterly Journal of Economics, May, 1966, pp. 190-207.

[2] Johnson, Harry G., "The State of Theory in Relation to the Empirical Analysis," in Raymond Vernon, editor, The Technology Factor in International Trade, Universities-National Bureau of Economic Research Conference Series No. 22 (New York: Columbia University Press, 1970), p. 13.

[3] Brady, Robert A. Organization, Automation, and Society (Berkeley and Los Angeles: University of California Press, 1961), p. 142, cited in Struglia, Erasmus J., Standards and Specifications -- Information Sources, Management Information Guide 6 (Detroit: Gale Research Company, 1965), p. 9.

[4] See "Making Ricardo's Prophecy Come True," Business Week, December 19, 1970, p. 61.

[5] Hufbauer, G. C., "The Impact of National Characteristics and Technology on the Commodity Composition of Trade in Manufactured Goods," in Raymond Vernon, editor, The Technology . . . , pp. 189-193. For a review of the two other studies motivated by the Vernon model and related empirical work see Vernon, Raymond, Sovereignty at Bay, the

Multinational Spread of U.S. Enterprises (New York: Basic Books, Inc., 1971), pp. 69-71.

[6] The view that product standardization is the converse of product differentiation is a common error among economists. I develop this material in chapter II, section three.

[7] Mansfield, Edwin, The Economics of Technological Change (New York: W. W. Norton & Co., 1968), p. 16. Also see Taviss, Irene, editor, The Computer Impact (Englewood Cliffs, N. J.: Prentice-Hall, Inc., 1970).

[8] Organisation for Economic Co-operation and Development, Gaps in Technology, Electronic Computers (Paris: 1969), p. 27.

[9] Blaug, M. "A Survey of the Theory of Process-Innovations," Economica, February, 1967, pp. 14-15. Cited in Mansfield, p. 20.

[10] The most comprehensive attempt to assess the impact of automated office equipment upon clerical employment is the survey by the United Kingdom Ministry of Labour published in December, 1965. This survey covers approximately two-thirds of the computer installations in offices in Great Britain in 1964 (numbering approximately 562). This study estimated that in the average computer installation 14.5 per cent of the jobs existing in the data-processing section of the office before the equipment was installed were abolished. An additional 12.5 per cent would have been created to cope with increasing work had the automated office equipment not been installed. The number of jobs taken over by the equipment thus amounted to 27 per cent against which had to be set 4.5 per cent of new jobs created to operate the equipment. This gave

> a net reduction of 22.5 per cent in the number of job opportunities in the data-processing sections of the offices surveyed.

International Labour Office, Labour and Automation Bulletin No. 5 (Geneva, 1967), pp. 43-44. The survey citation is Ministry of Labour (United Kingdom): Computers in Offices. Manpower Studies No. 4 (London: H. M. Stationery Office, 1965).

[11] Council for Technological Advancement, Automation and Job Trends, Pamphlet No. 3 of a series on "Technology and Employment" (Chicago, October, 1955), pp. 4-6. Cited in Brady, p. 8. Also see, Lytel, Allan, Digital Computers in Automation (Indianapolis, Indiana: Howard W. Sams & Co., Inc., 1966).

[12] Hirsch, Seev, Location of Industry and International Competitiveness (Oxford: Claredon Press, 1967), Chapter Two, pp. 16-41. "This book is based on (the author's) doctoral dissertation submitted at the Harvard Graduate School of Business Administration in June 1965," p.v. Vernon was Hirsch's dissertation adviser, p. vi. Also see Vernon, "International . . ." fn.3, p.191.

[13] In fn. 1, p. 16, of his book Hirsch cites Kuznets, Simon, "Retardation of Industrial Growth," Economic Change, Selected Essays in Business Cycles, National Income and Economic Growth (New York: W. W. Norton & Co., 1953), pp. 253-277. "This article presents a preliminary summary of

findings published later in greater detail in" Kuznets, Simon, Secular Movements in Production and Prices (Boston: Houghton Mifflin Co., 1930). Kuznets, Simon, "Retardation . . ." p. 253. While "Retardation . . ." was reprinted in the 1953 collection, the 1930 volume is then the later and more developed work. All subsequent Kuznets citations in this chapter will therefore refer to Secular Movements in Production and Prices. Vernon cites neither work.

[14] Kuznets, pp. 5, 10.

[15] Kuznets, pp. 59-69.

[16] Kuznets, pp. 10-11.

[17] Kuznets, p. 11.

[18] Kuznets, pp. 26-34.

[19] Hirsch, pp. 16-17.

[20] Hirsch, p. 18.

[21] Hirsch, pp. 20-21.

[22] Hirsch, p. 29.

[23] Hirsch, pp. 34-41.

[24] Hirsch, p. 29.

[25] Hirsch, pp. 25-27. Even if the existence of such industries results from a "production demonstration" effect, the advanced product cycle phase can still be considered a necessary condition for this phenomenon.

[26] Hirsch, p. 32.

[27] Hirsch, p. 34.

[28] Hirsch, p. 38.

THE VERNON MODEL

Presentation and Comparison to Hirsch Model

Like the Hirsch model, the Vernon model also links international trade to a product cycle; though Vernon's product cycle will prove to differ significantly from Hirsch's. Unlike Hirsch, Vernon does not seek to merely extend the Hecksher-Ohlin model. As Vernon states, he is seeking "better tools . . . for the solution of problems in international trade;"[1] tools that would supplant the Heckscher-Ohlin factor endowments model from its central position in international trade theory.

G. C. Hufbauer has offered the following useful comments on the Vernon model.

> Successive stages of standardization, argues Vernon, characterize the product cycle. Initially a new good is made in small lots, each firm with its own variety. Manufacturing processes are highly experimental; many different techniques are given a try. But as markets grow, changes take place; national and international specifications are agreed upon. Simultaneously, the number of processing technologies decreases as inferior methods are weeded out. The surviving techniques grow more familiar and marketing channels become better established. The expansion of output transforms the items from "sideline" to "mainline" status.
>
> In the early stages, production and export advantages lie with sophisticated firms in advanced nations. As the product cycle unfolds, however, firms and nations with less technical expertise begin making and exporting the item.

> Standardization aids and abets this migration of industry in two ways--longer production runs and proven production technology bring industry within the technical grasp of more nations; standardized goods are more easily marketed, both because sales channels have been established and because feedback problems are less severe.[2]

While this elucidation is useful, it concentrates on the technological development of the process of production and omits any consideration of the technological development of the product itself. This will be seen to be far too narrow a view of Vernon's product cycle. As a first step in our analysis of the Vernon model it will prove profitable to compare the Vernon and Hirsch models to determine relevant differences and similarities.[3]

Vernon's stage one discussion draws attention to one such difference. Vernon will treat only the subset of new products comprised of income elastic or labor saving goods. United States entrepreneurs, responding to the domestic market, play the innovating role in these goods.[4] "The unstandardized nature of the design at this early stage carries with it . . . locational implications."[5] Consideration of the same type of external economies discussed by Hirsch will cause initial production facilities to be located in the United States.[6]

Unlike Hirsch, Vernon does not explicitly discuss national trade patterns in stage one products. Vernon does however indicate by graph that the United States is the sole net exporter throughout stage one.[7] Vernon would then also no doubt explain this implied United States comparative advantage in these new products essentially by linking it through abundant external economies to the unstandardized nature of the product.

In the second stage of the Vernon model, contrary to the Hirsch model, product standardization plays an important role in the product cycle.

> As the demand for a product expands, a certain degree of standardization usually takes place. . . . A commitment to some set of product standards opens up technical possibilities for achieving economies of scale through mass output. . . . The industry has begun to settle down in the United States to some degree of large scale production.[8]

Commencement of the second stage of Vernon's product cycle is thus defined by the United States industry having entered an era of large scale production. Intrinsically associated with this phenomenon is a certain degree of product standardization necessary for the large scale production of stage two.

Vernon's analysis of trade in stage two products is confined to a discussion of the activities of the American based multinational firm. Shipments to third country and United States markets from American owned production facilities abroad will occur if labor cost differentials are sufficient to overcome transportation friction.[9] Again, Vernon does not explicitly discuss national trade patterns during stage two. Vernon does however again indicate by graph that the United States is the sole net exporter throughout stage two of the product cycle.[10] The continuing implied comparative advantage of the United States in stage two products could plausibly result from several factors. Drawing directly upon Vernon's description of stage two of his product cycle, the implied comparative advantage could result from the aforementioned economies of scale. Drawing upon a related work, the continuing comparative advantage of the United States could also be based on "accumulated knowledge . . . and continuing research and development."[11]

In the following discussion of stage three of his product cycle, Vernon allots importance to the marketing function in international trade. Given this importance, the continuing comparative advantage of the United States during stage two could then also be based upon an abundant marketing-management factor endowment of the United States. Hirsch's justification of the comparative advantage of the United States during phase two of his product cycle, i.e., the abundant management factor endowment of the U.S., is however not being simply transposed to the Vernon model. For Vernon, unlike Hirsch, does not conceive of the phenomenon of the mass production of non-uniform outputs. There is therefore no necessity in the Vernon model to assign to management a critical role in production during this stage.

Given this absence of a critical production role for management in the large scale production which characterizes stage two of Vernon's product cycle, the more acceptable is Vernon's stage two hypothesis concerning direct investment abroad by American firms. Vernon states that "the establishment of production units in the [other] advanced countries" will commence during stage two of his product cycle.[12]

> As long as the marginal production cost plus the transport cost of the goods exported from the United States is lower than the average cost of prospective production in the market of import, United States producers will presumably prefer to avoid an investment.[13]

Initial investments in production facilities abroad will then normally await the capturing of economies of large scale production at domestic production locations. The existence of the product standardization necessary to implement large scale production is then also a necessary condition for direct investment by American firms in production facilities in the other economically advanced nations. Vernon however avoids offering any hypothesis concerning the sufficient conditions for these initial direct investments abroad, stating that given the complexity of the subject, "one ought not anticipate that any hypothesis will have more than a limited explanatory power."[14] Vernon does however note that the initial investor in production facilities abroad may be imitated by competitors seeking solely to maintain the status quo or to reduce uncertainty, rather than to reduce the costs of production.[15]

Vernon terminates his presentation of his model with a discussion of the implications for international investment and trade of the highly standardized products of stage three of his product cycle. Vernon presents an interesting hypothesis concerning investment in production facilities in the economically less-developed nations. The hypothesis is that the high degree of product standardization of stage three is "a necessary if not a sufficient condition for investment."[16] This hypothesis is however contradicted by Vernon elsewhere, where he indicates by graph that production in the less-developed nations, albeit at modest levels, will begin during stage two.[17] One means of resolving this contradiction would be to interpret the stage three investment hypothesis as referring only to investments in production facilities which are motivated by considerations of comparative advantage. Under this alternative interpretation, Vernon's stage three investment hypothesis is then that the high degree of product standardization of stage three is a necessary if not a sufficient condition for investment in production facilities which will produce for export because of comparative advantage considerations. In contrast to the initially presented stage three investment hypothesis, under this alternative interpretation of the Vernon model, it would then not contradict the model for production in less-developed economies, and also exports, to occur before stage three of the product cycle had been reached if this domestic production and exports were motivated by considerations other than comparative advantage, commercial policy for example. As the following discussion of comparative advantage in highly standardized products will indicate, this latter alternative interpretation is not inconsistent with the context within which the investment hypothesis is presented. There are nevertheless now these two alternative hypotheses concerning investment in the less-developed nations which have been drawn from the Vernon model. The a priori validity of these hypotheses will be considered in the following section of this chapter.

These hypotheses are reminiscent of Hirsch's discussion of the less-developed nations manufacturing capital intensive standardized products. Vernon, however, goes further than did Hirsch. For Vernon claims that the less-developed nations will not only have the means of manufacturing such products as import substitutes, but "at an advanced stage in the standardization of some products, the less-developed countries may offer competitive advantages as a production location."[18]

Vernon justifies this claim in the following manner. Vernon believes that highly standardized products have easily accessible markets which pose no marketing problem for the less-developed nations. Vernon further says that the belief that capital is scarce and therefore expensive in the economically less-developed nations is not true with respect to all potential investors. Specifically, the international investor and the government sponsored project to improve the balance of payments can finance investments in capital intensive producing facilities at interest rates sufficiently similar to those obtaining in the advanced economies so as to eliminate national capital endowments as an explanation of international trade. Vernon also speculates that the highly standardized product is most capable of being produced on a vertically integrated basis, thus reducing to a minimim the contribution of external economies to comparative advantage. Comparative advantage in these highly standardized products is then determined by factor endowment considerations concerning the nation's abundance and cheapness of labor alone.[19]

In stage three of Vernon's model direct investment and trade are then two sides of the same coin. For direct investment in production facilities for highly standardized products permits the less-developed economy to utilize its labor factor endowments to obtain a comparative advantage in highly standardized products. Now while the phenomenon of the less-developed nations having a comparative advantage in stage three products whose production processes do not tend to be labor intensive can be discussed using the terminology of factor endowments, this obviously represents a major parting of the way with respect to the Heckscher-Ohlin model.

To summarize, Vernon has replaced the factor endowments concerns of Heckscher and Ohlin with what he considers to be a more basic determinant of a nation's exports, product standardization. Vernon has also, directly with respect to stage three and indirectly with respect to stage two, hypothesized appropriate levels of product standardization as necessary but not sufficient conditions for direct investment abroad. And finally, Vernon's international economic model is not exclusively concerned with nations, but instead innovatingly grants a major role within the dynamic context of his product cycle to the international activities of the multinational firm.

In developing his product cycle Vernon has however used concepts of product standardization without sufficient development of the meaning of these concepts. For example, how are we to identify the highly standardized products of stage three? What are their shared characteristics? With regard to stage two, what is meant by the degree of standardization associated with the implementation of large scale production? Further analysis of the Vernon model will therefore await an examination of the product standardization literature.

Product Standardization Literature Review

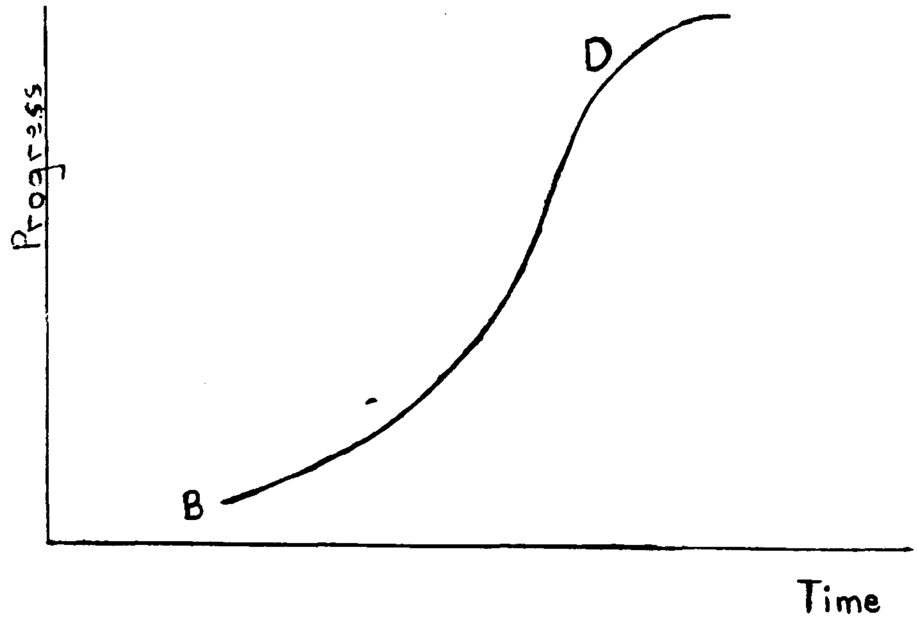
> Standardization may obviously be adopted either by individual manufacturers . . . or, alternatively, all or some of the manufacturers of a certain article may agree on the standard which they will employ. . . . While the full advantages of standardization from the point of view of the manufacturer, dealer, and user can, as a rule, be obtained only by the general adoption of standards, considerable advantages and economies can be secured by the use by individual manufacturers of their own standards; and this applies even in comparatively small works not operating on a so-called mass production scale. . . .
>
> While standardization . . . has advantages even in small scale production it frequently becomes essential when mass production is involved. . . . To a considerable extent, standardization automatically follows the adoption of such production methods. The assembly shop could never cope with its task if it were burdened with either fitting or selective assembly. . . . Mass production is therefore generally associated with standardization.[20]

There are then two levels of product standardization. The lower level of product standardization relates to the standards of the plant or firm only. The higher level of product standardization relates to these standards which span the entire industry. With respect to the lower level of product standardization, the view that mass production necessitates the implementation of standards at the plant level is presented even more forcibly by other writers in the field.[21] This view has also entered the mainstream of economic thought.[22] Note however that as standardization at the plant level offers advantages even in small scale production, the implementation of the lower level of product standardization may often long precede mass production.

The higher level of product standardization, that which spans the entire industry, is discussed in the product standardization literature in relation to the technological development of the product. In this discussion product technological development is illustrated by the S shaped curve of Figure 2, wherein progress is plotted against time. Despite superficial similarities, this S shaped curve is not to be confused with the curves used by Kuznets and Hirsch to describe the secular growth of industry outputs. Also, the "Progress" axis has no unit of measurement. The curve is therefore also not to be taken as a true quantitative relationship. The curve merely illustrates the following verbal description of product technological development.

Figure 2

Progress-Time Curve of Product Standardization Literature



> [After the product innovation,] from the point B on, the rate of progress will increase. . . . Improvements follow each other in quick succession. . . . From D on, only minor improvements are made.[23]

Note the basic similarity between this model of product technological development and Kuznets' thoughts concerning product technological development, here presented in summary form.

> Improvements which appear rapidly at first, occur less and less often, until finally there is practically nothing left to improve.[24]

Both share the common thread of having rapid technological advance followed by technological stability.[25]

Industry standards cannot be established before D, when technological advance slows down. For prior to D, the rapidly changing product technology will soon exercise a "pull" to change the industry standard.[26] While standards at the plant level will be established before this period, they, also as a result of the rapidly changing product technology, will be of a temporary nature only.[27] Even those industry standards established at D would still be subject to future revision. For advances in technology have not ceased altogether. However, as the post D period of technological stability continues, "stabilization of the standard" also occurs.[28] The highly standardized product is then, given the necessary stability of product technology, characterized by a well developed set of industry-wide standards.

Synthesis

Having in hand a brief review of the product standardization literature we are now in a position to utilize the insights offered by this literature to further analyse the Vernon model. Let us begin with a basic criticism of Vernon's use of product standardization to characterize and delineate the stages of his product cycle. That is, that Vernon has masqueraded the familiar concept of product technological development in the unfamiliar garb of product standardization. For according to the product standardization literature, standardization on the industry level is a function of the product's technological development. Should this hypothetical relationship be confirmed by empirical investigation, an important question to consider is then what are the gains which could justify Vernon's utilization of standardization rather than technological development to characterize his product life cycle. Also, are these gains sufficient to justify the use of concepts which are unfamiliar to most economists?

In the Vernon model the concept of product standardization was first encountered, in a positive sense in contrast to Vernon's earlier consideration of the unstandardized product, in the discussion of stage two. The commencement of stage two, it will be remembered, is defined by the United States industry having entered an era of large scale production. Associated with this was a "certain degree of standardization."[29] Drawing upon the product standardization literature to develop the meaning of this phrase, Vernon's "set of product standards [that] opens up technical possibilities for achieving economies of scale through mass output"[30] is the lower level of product standardization, i.e., standards at the plant level.

The existence of product standardization at the plant level does not however necessarily imply that stage two of the product cycle has been or will soon be reached. For the product standardization literature informs us that "standardization . . . has advantages even in small scale production."[31] It can therefore be expected that the lower level of product standardization will often have been instituted in an industry long before the large scale production of stage two, perhaps even as early as the commencement of stage one, i.e., upon the product's innovation. If the empirical study should indicate that this insight gleaned from the product standardization literature is correct, the inclusion of product standardization in the discussion of the commencement of stage two is both unnecessary and misleading. For if the existence of product standards at the plant level is not indicative that stage two has been or will soon be reached, the arrival of stage two can then be simply and solely characterized by the implementation of large scale production in the United States industry.

Nevertheless, the degree of product standardization associated with stage two of Vernon's product cycle remains the lower level of standardization. It is therefore also the degree of standardization necessary for direct investment by United States firms in production facilities in the other economically advanced nations. This necessary condition for such investments can now be quite easily justified. For the transference of domestic plant standards to the foreign producing facility is the means by which the absentee United States management can ensure the quality and other characteristics of production abroad.[32] This however still does not justify the prominent role of standardization in stage two of Vernon's product cycle. For while domestic standards at the plant level may have an important role in the physical act of foreign production, there is no reason to expect that they also play an important role in the foreign investment decision process.

Vernon's highly standardized products of stage three of his product cycle can now be characterized by the existence of a well developed set of industry-wide standards. Unfortunately, this criterion does not readily lend itself to quantification and programmed decision rules. An empirical analysis of the Vernon model, even for a single case study, will then prove difficult. For the economist performing the study will have to acquire the product expertise necessary to judge its industry-wide standards and determine whether or not they are well developed. However, as the earlier presentation of Kuznets' discussion of the steam engine indicates, such expertise is not entirely alien to the profession.

The higher level of product standardization was in the literature reviewed presented as being dependent on a high degree of stability of product technology. For only when technology is no longer rapidly changing can industry-wide standards be established. This would tend to support Vernon's speculation that highly standardized products are most capable of being produced on a vertically integrated basis, thus reducing to a minimum the contribution of external economies to comparative advantage. For only when product technology is no longer advancing rapidly will long term commitments to specific intermediate inputs tend to be made. Here the long term commitments take the form of investments in production facilities for these intermediate inputs.

Vernon's associated belief that highly standardized products have easily accessible markets is also supported by the product standardization literature. For as the highly standardized product is characterized by a well-developed set of industry standards, the very act of simply becoming aware of and meeting these standards eliminates or simplifies many marketing tasks.

The insights offered by the product standardization literature thus support Vernon's beliefs concerning ease of marketing and integrated production facilities. These were two of the considerations discussed by Vernon with respect to the comparative advantage of less-developed economies in highly standardized goods. A major justification of such a possible comparative was however touched upon only obliquely by Vernon. That is, as the highly standardized product is one whose technological development is such that only minor improvements in the product are anticipated, then it is also a product whose technology can be copied without fear that the imitated technology will be made obsolete by subsequent improvements in the product. Vernon obliquely touched upon technological obsolescence in his discussion of the implications of remoteness for the exports of less-developed economies.

> Products which could be precisely described by standardized specifications and which could be produced for inventory without fear of obsolescence would be more relevant than those which had less precise specifications.[33]

It will be remembered that two alternative hypotheses concerning investment in the economically less-developed nations were drawn from Vernon's discussion of stage three of his product cycle model. The first was that a high degree of product standardization, i.e., a well developed set of industry-wide standards, is a necessary condition for investments in all production facilities in less-developed economies. The second alternative hypothesis was that the high degree of product standardization is a necessary condition for only those investments in production facilities which will produce for export because of comparative advantage considerations. While this latter hypothesis can be justified by the same standardization considerations as dealt with in the previous three paragraphs, the former investment hypothesis is not so readily justified.

There is little a priori reason to accept the sharp dichotomy of the production capabilities of underdeveloped and developed economies embodied in the former stage three investment hypothesis. Especially as research and development is an activity which is distinct from production. For, just as Vernon has himself posited with respect to physical capital, the less-developed economies are not characterized by an absolute absence of human capital. An economically less-developed nation can therefore still have a sufficiently large amount of skilled labor to produce at least some products whose technology is not yet stabilized. Also, empirical evidence exists that firms in the less-developed economies "use considerably lower educational inputs than companies making the same product in the advanced countries."[34] In addition, required intermediate inputs not available from domestic sources in the economically less-developed nations can be imported. And finally, the very same plant standards of stage two which are used to ensure the quality and other characteristics of production by United States firms in the other economically advanced nations can be similarly used in the economically less-developed nations. For these reasons the dichotomy of the production capabilities of advanced and less-developed economies embodied in the former stage three investment hypothesis, the hypothesis which encompasses all production facilities in the economically less-developed nations, appears to represent an unacceptable interpretation of the Vernon model.

During Vernon's presentation of stage two of his product cycle, he touched upon the subject of product differentiation Vernon states that the implementation of the lower level of product standardization does not cause

> efforts at product differentiation [to] come to an end. On the contrary; such efforts may even intensify, as competitors try to avoid the full brunt of price competition. Moreover, variety may appear as a result of specialization. . . . Nevertheless, though the subcategories may multiply and the efforts at product differentiation increase, a growing acceptance of certain general standards seems to be typical.[35]

Vernon here is correct in his belief that product differentiation and product standardization are not necessarily negatively related. For even with the highly standardized product of stage three which has a well developed set of industry-wide standards, there is no necessary preclusion of product differentiation in response to market demand conditions. For example, in chapter III it is demonstrated that computers are not yet highly standardized.[36] Nevertheless, let us for the moment suppose that computers did indeed have a well developed set of industry-wide standards. This would not preclude computer manufacturers from marketing computers having different memory sizes.[37] Product differentiation and product standardization thus do not have the converse relationship that is so often incorrectly attributed to them by economists.[38]

To briefly summarize, assimilating the product standardization literature and the insights offered therein has permitted us to interpret the Vernon model sufficiently to perform an empirical study. It has also opened up the possibility that Vernon's product cycle could have been presented in terms of technological development and large scale production without altering in any way the essence of his product cycle model.

Footnotes to Chapter II

[1] Vernon, Raymond, "International Investment and International Trade in the Product Cycle," Quarterly Journal of Economics, May, 1966, p. 190.

[2] Hufbauer, G. C., "The Impact of National Characteristics & Technology on the Commodity Composition of Trade in Manufactured Goods," in Raymond Vernon, editor, The Technology Factor in International Trade, Universities-National Bureau of Economic Research Conference Series, No. 22 (New York: Columbia University Press, 1970), p. 189.

[3] A) It should be pointed out that Vernon originally presented many of the ideas incorporated in his model in an earlier paper which preceded Hirsch's work; although the original presentation was made without reference to a product cycle. See Vernon, Raymond, "Solutions: Trade Policy" in Seymour E. Harris, editor, The Dollar in Crisis (New York: Harcourt, Brace & World, Inc., 1961), pp. 207-208.

B) Likewise, specifically with respect to the importance of external economies in the location of industry, see Vernon, Raymond, Metropolis 1985 (Cambridge, Mass.: Harvard University Press, 1960), pp. 38-85.

All subsequent Vernon references will be to "International Investment and International Trade in the Product Cycle."

[4] Vernon, pp. 191-193.

[5] Vernon, p. 195.

[6] Vernon, pp. 195-196. Also note preceding footnote 3B.

[7] Vernon, figure I, p. 199.

[8] Vernon, p. 196.

[9] Vernon, pp. 198, 200.

[10] Vernon, figure I, p. 199.

[11] Freeman, C., "The Plastics Industry: A Comparative Study of Research and Innovation," National Institute Economic Review, November, 1963, p. 44. See Vernon, fn. 6.

[12] Vernon, p. 198.

[13] Vernon, p. 197.

[14] Vernon, p. 198.

[15] Vernon, pp. 200-201.

[16] Vernon, p. 203.

[17] Vernon, figure I, p. 199.

[18] Vernon, p. 202.

[19] Vernon, pp. 202-207.

[20] Harriman, Norman Follet, *Standards and Standardization* First Edition (New York: McGraw Hill Book Co., 1928), pp. 83-84.

[21] Edwards, Corwin D. S., "Standards and Product Differentiation" in Reck, Dickson, ed. *National Standards in a Modern Economy* (New York: Harper & Brothers, 1956) p.331; Powell, F. E., "Economic Aspects of Standardization," *Standards World*, Spring, 1949, p. 76; George, Claude S. Jr., *Management in Industry* (Englewood Cliffs, N. J.: Prentice Hall, 1959), p. 110.

[22] Alchian, Armen A. and William R. Allen, *University Economics*, Second Edition (Belmont, California :Wadsworth Publishing Co., Inc., 1967), p. 230.

[23] Gaillard, John, *Industrial Standardization, Its Principles and Applications* (New York: The H. W. Wilson Co., 1934), pp. 15-16.

[24] Kuznets, Simon, "Retardation of Industrial Growth" in *Selected Essays in Business Cycles, National Income and Economic Growth* (New York: W. W. Norton & Co., 1953), p. 266.

[25] This common thread is perhaps attributable to the earlier work of Julius Wolf. See Kuznets, pp. 259-260.

[26] Gaillard, pp. 17-18.

[27] United Nations, Department of Economic and Social Affairs, Centre for Industrial Development, Industrial Standardization in Developing Countries (New York, 1964), pp. 43-44. "Prepared . . . with the consultant help of Dr. John Gaillard," p. iv.

[28] Gaillard, pp. 18-19.

[29] Vernon, p. 196.

[30] Vernon, p. 196.

[31] Harriman, p. 83.

[32] Organisation for Economic Co-operation and Development, Technological Gaps, Electronic Computers (Paris: 1969), p. 86.

[33] Vernon, p. 203.

[34] Leff, Nathanial, The Brazilian Capital Goods Industry, 1929-1964 (Cambridge, Mass.: Harvard University Press, 1968), p. 46. Also fn. #10, pp. 46-47.

[35] Vernon, p. 196.

[36] See "Industry Wide Standardization" in chapter III.

[37] For a discussion of computer memory, see "The Computer Product" in chapter III.

[38] See for example, A) Hufbauer, p. 190; B) Chamberlin, Edward H. <u>The Theory of Monopolistic Competition</u>, fifth edition (Cambridge, Mass.: Harvard University Press, 1946), p. 7.

COMPUTER PRODUCT STANDARDIZATION

In this chapter I empirically deal with the Vernon model's two levels of product standardization--the standards at the plant level of stage two and the industry-wide standards of stage three. Before investigating these stage two and stage three standards, I briefly describe the computer itself. For as it was pointed out earlier, an analysis of the Vernon product cycle requires knowledge of the product. This is especially true with respect to the discussion of stage three, wherein it will be determined whether or not the computer has acquired a well developed set of industry-wide standards.

The earlier review of the product standardization literature suggested that the development of the industry-wide standards of stage three is dependent upon the stability of product technology. This relationship, if true, would have serious implications for the Vernon model. For it would mean that instead of the unfamiliar concept of product standardization utilized by Vernon to characterize stage three, the more familiar concept of product technological advance could have been used. I therefore terminate this chapter with a brief survey of computer product technological advance.

The Computer Product

Strictly speaking, there are actually two main computer products--the general purpose digital and analog computers.[1] However as Table 1 indicates, almost all computers produced in the United States are digital. The terms "computer" and "digital computer" are therefore generally used interchangeably by economists and computer scientists.[2] I too will use these terms interchangeably.

The computer can be comprehended by briefly considering its component units. These are main memory, the control unit, the arithmetic-logical unit, auxiliary memory, and the input-output units.[3]

Main memory is comprised of two state storage devices, ferrite cores currently being the most popular of these devices. The direction of a core's polarization determines whether it is on, a one bit, or off, a zero bit. Groups of such binary bits are used by means of an internal computer code to represent and store data.[4]

Instructions to the computer are also stored in main memory. The instructions are written in a machine language which is also coded in the aforementioned binary bits. "Each computer has its own repertoire of instructions based

Table 1

Value of Computer Shipments
(million dollars)

	1967	1963
Digital		
General Purpose	1905.0	1074.3
All Other	67.8	48.0
Analog		39.7

Source: U. S. Bureau of the Census, *Census of Manufacturers, 1967*, Volume II, Part 3, U. S. Government Printing Office, Washington, D. C., 1971, p. 35 F-14.

on its circuitry and design."[5] A set of instructions for performing a data processing task is called a program.[6] The stored program has the capability of modifying itself.[7] It is this "flexibility of the program and ability to treat exceptions . . . given to the computer through the use of (a) stored program" which distinguishes the computer from the calculator.[8] Computer programs which are themselves aids to humans attempting to program the computer are referred to as computer software,[9] in contrast to the component units of the computer system which comprise the hardware.[10]

To continue with this survey of the computer's component units, the control unit interprets the program instructions which are in main memory and, following these instructions, gives appropriate electronic signals to the other component units of the computer. The arithmetic-logical unit is composed of circuitry to carry out arithmetic and logical operations on the stored data upon receipt of these signals from the control unit.[11]

Main memory, the control unit and the arithmetic-logical unit can also be considered subunit components of the central processing unit. The "central processing unit, or CPU, is the 'computer' part of the computer system."[12] The CPU will therefore henceforth be the focus of this dissertation.

The remaining component units of the computer system are auxiliary memory and the input-output units. Auxiliary memory also utilizes the two bit, on-off, zero-one, codes to represent data and instructions. The reason for the existence of auxiliary memory is that, because of different materials used, it is lower in cost than main memory. As information stored in auxiliary memory must first be moved into main memory before it can be processed, access time by the control unit for instructions and data stored in auxiliary memory is slower than the access time for the more costly main memory.[13]

The input-output units, as their name suggests, perform input and/or output functions, e.g., reading and writing. They are the units through which communication to and from the computer occur.[14] If the input-output function is performed rapidly enough, the medium on which information is written can also serve as auxiliary storage. Computer output that is stored in auxiliary storage remains in a coded form rather than being translated further into a form more "amenable to examination by human beings,"[15] the decimal number system being an example of the latter.

Standards at the Plant Level

Stage two of Vernon's product cycle is characterized by large scale production. While large scale production will also exist during stage three, the product of stage two has not yet reached the high level of product standardization that is characteristic of stage three. With respect to product standardization, the product of stage two of Vernon's product cycle is characterized by only the lower level of product standardization, i.e., standards at the plant. Vernon's discussion of the beginning of stage two emphasizes the "set of product standards [that] opens up technical possibilities for achieving economies of scale through mass output,[in addition to the fact that] the industry has begun to settle down in the United States to some degree of large-scale production."[16] Drawing upon the insights offered by the product standardization literature, these standards were seen to be standards at the plant level. The product standardization literature however also noted that standards at the plant level are advantageous even in small scale production. If the product standardization literature is correct, standards at the plant level would then certainly not have the strong association implied by Vernon with either the commencement of stage two or the investment decisions of stage two. As standards at the plant level is a topic not normally dealt with by economists, the engineering and business literature was surveyed for relevant references.

In a 1952 issue of Chemical and Engineering News the Elecom 100 computer is described as "mass-produced." The rate of production of this computer was only one per month.[17] The term "mass-produced" thus obviously refers to the production techniques used rather than to large scale outputs. A second article appearing in the journal Iron Age at approximately the same time describes the Elecom 100 as "being produced on assembly line basis."[18] As assembly line production methods imply standardized or interchangeable parts, the Elecom 100 appears to represent the phenomenon of standardization at the plant level being advantageous in small scale production.

In a 1953 issue of Electronics the IBM 701 computer is described as "being among the first large-scale digital computers to be mass produced."[19] A somewhat earlier issue of Midwest Engineer further stated that "the 701 is being manufactured in IBM's Poughkeepsie, N. Y. plant where production techniques of assembly and standardization are used."[20] While the IBM 701 can therefore be considered a product that is standardized at the plant level, its first year's production schedule was still only eighteen.[21] Again it appears that the term "mass produced" is being used to describe production techniques rather than the scale of production. The IBM 701 therefore represents another example of standardization at the plant level offering advantages even where small scale outputs are being produced.

While the IBM 701 was IBM's first computer product,[22] it is not surprising that IBM began computer production with a standardized product. For it is IBM policy "that, whenever possible, standardization should occur during the design of a new product rather than after it is in production."[23] However, as the lower level of product standardization was instituted with respect to IBM computers even while "there was substantial opinion that no more than fifty companies would ever use . . . computers,"[24] the IBM 701 conclusively indicates that the lower level of product standardization is not properly a stage two phenomenon. The lower level of product standardization, while it is necessary for large scale production, in no way implies that stage two of the product cycle has been or will soon be reached.

Industry-Wide Standardization

Drawing upon the product standardization literature, the highly standardized product of stage three of Vernon's product cycle is characterized by a well developed set of industry-wide standards. The material encompassed in the examination of industry-wide computer standards will prove tedious reading. The examination itself has been therefore relegated to the appendix of this chapter. This in no way is meant to deny or minimize the importance of this material with respect to an empirical investigation of the Vernon model. Rather it is a means of allowing the reader to have access to the results of this examination, without himself having to work through this material.

The industry-wide computer product standards as of February 15, 1971 are listed in Table 2. The examination of these standards indicates that no standards exist which directly concern the central processing unit. As the central processing unit is the "computer part of the computer system,"[25] the computer certainly does not have a well developed set of industry-wide product standards. Stage three of the computer product cycle has therefore not yet been reached.

Computer Technological Advance

The computer is a United States product innovation.[26] In 1947, two University of Pennsylvania academicians turned entrepreneurs organized the Eckert-Mauchley Computer Corporation. Their first product was the BINAC computer.[27] This computer, while one was sold,[28] "apparently never worked satisfactorily. (However, the firm's next product, the UNIVAC I computer), was in many ways an outstanding technological achievement."[29] Until UNIVAC I, computers had always been "one of a kind,"[30] and with the exception of the BINAC, produced by government agencies or academic institutions rather than firms.[31] The first UNIVAC I was delivered to its purchaser in 1951.[32] By this time the innovating Eckert-Mauchley Computer Corporation had been acquired by the Remington Rand Corporation.[33] These events marked the birth of an industry and the commencement of stage one of Vernon's product cycle.

The UNIVAC I computer circuitry utilized diodes and vacuum tube elements.[34] This was characteristic of computer technology at the time.[35] Its main memory utilized mercury delay lines.[36] "The UNIVAC I was the only mercury delay line storage computer that achieved the status of a commercial product."[37] Other early computers introduced after the UNIVAC I had cathode ray tube[38] and magnetic drum[39] main

Table 2

Industry-wide Computer Standards

X3.1-1969	Synchronous Signaling Rates for Data Transmission
X 3.2-1970	Print Specifications for Magnetic Ink Character Recognition
X3.3-1970	Bank Check Specifications for Magnetic Ink Character Recognition
X3.4-1968	Code for Information Interchange
X3.5-1970	Flowchart Symbols and Their Usage in Information Processing
X3.6-1965	Perforated Tape Code for Information Interchange
X3.9-1966	Fortran
X3.10-1966	Basic Fortran
X3.11-1969	General Purpose Paper Cards for Information Processing
X3.12-1970	Vocabulary for Information Processing
X3.14-1969	Recorded Magnetic Tape for Information Interchange (not yet available) - 200 CPI
X3.15-1966	Code for Information Interchange in Serial-by-Bit Data Transmission
X3.16-1966	Character Structure and Character Parity Sense for Serial-by-Bit Data Communication in the American National Standard Code for Information Interchange
X3.17-1966	Character Set for Optical Character Recognition
X3.18-1967	One-Inch Perforated Paper Tape for Information Interchange

Table 2 - continued

X3.19-1967	Eleven-Sixteenths Inch Perforated Paper Tape for Information Interchange
X3.20-1967	Take-Up Reels for One-Inch Perforated Tape for Information Interchange
X3.21-1967	Rectangular Holes in Twelve-Row Punched Cards
X3.22-1967	Recorded Magnetic Tape for Information Interchange - 800 CPI
X3.23-1968	Cobol
X3.24-1968	Signal Quality at Interface Between Data Processing Terminal Equipment and Synchronous Data Communication Equipment for Serial Data Transmission
X3.25-1968	Character Structure and Character Parity Sense for Parallel-by-Bit Data Communication in the American National Standard Code for Information Interchange
X3.26-1969	Hollerith Punched Card Code
X3.27-1969	Magnetic Tape Labels for Information Interchange

Source: American National Standards Institute, Catalog 1971 (New York, February 15, 1971), p. 57.

memories.

By 1956 ferrite cores had become "the dominant technology for main memories."[40] Also by 1956, it was already widely recognized that the use of transistors to replace vacuum tubes in computer circuits would result in "computers whose performance would dwarf that of the largest vacuum tube computers ever built."[41] The utility of transistors in computer circuits rather than vacuum tubes derives from the former's reduced size, power consumption and cost. This improvement in the characteristics of computer circuits in turn stimulated alterations and improvements in central processor design.[42]

In the mid sixties, IBM, which by that time had come to dominate the computer industry (see Tables 3 and 4), introduced a series of computers of varying size called the System 360. For the System 360 IBM developed solid logic technology, which still used "discrete transistors, but very small ones."[43] Although IBM was the only computer manufacturer to utilize such electronic components,[44] the System 360 design was widely imitated by other computer manufacturers. This imitation resulted from the System 360's superior design[45] and/or IBM's dominant position within the industry.[46]

The transistor-diode computer circuit has in turn been superseded by monolithic integrated circuits. By 1965 their use in large-scale computers was "common design practice."[47]

These in turn will be superseded by large-scale integrated circuits. It is widely believed that the improved characteristics of large-scale integrated circuits will also lead to new computer design innovations.[48] Other computer technological advances are also presently anticipated.[49]

The following evaluations of future computer product development have been drawn from the computer science literature.

> An appropriate prediction for the next twenty years is that technological advances will continue to be extraordinary both in quantity and quality -- and the computers of today will in 1990 seem as primitive to computer people as the computers of 1950 seem to us now in 1970.[50]
>
> Computer hardware design is progressing at such a rate that it is difficult to understand where it is now, much less where it is going.[51]

The computer product thus appears to be in the midst of a period of rapid and continuing technological advance. As the examination of industry-wide computer standards has indicated that stage three of the computer product cycle has not yet been reached, this finding is consistent with the product standardization model examined earlier. That is, a high degree of product standardization implies stability in product technology.

Table 3

IBM's Position in the International Computer Industry

	Number of Computers Installed as of 1/65 (1,000s)	Percent IBM*
United States	20.16	65
West Germany	1.6	65
France	1.6	63
United Kingdom	1.2	30

*"The proportion by value would probably be higher."

Source: Freeman, C., "Research and Development in Electronic Capital Goods," National Institute Economic Review, November, 1965, p. 45.

Table 4

Manufacturers' Positions in U.S. Computer Industry

Manufacturer	Percent of Installed Value as of		
	8/62	9/64	11/65
IBM	71.1	74.2	71.4
GE	2.1	2.5	3.0
Sperry Rand	12.1	7.2	7.4
Honeywell	1.5	1.9	4.7
RCA	4.1	3.9	3.5
Control Data	3.1	3.5	4.4
Burroughs	2.1	2.1	2.8
NCR	1.5	2.5	1.6
Other	2.4	2.2	1.2

Source: Withington, Frederic G., The Computer Industry -- The Next Five Years, Arthur D. Little, December, 1965, p. 27. Cited in Sharpe, William F., The Economics of Computers (New York: Columbia University Press, 1969), p. 191.

Footnotes to Chapter III

[1] Davis, Gordon B., <u>Computer Data Processing</u> (New York: McGraw Hill Book Co., 1969), p. 58. Also see Johnson, Clarence L., <u>Analog Computer Techniques</u>, Second Edition (New York: McGraw Hill Book Co., 1963), p. 2.

[2] Note usage in Mansfield, Edwin, <u>The Economics of Technological Change</u> (New York: W. W. Norton & Co., 1968), pp. 15-16. Also see Davis, p. 59.

[3] Harvill, John B., <u>Basic Fortran Programming</u>, Revised Edition (Englewood Cliffs, N. J.: Prentice-Hall, Inc., 1968), p. 2.

[4] Laurie, Edward J. <u>Computers and Computer Languages</u> (Cincinnati: South-Western Publishing Co., 1966), pp. 16-28.

[5] Davis, p. 178.

[6] Davis, p. 66.

[7] Davis, p. 58.

[8] Reveillion, P., "A Comparison of the Approach to E. D. P., Systems in America and in Europe," in OEEC, <u>Integrated Data Processing and Computers</u>, EPA Project 6/02B (Paris, 1961).

[9] Davis, pp. 188-191.

[10] Klerer, Melvin, "Elements of Programming," Chapter 1.1 of Klerer, Melvin and Korn, Granino A., editors, <u>Digital Computer User's Handbook</u> (New York: McGraw Hill Book

Company, 1967), pp. 1-4.

[11] Brightman, Richard W., Bernard J. Luskin, Theodore Tilton, Data Processing for Decision-Making, Second Edition (New York: The Macmillan Co., 1971), p. 217.

[12] Davis, p. 67.

[13] Laurie, pp. 43-45; Davis, p. 70.

[14] Davis, p. 292.

[15] Laurie, pp. 34-35; Brightman, p. 238.

[16] Vernon, Raymond, "International Investment and International Trade in the Product Cycle," Quarterly Journal of Economics, May, 1966, p. 196.

[17] "Mass-Produced Low-Cost Computer Remembers 102,400 'Words'," Chemical and Engineering News, August 18, 1952, p. 3476.

[18] "Research, Electronics," Iron Age, August 14, 1952, p. 91.

[19] "Computer Assembly Line," Electronics, July, 1953, p. 1.

[20] "Production Model of Calculator, Newest 'Brain', Now Installed," Midwest Engineer, April, 1953, p. 16.

[21] "Production Model . . . ," p. 16.

[22] Earlier IBM products did not have the aforementioned stored program capability. Rosen, Saul, "Electronic Computers: A Historical Survey," Computing Surveys, March, 1969, pp. 12-13.

[23] National Industrial Conference Board (NICB), Industrial Standardization, Company Programs and Practices, Studies in Business Policy, No. 85 (New York, 1957), p. 57.

[24] Watson, Thomas J., Jr., "To the Stockholders," I.B.M. Annual Report 1967, p. 5.

[25] Davis, p. 67. Also see earlier discussion "The Computer Product."

[26] Organisation for Economic Co-operation and Development (OECD) Gaps in Technology, Electronic Computers, (Paris: 1969), p. 7.

[27] Rosen, p. 10.

[28] Wilson, Louis D., letter dated June 15, 1971. Reproduced in appendix to chapter IV, "Correspondence."

[29] Rosen, p. 10.

[30] Davis, p. 63.

[31] Rosen, pp. 7-10.

[32] Davis, p. 63.

[33] Moody's Investors Service, Moody's Industrial Manual, 1955, New York, p. 86.

[34] Serrel, R., M. M. Astrahan, G. W. Patterson and I. B. Pyne, "The Evolution of Computing Machines and Systems," Proceedings of the Institute of Radio Engineers, May, 1962, p. 1049.

[35] Rosen, p. 21.

[36] Serrel, p. 1049.

[37] Rosen, p. 12.

[38] Rosen, pp. 13-14.

[39] Rosen, pp. 18-20.

[40] Nisenoff, N., "Hardware for Information Processing Systems: Today and in the Future," Proceedings of the Institute of Electrical and Electronic Engineers, December, 1966, p. 1821.

[41] Rosen, p. 25.

[42] Nisenoff, p. 1822.

[43] Rosen, p. 30.

[44] OECD, p. 67.

[45] Gruenberger, Fred, "The Shakedown Decade," Datamation, January, 1970, p. 71.

[46] OECD, p. 67; Grosch, Herbert, Statement of A. V. Astin, Director of National Bureau of Standards, Accompanied by John Eberhard, Director, Institute of Applied Technology, and Herbert Grosch, Director, Center for Computer Sciences and Technology. "Data Processing Management in the Federal Government," Hearings Before a Subcommittee of the Committee on Government Operations, House of Representatives, 90th Congress, 1st Session, July 19, 1967 (Washington, D.C., U.S. Government Printing Office, 1967), p. 76.

[47] Richmond, William H., "Integrated Circuits for Commercial Computers," Datamation, November, 1965, p. 29.

[48] Davis, p. 522; Farina, Donald, "Large-Scale Integration: A Status Report," Datamation, February, 1968, p. 27; Wayne, David, "What's Next in Memories?" Datamation, February, 1968, p. 32.

[49] See Davis, pp. 522-526.

[50] Berkeley, Edmund C., "The Future of Automatic Computers: 1949, 1961, 1970" Computers and Automation, January, 1970, p. 26.

[51] Graham, William R., "The Impact of Future Developments in Computer Technology," Paper P-4401 (Rand Corporation, Santa Monica, California, 1970), p. 1.

THE COMPUTER MANUFACTURING INDUSTRY

As developed earlier, in the section on "Computer Technological Advance" of chapter three, the computer product cycle commenced in the United States. This is in accord with the Vernon model's stage one hypothesis that United States entrepreneurs, responding to the domestic market, play the innovating role in the initial development and introduction of labor saving products. While the computer is thus, in accord with the Vernon model, a United States product innovation, it is of interest to note that if World War II had not intervened, the computer might have been a German entrepreneurial product innovation.[1]

The American firm that marketed the original product innovation was established by University of Pennsylvania academicians who became entrepreneurs.[2] The initial production facilities of the innovating firm were located in Philadelphia.[3] This lends credence to Vernon's contentions concerning the importance of external economies during stage one. For the site was no doubt selected because of the economies resulting from proximity to the University of Pennsylvania.

In Chapter III it was also determined that the computer has not yet reached stage three of Vernon's product cycle, stage three being characterized by a high degree of product standardization. Stage two of Vernon's product cycle is then characterized by the large scale production of a product that is not yet highly standardized. As Table 5 indicates, the United States computer manufacturing industry is characterized by large scale production. The computer is therefore currently in stage two of Vernon's product cycle.

Table 5

Percentage Distribution of Value Added

1967, SIC 3573 - Electronic Computing Equipment

Employee Size of Establishment	Percentage of Industry's Total Value Added*
2500 or more	56.8
1000 to 2499	22.8
500 to 999	9.0
250 to 499	7.8
100 to 249	1.6
50 to 99	1.0
1 to 49	1.1

Source: U. S. Bureau of the Census, Census of Manufacturers, 1967, Volume 1, pp. 2-94.

*Due to rounding, elements do not sum to 100.0.

This chapter discusses, primarily with respect to stage two, international aspects of the United States computer manufacturing industry. The coverage of this chapter is delimited by its function, to serve in an empirical analysis of the Vernon model. I have not taken the opportunity to develop a broad study of the computer industry because several useful computer industry studies already exist.[4] The first section of this chapter draws very heavily upon one of these, an OECD study entitled _Gaps in Technology, Electronic Computers_.

International Aspects of the United States Industry

The United States dominates the international computer industry.

> On the basis of the available evidence, it would appear that American companies account for approximately 95 per cent of the Western World's production of digital computer systems. . . . Leaving the United States market aside, American companies do still nevertheless account for 80-85 per cent of the production.[5]

The international dominance of the United States in large part merely reflects the dominant position of the International Business Machines Corporation in the industry. "IBM alone accounts for about 80 percent of the world market."[6] A second source gives IBM 70 per cent of the United States central processing unit market.[7] To summarize, using yet a third source, the "most significant fact which emerges from an analysis of market shares is the predominant position of IBM in the United States and on the world markets."[8] While the precision of published estimates of IBM's position in the industry, such as those previously presented in Tables 3 and 4, are suspect,[9] the high degree of IBM's dominance in the computer industry attested to by the various sources here referenced can not be minimized.

> IBM's fundamental advantage over all its competitors is the excellent marketing and servicing network it has established throughout the world.[10]

As Table 6 indicates the United States is a large computer exporter. The positive computer trade balance of the United States even exceeds that indicated. For while the export data is limited to electronic digital computers, the import data refers to a broader group of commodities.[11] It is generally believed that this strong export performance results from a comparative advantage based upon technological leadership.[12] In addition, given the international dominance of IBM, the aforementioned marketing-management skills of this organization played a key role in establishing the comparative advantage of the United States in computers.

Although the computer was a United States innovation, the technological leadership of the United States does not date from the commencement of the product cycle.

TABLE 6

U.S. COMPUTER TRADE

Year	\$ Exports* (000,000)	\$ Imports** (000,000)
1970	441	60
1969	337	37
1968	229	18
1967	206	20
1966	155	15
1965	96	4

Source: Exports--U.S. Bureau of the Census, _U.S. Exports --Schedule B, Commodity and Country, Report FT 410_, December of years covered.

Imports -- 1966, 1965 -- U.S. Bureau of the Census, _U.S. Imports of Merchandise for Consumption, Report FT 125_, December issues.

1967-1970 -- U.S. Bureau of the Census, _U.S. Imports, General and Consumption, Schedule A, Commodity and Country, Report FT 135_, December issues.

*Schedule B classification number
1970 - 714.2002
1965 through 1969 - 714.2005

**Schedule A classification number - 714.3000

> If one looks at the developments listed in Table [7, one notes that] in the pre-industrial period (or before the commencement of the product cycle), Germany, the United Kingdom and United States appear to have been more or less at the same [technological] level. . . . The 1950's is marked by the disappearance of Germany in the group of techological leaders. [After 1960,] only one country remains: the United States.[13]

In this context it is interesting to note that IBM's development of the System 360 in the early sixties cost "over $5 billion, the largest industrial investment ever made anywhere by a private company."[14] While IBM dominated the computer industry even before its development of the System 360,[15] this record development cost does indicate that the ability to finance as well as manage product development may play an increasingly important role as the product cycle advances through its first two stages.

With regard to U.S. imports, the findings of the OECD study are strongly in accord with the Vernon model

> United States imports tend to reflect the growth of American direct investment abroad, rather than the competitiveness of foreign computer manufacturers . . . A confirmation of this point can be found in the fact that large scale direct investment by companies other than IBM (in computer production facilities) started only after 1960, i.e., about the same time as imports into the United States began to grow.[16]

The OECD study further found that "only two American companies -- IBM and General Electric -- have large scale international manufacturing facilities."[17] While the computer division of General Electric was acquired by Honeywell in 1970,[18] IBM of course retains its significant

TABLE 7

TECHNOLOGICAL DEVELOPMENT IN AN INTERNATIONAL SETTING

(A = theoretical advance, B = first application. C = first commercial application)

Description	Type, country and year	Responsible firm or individual	Remarks
1. General theory of computers	A. France 1936 Germany 1936 United Kingdom 1937	L. Couffignal K. Zuse A.M. Turing	Unknown outside France No publications. Totally unknown Relatively important influence
2. First electronic computer	B. Germany 1941 United States 1946 C. United States 1951	K. Zuse J.P. Eckert and J.W. Mauchley Remington Rand	Z3 computer. Little known outside Germany ENIAC. Important work was also done by G. Stibitz at Bell Telephone (1940), H. Aiken and IBM at Harvard (1944) and V. Bush at MIT (late 1930's and early 1940's). UNIVAC I
3. Internally stored program	A. United Kingdom 1937 United States 1946 B. United Kingdom 1948 1949 C. United States 1951	A.M. Turing J. von Neumann (Univ. of Pennsylvania) Univ. of Manchester Univ. of Cambridge Remington Rand	MADM EDSAC UNIVAC I } Close scientific, interchange between the United States and the United Kingdom
4. Subroutine concept	A. United Kingdom 1937 United States 1946	A.M. Turing J. von Neumann	
5. Read-only memory	A. - B. United States 1946 United Kingdom 1949 C. Several countries	- J.P. Eckert and J.W. Mauchley University of Cambridge Most manufacturers	The read-only memory has been used in automatic telephone exchanges ENIAC computer. Limited storage EDSAC II computer. Storage of the entire control information
6. Associative memory concept	A. United States 1946 B. United Kingdom 1952 C. United States 1965	V. Bush Ferranti IBM	ATLAS 360-67 } The full possibilities of associative memories have not yet been exploited
7. Microprogramming	A. United Kingdom 1948 B. United States 1948	University of Manchester University of Cambridge IBM (J. Backus), U.S. Navy (G. Hopper)	Close interchange
8. First compiler(A2)	B. United States 1951 C. United States 1951	U.S. Navy (G. Hopper) Remington Rand	In the late 40's, Grace Hopper worked In the U.K. UNIVAC I: first computer to have a compiler
9. FORTRAN language	B. United States 1953-1954 C. United States 1954	IBM Users Association (SHARE) and IBM IBM	First FORTRAN compiler written by J. Backus of IBM
10. High speed drum printer	C. France 1954	Bull	First application of the "on the fly" principle for printing
11. Ferrite core memory	A. B. United States 1955 C. United States 1956	MIT (Lincoln Laboratory) Remington Rand, then IBM	Important work was also done at Harvard UNIVAC 1103A, IBM 704 and 705
12. Transistorized computers	A. United States 1947 B. United States 1956 C. United States 1958 United Kingdom 1959 Germany 1959	Bell Telephone Bell Telephone Philco, IBM, GE Elliott S.E.L.	Discovery of the transistor effect in 1947 Leprechaun computer Philco 2000, IBM 7090, ERMR system. Elliott 803 ER56 computer, (S.E.L. is a subsidiary of the American ITT)
13. ALGOL language	B. Several countries 1958 C. All countries after 1958	ACM(USA) and GAMM (Germany) Several manufacturers	ALGOL was jointly developed by American and European specialists convened in Zurich, Switzerland. The first ALGOL compiler was written by Dijkstra of the Netherlands. ALGOL was subsequently adopted by most manufacturers, and is presently more widely used in Europe than in the U.S.
14. Multiprogramming	C. United States 1960 United Kingdom 1962	Honeywell Ferranti	H800 computer Orion I computer } No interchange independent developments
15. COBOL language	B. United States 1960 C. Several countries after 1960	U.S. Department of Defence Most manufacturers	
16. Family of compatible computers	B. United States 1955 C. United States 1963-1964	U.S. Army IBM, Honeywell, RCA, GE, CDC	FIELDATA plan. IBM 360 series, CDC 3000 and 6000 series, Honeywell H 200 series, RCA Spectra 70 series
17. Time-sharing	B. United States 1964 C. United States 1966	MIT, Dartmough College, GE GE, then several large U.S. manufactures (IBM, CDC, etc.)	Civilian application (Project MAC)

Source: Organisation for Economic Co-operation and Development, *Gaps in Technology, Electronic Computers,* (Paris, 1969) p. 61.

position in the international computer industry.

IBM led the way with regard to computer production abroad. As Table 8 indicates, the first American computer produced abroad was the IBM 650 in 1956 in France. IBM's early commencement of computer production abroad was no doubt in part due to its having manufactured office equipment in Europe even before it had become a computer manufacturer.[19] Nevertheless, the 650 was initially produced by IBM in the United States in 1954.[20]

The manufacturing facilities of IBM in France used standards of the plant level that had been developed in the United States.[21] This is in accordance with the justification offered earlier with respect to having the development of standards at the plant level as a necessary condition for investment abroad. That is, standards at the plant level are the means by which the absentee American management can assure the characteristics of the product produced abroad.

As Table 9 indicates, the IBM 650 represents a break with earlier computers in terms of total production in that approximately 1500 IBM 650 computers were produced.[22] On a yearly basis beginning in 1954, this represents more than two hundred IBM 650 computers produced per year during the period in which IBM manufactured the 650.[23] As Table 10 indicates, other American computers introduced subsequently also achieved the large scale production levels characteristic of stage two of the product cycle. In addition, industry-wide measures that commence in 1954 demonstrate

Table 8

Timing I.B.M. Computer Production Abroad

Computer Model	First Produced Abroad
650	1956 - France
	1957 - Germany
	1958 - Scotland
705	1959 - France
Ramac 305	1959 - Germany
1401	1961 - Germany
	1961 - Brazil
	1961 - Canada
	1962 - Italy
	1966 - India
7070	1961 - France
1620	1961 - Canada
1410	1962 - France
1440	1963 - Germany
	1963 - Japan
1460	1964 - Germany
1130	1965 - Scotland

Table 8 (continued)

Computer Model	First Produced Abroad
360/20	1965 - Italy 1966 - Japan
360/30	1965 - Germany
360/40	1965 - France 1966 - Japan
360/25	1968 - Germany

Source: "Chronology - I.B.M. World Trade Corporation," IBM Facts Book, Revision #3, (New York: I.B.M. World Trade Corporation, 1970), pp. WTC 18 - WTC 53.

growth rates consistent with stage two.

> We have found the stock of computers growing by more than 100 per cent per year between 1954 and 1957, and by more than 40 per cent per year between 1962 and 1965, averaging to about 78 per cent from 1954 to 1965.[24]

The IBM 650 in 1954 thus ushered in an era of large scale production in the United States computer industry and also therefore stage two of Vernon's product cycle. Two years later the IBM 650 also ushered in an era of United States computer production abroad, beginning in the other economically advanced nations. This timing is in accord with the Vernon model. Production abroad in the other economically advanced nations did not commence until the industry had "begun to settle down in the United States to some degree of large-scale production."[25]

It will be remembered that it was earlier determined that IBM's first computer product, the 701, was standardized at the plant level. Nevertheless, as Table 8 indicates, the IBM 701 was not produced abroad. This is consistent with the Vernon model. For as Table 9 indicates, the 701 was not produced on a large scale in the United States.

While stage three of the computer product cycle has not yet been reached, IBM has, as Table 8 indicates, nevertheless invested in production facilities in the economically underdeveloped nations of Brazil and India. These two investment decisions will therefore be subjected to further scrutiny.

Table 9

U.S. Computers, 1950-1954

Year First Installed	System	Manufacturer	Total Installations in the U.S.
1950	SEAC	US Department of Commerce	1
	WHIRLWIND II	Massachusetts Institute of Technology	1
1951	SWAC	US Department of Commerce	1
	UNIVAC I	Remington Rand	- *
	EDVAC	University of Pennsylvania	1
1952	MANIAC I	University of California	1
	ORDVAC	University of Illinois	1
	ILLIAC	University of Illinois	4
	RAYDAC	Raytheon	1
	ELECOM 100	Underwood Corp.	3
1953	LOGISTICS	Remington Ran	1
	OARAC	General Electric	1
	IBM 701	IBM	+ 18
	MAGNEFILE D	Electronics Corp. of America	1
	UNIVAC 1103, 1103 A	Remington Rand	+ 13
	UDEC	Burroughs	2
	NATIONAL 102 A	National Cash Register Co.	16

Table 9 - continued

Year First Installed	System	Manufacturer	Total Installations in the U.S.
1954	MAGNEFILE B	Electronics Corporation of American	1
	JOHNNIAC	The RAND Corporation	1
	DYSEAC	US Department of Commerce	1
	ALWAC II	Alwac Computer Division, Hawthorne	2
	CIRCLE	Hogan Laboratories Inc.	2
	MODAC 5014	Airborne Instruments Laboratory	1
	MODAC 404	Airborne Instruments Laboratory	1
	BURROUGHS 204	Burroughs	112
	BURROUGHS 205	Burroughs	
	IBM 650 RAMAC TAPES	IBM	1,500
	LGP 30	General Precision (Librascope Div.)	462
	WISC	University of Wisconsin	1

Source: "A Third Survey of Domestic Electronic Digital Computing Systems," by Martin H. Weik, Department of Commerce, Washington, D.C., 1961, cited in Electronic Computers, Gaps in Technology, Organization for Economic Co-operation and Development, Paris, 1969, pp. 172-173.

Table 9 - continued

* Using an alternative source, there were sixty UNIVAC I installations in the United States. "Diebold Computer Census," _Automatic Data Processing Newsletter_, July 27, 1959.

Table 10

Selected U.S. Computers

Manufacturer	System	Date First Installed	Total Installations in the U.S. as of end of year given	
			Year	Number
I.B.M.	305	11/57	1961	1050
	1620	10/60	1962	1345
	1401	9/60	1964	1894 *
	1460	10/63	1965	2200
	1440	11/63	1966	3400
	360/30	5/65	1966	2750
Sperry Rand Corp.	UNIVAC SS 80/90	1/60	1962	529
	UNIVAC 1004	9/63	1966	1500
National Cash Register	390	5/61	1965	1060
Honeywell, Inc.	200	7/64	1966	1020
R.C.A.	301	2/61	1964	540

Source: Charles W. Adams Associates, "Computer Characteristics Table," in Melvin Klerer and Granino A. Korn, editors, Digital Computer User's Handbook (New York: McGraw Hill Book Company, 1967), pp. 1-135.

Table 10 - continued

Harman, Alvin J., The International Computer Industry, Innovation and Comparative Advantage (Cambridge, Mass.: Harvard University Press, 1971), pp. 121-128.

* This figure excludes all 1401 computer systems having magnetic tape input-output units.

Using an alternative source, over 14,000 1401 computer systems were installed worldwide. Organization for Economic Co-operation and Development. Gaps in Technology, Electronic Computers (Paris: 1969), p. 64.

In contrast to IBM, General Electric's computer production facilities abroad were acquired in 1964 as part of its purchases of entire European computer manufacturing concerns, Bull of France and the computer division of Olivetti of Italy.

> The acquisition of Bull by GE was . . . an attempt by GE to beat IBM at its own game, by buying out a company whose main attraction was its commercial network.[26]

Honeywell, before its acquisition of GE's computer division, had established computer production facilities in the United Kingdom and West Germany.[27] And finally, Burroughs has computer manufacturing facilities in Great Britain.[28] I have however come across no evidence to suggest that any American firm aside from IBM has established computer production facilities in a less-developed economy during stage two of the computer product cycle.

IBM Computer Production in Brazil

In 1961 IBM began to assemble 1401 computers in Brazil.[29] IBM Brazil later also exported a number of these Brazilian assembled computers.[30] These were exported to Venezuela[31] and presumably to other Latin American nations. An enquiry to IBM World Trade concerning the selection of Brazil as a production site elicited the following response.

> Brazil between 1962 and 1964 was in a depression. The Brazilian government closed the border and put restrictions on capital flow. It was a marketing and manufacturing decision to utilize the foreign exchange available in Brazil. In addition, we brought main frames into Brazil and had IBM in Brazil assemble the computers instead of importing completely built computers.[32]

It is interesting to note that comparative cost considerations go unmentioned in the IBM statement. The selection of Brazil as a production site, IBM states, was prompted by 1) economic stagnation in Brazil and 2) Brazilian restrictions on capital flow. As multinational corporations are normally persuaded to increase their activities abroad by the exact opposite of such conditions, i.e., prospects of rapid economic growth and high profit remissions, at first blush, there then appears to be somewhat of a contradiction here.

Fortunately, Brazilian economic development and policies are well documented. Drawing upon this documentation as a check on the accuracy of the IBM statement does reveal that "after 1962 Brazilian economic growth slackened while the inflation accelerated to new and relatively high levels."[33] Also,

> in 1962 a new profits remission law was enacted which ended the previous policy of welcoming foreign capital. . . . The new policy stemmed from the radicalization of Brazilian politics that began with the [presidential] election in 1960.[34]

Given the relative accuracy of the IBM statement, what was then IBM's motivation to begin assembling computers in Brazil? As this is an activity which would increase the local value added of IBM Brazil's computers, one might normally also expect that this activity would increase the pool of accumulated profits in blocked cruzeiros.

The following is I believe a plausible explanation of IBM's activities which at first appear to be contrary to IBM's self interest. Let P be the price which IBM had previously charged its Brazilian subsidiary for an assembled 1401 computer. Let X be the percentage value added per computer by assembly of 1401 computer components in Brazil. If IBM's Brazilian subsidiary then pays its North American parent corporation a price greater than P(1 - X/100) for a computer's components, previously blocked profits have in effect then been transmitted in the form of inflated costs.

IBM Brazil's exports of 1401 computers were probably also similarly motivated. For an increased rate of the local assembly of computers and therefore an increased rate of profit remission could be accomplished by having IBM Brazil export locally assembled computers.

There is however an additional factor to consider. For as a result of a 1959 regulation, Brazilian exporters were officially required to demonstrate

> '...that national labor and raw materials contributed at least 70 per cent of the respective cost of production.' This rule was apparently motivated by a desire to prevent the loss of hard currency through the export to soft currency areas of products incorporating hard currency imports. ...(Nevertheless, a multinational corporation which participated in the 1960-1961 study from which this quotation is drawn) reported that 'the Brazilian governmental policy is to ease exports of such items by granting immediately the necessary licenses without any particular or exceptional inquiries as to ...locally manufactured content.'[35]

Let us accept IBM's claim that only a "very few" computers were exported from Brazil during this period.[36] It is then possible that while IBM Brazil was initially allowed to export its locally assembled computers by a permissive bureaucracy, this permission was later withdrawn as a result of a stricter enforcement of the foreign exchange regulations.

To summarize, according to my model of IBM's computer production activities in Brazil, IBM's Brazilian investments and exports were not motivated by comparative advantage related considerations. IBM's computer production and export activities in Brazil were rather evasionary responses to Brazil's capital flow restrictions.

IBM computer production in Brazil therefore contradicts only the initial stage three investment hypothesis drawn from the Vernon model, the hypothesis that the high degree of product standardization of stage three is a necessary condition for all investment in production facilities in less-developed countries. IBM's computer production and export activities in Brazil do not however contradict the alternative stage three investment hypothesis drawn from the Vernon model. This alternative stage three investment hypothesis is that the industry wide, high degree of product standardization of stage three is a necessary if not a sufficient condition for investment in production facilities which will produce for export because of comparative advantage considerations. As previously stated, my examination of IBM computer production in Brazil causes me to conclude that the exports associated with IBM's computer production activities in Brazil were not motivated by comparative advantage related considerations.

IBM Computer Production in India

During 1966 the "first IBM 1401 (was) shipped from (the) IBM plant, Bombay, India."[37] The 1401 is currently still being produced in India.[38] The following is IBM's response to my query concerning IBM's selection of India as a 1401 production site.

> We started manufacturing in India because we wanted to contribute to the economy of that country. We are manufacturing 1401s in India because we felt the 1401 is a level of computer that the Indian marketplace could assimilate.[39]

IBM's explanation of its Indian investment decision is thus composed of two parts. The first part suggests altruism rather than self interest or the profit motive as the motivating force behind a foreign investment decision. The second part of this explanation is more compatible with conventional economic thought. Here IBM states that it was responding to the characteristics of the Indian computer market in manufacturing a product that is suited for this market.

The IBM 1401 does indeed appear to be a suitable product for the Indian computer market.

> The IBM 1401 is a small-scale data processing system, oriented toward business applications, that features a wide range of peripheral devices and supporting software...The IBM 1401 was originally announced in 1959 as a system specifically designed to facilitate the transition from punched card unit-record equipment to faster larger-scale data processing. The first 1401 system was installed in September 1960, and during the ensuing years it has been regarded as the workhorse of the data processing industry. This reputation has evolved as a result of the wide acceptance that the 1401 has received.[40]

As of February 1966, there were approximately nine thousand 1401s in use in the United States.[41]

However, having in hand the previously discussed material concerning the technological development of the computer, one is struck by the fact that by 1966 when IBM commenced 1401 production in India, the 1401 was already technologically obsolete. For by 1966 the 1401 had been made technologically obsolete by the IBM System 360, a series of computers of varying size in which the earlier type of transistorized circuits used in the 1401 had been replaced by solid logic technology.[42] "The 1964 introduction of the ... IBM System/360 series, with its 1401 emulation facility and improved performance/cost ratio, made it apparent that the 1401 would gradually be replaced."[43]

Also of interest is that in the U.S. more than eighty per cent of the 1401 computer systems were leased from IBM rather than purchased.[44] Given IBM's policy of not reducing 1401 prices,[45] the transition to the System 360 or the computers of other manufacturers would then result in IBM having a stock of obsolete 1401 computer systems. These obsolete 1401 computers are however still physically capable of continued operation. In fact, "there are still several hundred (functioning) IBM 1401 computers left in the U.S."[46]

It is then highly plausible speculation that IBM in India is merely reassembling and/or refurbishing used computers. For would IBM assume costs in India to manufacture products which exist as a stock of free goods in the United States? My conclusions concerning IBM's computer production activities in India are consistent with IBM's statement that "IBM in India uses mostly imported parts for its 1401s."[47] These imported parts I however suggest are used computer system components which probably have been little or not at all disassembled. For to believe otherwise is to believe that IBM is importing obsolete transistorized computer circuitry[48] to manufacture 1401s in India rather than taking advantage of either the zero opportunity cost of its stock of used 1401 computers or the stronger competitive position of its small scale System 360 computers which, while equally well suited for the Indian computer market, have superior performance/cost ratios. Investments made by IBM to produce, i.e. refurbish, computers in India would then for the most part consist of investments in human capital, inventories, and distribution facilities, rather than in the manufacturing/production facilities focused upon in the Vernon model.[49]

Let us however for the moment assume that all my insights concerning IBM computer production in India are incorrect and that IBM is, as it claims, manufacturing 1401 computer models in India. IBM's computer production activities in India would then have the same implications for the Vernon model as did IBM's earlier computer production activities in Brazil. It would contradict only the initial stage three investment hypothesis, the hypothesis that the high degree of product standardization of stage three is a necessary condition for all investments in production facilities in less-developed economies. IBM's computer production activities in India would not however contradict the alternative stage three investment hypothesis drawn from the Vernon model, the hypothesis that the high degree of product standardization is a necessary condition for investments in production facilities in the less-developed economies which will produce for export because of comparative advantage related considerations. For as IBM India does not export any of its Indian produced computers,[50] even while computers have a well developed international market, this indicates that India does not have a comparative advantage in computer manufacturing.

Footnotes to Chapter IV

[1] Desmonde, William H. and Klaus J. Berkling, "The Zuse Z3," Datamation, September, 1966, pp. 30-31.

[2] See discussion of "Computer Technological Advance" in chapter III.

[3] Wilson, Louis D., letter dated June 15, 1971. Reproduced in appendix to this chapter, "Correspondence."

[4] A) Organisation for Economic Cooperation and Development (OECD), Gaps in Technology, Electronic Computers (Paris, 1969).

B) Harman, Alvin J., "The Computer Industry in an International Setting," Chapter 2 of The International Computer Industry, Innovation and Comparative Advantage (Cambridge, Mass.: Harvard University Press, 1971), pp. 6-38.

C) Sharpe, William F., "Applications," Part II of The Economics of Computers (New York: Columbia University Press, 1969), pp. 183-540.

[5] OECD, p. 20.

[6] Harman, p. 19.

[7] Smith, William D., "Computers Keeping Nation Competitive," N. Y. Times, 1/9/72, Section 12, Part 2, p. 37.

[8] OECD, p. 38.

[9] Manufacturers almost uniformly refuse to release such data. IBM apparently prefers not to confirm the Justice Department's suspicion that it has a very large share of the market. Similarly, other manufacturers apparently prefer not to confirm customers' suspicions that they have a very small share. Thus any attempt to assess the market involves a painstaking collection of information obtained from users, and the results will at best be approximate.

Sharpe, p. 202.

[10] Harman, p. 19. Also see OECD, p. 64.

[11] See appendix to this chapter, "Official United States Computer Trade Classifications."

[12] OECD, p. 51. Harman, pp. 104, 145.

[13] OECD, pp. 60, 62.

[14] OECD, pp. 66-67. Also see Wise, T. A., "I.B.M.'s $5,000,000,000 Gamble," Fortune, September, 1966, pp. 118-123, 224-228 and Part II, October, 1966, pp. 138-143, 199-212. This five billion dollar figure includes investments in manufacturing facilities.

[15] See Table 4 and associated discussion in chapter III.

[16] OECD, p. 50.

[17] OECD, p. 78.

[18] Smith.

[19] OECD, pp. 81, 83.

[20] As the first installation of an IBM 650 occurred in 12/54, the initial year of IBM 650 production is taken to be 1954. Charles W. Adams Associates, "Computer Characteristics Table," Chapter 1.4 of Melvin Klerer and Granino Korn, editors, Digital Computer User's Handbook (New York: McGraw Hill Book Co., 1967), p. 1-135.

[21] France, Boyd, IBM in France, Tenth Case Study in National Planning Association Series on United States Business Performance Abroad (Washington, D.C., 1961), p. 35.

[22] As production figures are unavailable, estimated U.S. installation figures will be used as a proxy for production. These figures would exclude exports. Nor do I believe them to be precise (See footnote 9). However, as our interest lies only in orders of magnitude, these figures are nevertheless acceptable proxies for actual production data.

An attempt to obtain production figures from IBM was unsuccessful. See Kean, Geoffrey, letter dated September 23, 1971, reproduced in appendix to this chapter, "Correspondence."

[23] The IBM 650 was a vacuum tube computer. Vacuum tube computers were made technologically obsolete by transistorized computers. The IBM transistorized models were first installed in 1960. (Charles W. Adams

Associates, pp. 1-135. Earlier discussion in "Computer Technological Advance" in chapter III.) Manufacturing of the IBM 650 had therefore ceased by 1960 or earlier.

The possibility exists that the distribution of IBM 650 production is highly skewed toward the later years. While this is possible, it is not probable. For during the years 1954 to 1960, the majority of IBM computer users rented rather than purchased their equipment. (Sharpe, pp. 259-260.) It would therefore be in IBM's interest to elongate the average period between manufacture and replacement.

Using an alternative source,* year end U.S. installation figures are 1200 and 650 for 1959 and 1957. Data for 1955, 1956 and 1959 was obtained by interpolating linearly for these intervening years. The installation figure for 1954 is taken as zero. This data is presented below. Again we arrive at annual production figures of more than two hundred per year.

Year	Year end installations	First difference
1954	0	-
1955	216.66	216.66
1956	443.43	216.66
1957	650.00	216.66
1958	925.00	275.
1959	1200.00	275.

* Source: Harman, p. 121.

[24] Chow, Gregory C., "Technological Change and the Demand for Computers," American Economic Review, December, 1967, p. 1130.

[25] Vernon, Raymond, "International Investment and International Trade in the Product Cycle," Quarterly Journal of Economics, May, 1966, p. 196.

[26] OECD, pp. 82.

[27] Harman, p. 26; OECD, p. 82.

[28] OECD, p. 80. American computer manufacturers have also granted extensive manufacturing licenses to European and Japanese firms. OECD, pp. 44-49; Harman, pp. 25-27.

[29] "Chronology - I.B.M. World Trade Corporation," IBM Facts Book, Revision #3 (New York: I.B.M. World Trade Corporation, 1970), p. WTC 27.

[30]

> Let's look at a customer in Venezuela who wants to install a 1401 system. He will receive his main frame (central processing unit) from Brazil. He receives his 1403 printer from Germany; the 1402 card reader from Sweden; tape drive units from France; . . .

Jones, G. E., statement by, in "Rio de Janeiro, South American Club Convenes," I.B.M. World Trade News, May, 1963, p. 4. Also see Kean, Geoffrey, letters dated October 4, 1971 and September 23, 1971, p. 2. Reproduced in appendix to this chapter "Correspondence."

[31] Jones.

[32] Kean, Geoffrey, . . . September 23, 1971.

[33] Leff, Nathaniel H., *Economic Policy-Making and Development in Brazil, 1947 - 1964* (New York: John Wiley & Sons, Inc., 1968), p. 163.

[34] Leff, p. 66.

[35] Gordon, Lincoln, and Engelbert T. Grommers, *United States Manufacturing Investment in Brazil, The Impact of Brazilian Government Policies, 1946 - 1960* (Boston: Division of Research, Graduate School of Business Administration, Harvard University, 1962), pp. 134-135.

[36] Kean, Geoffrey, . . . October 4, 1971.

[37] "Chronology . . .," p. WTC 49.

[38] Kean, Geoffrey, letter dated October 27, 1971. Reproduced in appendix to this chapter "Correspondence."

[39] Kean, Geoffrey, . . . September 23, 1971.

[40] Auerbach Corporation, "Summary: IBM 1401," *Auerbach Computer Notebook International* (Philadelphia, May 1968) p. 401:011.100.

[41] "Monthly Computer Census," *Computers and Automation*, March, 1966, p. 47.

[42] See "Computer Technological Advance" in chapter III.

[43] Auerbach, p. 401:011.100.

[44] *EDP Industry and Market Report*, October 8, 1965, p. 3. Cited in Sharpe, p. 261.

[45] Sharpe, p. 264.

[46] "Software and Services, 1401 Sorting," _Datamation_, January, 1972, p. 85.

[47] Kean, Geoffrey . . . October 27, 1971.

[48] OECD, pp. 143-146.

[49] IBM may also be using to its advantage India's import policies which are designed to discourage the outflow of foreign exchange. These policies, using the device of the import license, prevent the importation of any item which is also being produced in India itself. (Vartikar, V. S., _Commercial Policy and Economic Development in India_, Praeger Special Studies in International Economics and Development (New York: Frederick A. Praeger, Publishers, 1969), pp. 83, 103; Mason, Edward S., _Economic Development in India and Pakistan_, Occasional Paper in International Affairs No. 13 (Cambridge, Mass.: Center for International Affairs of Harvard University, 1966), p. 39) Perhaps then, India serves IBM not only as a relatively large export market, but also as a protected market.

[50] Kean, Geoffrey . . . September 23, 1971.

CONCLUSIONS

Post "Leontief paradox" international trade models have been of two broad types. Models of the first type have sought to expand the simple capital labor endowments trade model. Their essence remains however concern with factor endowments. The trade models comprising the second broad type have proposed alternative bases for international trade. The model explored in this dissertation is of this latter type.

Raymond Vernon has offered a firm oriented model of international trade and direct investment abroad in which international economic phenomena occur within the dynamic context of a product cycle. Each stage of Vernon's product cycle was developed in terms of the product's level of standardization. These are: stage one -- no product standardization, stage two -- the level of product standardization associated with the implementation of large scale production, stage three -- a high degree of product standardization. As product standardization eludes quantification, this structure of the model dictated an essentially nonquantitative case study empirical approach.

A single case study however cannot alone determine the adequacy of an economic model. For the single case may very well be a special case. The higher value of a single case study is rather that it requires the researcher to critically think through the model. This indeed has occurred, especially with regard to my attempt to understand the concepts of product standardization used by Vernon. Here I was greatly aided by the product standardization literature.

Product Standardization and the Vernon Model

The most important of the insights offered by the product standardization literature was that product standardization is a function of product technological development. The high degree of product standardization of stage three, i.e., a well developed set of industry-wide standards, implies the stability of product technology. This hypothesis was not contradicted by the empirical findings of this dissertation. The computer, which is in the midst of a period of rapid technological advance, does not have a well developed set of industry-wide standards. I therefore suggest that Vernon has unwittingly disguised the familiar concept of product technological development in the unfamiliar garb of product standardization.

With regard to stage two, the hypothesis gleaned from the product standardization literature was that the lower level of product standardization, i.e., standards at the plant level, would often be found in an industry long before the large scale production which characterizes stage two. In the computer industry this lower level of product standardization had been implemented at a time when it was still thought that the computer market would be too small to absorb large scale production outputs. There thus appears to be no compelling reason to link the lower level of product standardization and the foreign investment decisions of stage two. For the sole link is then merely that such standards are the means by which the absentee American management can control the specifications of products produced abroad.

What if any, are the gains of using product standardization in an international economics model. Only two come to mind. One possible gain stems from the ease of marketing associated with a product having a well developed set of industry-wide standards. Ease of marketing may very well be an important determinant of the exports of less-developed economies. Use of the concept of the highly standardized product in this context then results in somewhat of a presentation shorthand. For one then does not have to explicitly discuss the existence of industry-wide standards, these being implicit in the meaning of a high degree of standardization. The second possible gain stems from the condition that technological stability may be required for the less-developed countries to develop a competitive manufacturing industry. Inherent in the meaning of a high degree of product standardization is also technological stability. Here again there would then be somewhat of a presentation shorthand. However most economists are probably unaware of these inherent meanings. The presentation shorthand resulting from using standardization concepts in an economic model would then serve to becloud the model. So much for the possible gains.

Given the findings of this dissertation concerning standardization, it is at this point obvious that it would have been preferable for Vernon to have presented his product cycle without recourse to any of the unwieldy and unfamiliar concepts of product standardization. This could have been done by characterizing the product cycle in the following manner: stage one -- innovation and small scale production; stage two -- large scale production and continuing technological advance; stage three -- technological stability. Such a presentation would in no way have altered the essence of the Vernon model. An alternative procedure would be to follow Kuznets and Hirsch and define the product cycle in terms of market growth.[1] Although this latter approach eliminates the Vernon model's focus upon the development of the product itself, it would retain the innovative firm orientation of the model.

To sum up, I believe that the unwieldy and unfamiliar concepts of product standardization utilized by Vernon should in general not be incorporated in economic models. With regard to the unfamiliarity of these concepts, it should perhaps at this point be again noted that product standardization is not the converse of product differentiation.

Hypotheses of the Vernon Model

The computer has reached stage two of its product cycle. During this stage the United States has demonstrated a comparative advantage in computers which is based primarily upon technological leadership. The U.S. comparative advantage during stage two was implicitly predicted by the Vernon model. However, the technological leadership upon which this comparative advantage is based does not represent, as implied by Vernon, a simple continuance of the preceding stage one innovative leadership. For computer technological leadership was at first shared by the United States with other economically advanced nations. This is not an uncommon phenomenon. It in fact confirms

> the picture offered by several advanced industries, where the technological leadership of certain European countries in the initial stages is lost as the industry expands beyond a certain level of size and technological complexity.[2]

This common feature of international industrial development may result from the higher capital factor endowment of the United States as compared to Europe.

For, upon utilizing the restatement of Vernon's product cycle, it appears that the large scale production and the continuing product technological instability of stage two require the rapid replacement of capital intensive production facilities at the same time as there are also investments in the development of product technology.[3] Following this line of thought a bit further, Vernon's predicted comparative advantage of less developed countries in stage three products is then more consistent with a factor endowments explanation of trade than is at first thought. For while production methods of technologically stable stage three products may tend to be capital intensive when considered in a static sense, when examined in the dynamic context of the restated product cycle, they are seen to require lesser quantities of capital than stage two products. Indeed, given the stability of product technology in stage three, the two aforementioned capital using aspects of stage two are no longer relevant.

To now continue with our consideration of the hypotheses of the Vernon model, the establishment of computer production facilities in the other economically advanced nations by American computer manufacturers did not occur until stage two of the product cycle had been reached. This investment activity was in accord with the Vernon model. Direct investments in production facilities in the less-developed nations have however also occurred during stage two. This contradicted the initial stage three investment hypothesis, the hypothesis that a high degree of product standardization is a necessary condition for all investments in production facilities in less-developed economies. This empirical finding was not unexpected as there were also a priori objections to this investment hypothesis. However, as none of these investments in computer production facilities in the underdeveloped economies were motivated by comparative advantage related considerations, the alternative stage three investment hypothesis drawn from the Vernon model was not contradicted.

At this point it would be premature to evaluate the relative merits of Vernon's firm oriented product cycle model as compared to competing models of international trade. For Vernon's innovative approach still requires further development and empirical work before such a judgment would be useful. A more limited evaluation would however at this point be appropriate.

For the most part the Vernon model was successful with regard to its focus upon the international activities of multinational firms within the dynamic context of a product cycle. This degree of success is certainly sufficient to warrant further work in this area. Vernon's innovative approach to international economic analysis would however best be served by eliminating its present reliance upon product standardization concepts.

Footnotes

[1] See Stobaugh, Robert B., "The Product Life Cycle, U.S. exports and International Investment," unpublished D.B.A. dissertation. Harvard Business School, June, 1968, pp. 5, 39-40.

[2] Organisation for Economic Co-operation and Development, Gaps in Technology, Electronic Computers (Paris: 1969), p. 62.

[3] This factor was touched upon in the earlier discussion of the development of the IBM 360. See footnote 14 of chapter IV and the associated material in the body of the chapter.

Appendix to Chapter III

Computer Industry Standards

The industry-wide computer standards have been promulgated through the American National Standards Institute (ANSI).

> (ANSI) is a private voluntary federation of about 150 trade associations and professional societies plus over 2,000 member companies interested in developing standards . . . (ANSI) acts as a facilitating and coordinating agency in the development of voluntary standards . . . The sectional committee for computers is designated as X3, "Computers and Information Processing." . . . The sponsor organization for the X3 sectional committee is the Business Equipment Manufacturers Association (BEMA).[1]

The roster of BEMA members includes Burroughs Corporation, Control Data Corporation, Honeywell Inc., I.B.M., Sperry Rand Corporation and other American computer manufacturers.[2]

The standards examined below are current as of February 15, 1971.[3]

X3.1-1969 Synchronous Signaling Rates for Data Transmission

In a computer system whose component units are geographically separated, data is transmitted using communications facilities and equipment.[4] This involves the transmission of an electrical wave which is characterized by amplitude, phase, and frequency. These three characteristics comprising the state of the signal are then used to represent the binary bit. For example, if the three characteristics x, y, z represent the one or on binary bit, a different state or set of characteristics, e.g. x, A, z could be used to represent the off or zero binary bit. The length of time that a signal remains in a state in order to be received and interpreted is related to the receiving techniques used. These variable length time spans, or reciprocally the transmission or signaling rates, can be defined in terms of binary bits per second.[5]

The X3.1 standard "provides a group of specific (binary bits per second signaling) rates . . . for binary data transmission."[6] Reducing the set of data transmission rates increases the interchangeability of computer equipment at the interface between computer and communication equipment. For it permits equipment to be designed for a generally used rate, rather than for a specific application.

X3.2-1970 Print Specifications for Magnetic Ink Character Recognition

Magnetic Ink Character Recognition (MICR) is a computer input technique. The characters, such as those on checks, are written in an ink which contains magnetic materials and which therefore can be magnetized. Before a document with such characters is to be read, it is passed through a magnetic field to magnetize the ink. The document is then passed under an electromagnetic head wherein the characters produce "an electric current proportional to the amount of the magnetic ink passing under the head. The pattern of the variation in the electric current is (then) interpreted."[7]

For the aforementioned pattern to be recognized and interpreted it must be of a type expected by the equipment. This in turn means that the inked characters producing the pattern must also have specific shapes which produce the specific patterns which the equipment has been designed to recognize. Each equipment manufacturer could individually, however, design equipment requiring differently shaped characters, thereby preventing an individual computer user from using the MICR input technique for communicating with computer systems having input equipment of a design different from his own. To forestall such an occurrence "this standard specifies the shape, dimensions and tolerances for the ten digits and four special symbols printed in magnetic ink and used for the purpose of character recognition."[8]

X3.3-1970 Bank Check Specifications for Magnetic Ink Character Recognition

"This standard is intended to cover those design considerations that primarily apply only to the placement and location of magnetic ink printing on checks intended for use in bank automation."[9] This standard therefore yields no new insights concerning computer product standardization.

X3.4-1968 Code for Information Interchange

By 1963 approximately sixty different internal computer codes were in use. For full intercommunication among existing computers, each computer system would individually require the capability of translating the fifty-nine other internal computer codes; 3540 (60 × 59) translation mechanisms would have been required.[10] However, if there were one standard internal computer code for data representation this would eliminate entirely the need for translation mechanisms for communication between different computer systems.

Between these two extremes lies an intermediate step whose implementation would also lead to full intercomputer communication capability. This intermediate step is embodied in standard X3.4 which presents the seven bit "standard coded character set to be used for information interchange among information processing systems."[11] Now for full intercommunication among computers each computer must have the capability to translate 1) from its internal code into the standard code and 2) from the standard code into its internal code. Letting N be the number of internal computer codes, full computer intercommunication capability can then be obtained by $2 \cdot N$ translations mechanisms, rather than the $N \cdot (N-1)$ previously required.[12]

X3.5-1970 Flowchart Symbols and Their Usage in Information Processing

A flowchart is a symbolic representation of a data processing flow, from input to output, wherein symbols represent the operations performed upon the data.[13] While flowcharts can be used to describe any information processing system, their use "became widespread in the field of information processing concurrent with the application of the computer to problems of business and industry."[14]

Certain symbols have an obvious and unique use and interpretation. Others however are subject to varying interpretations and uses which limit the usefulness of the flowchart as a means of communication with regard to a particular computer application. "The purpose of this standard (then) is to establish flowchart symbols and their usage in the preparation of flowcharts."[15] This will in turn serve sharply to narrow the range of possible interpretations of flowchart symbols. The range is, I believe, merely narrowed, rather than eliminated because perfect human usage and comprehension, as well as a perfect standard, is required to establish a single possible interpretation. For this reason even detailed flowcharts are usually accompanied by prose documentation.[16]

X3.6-1965 Perforated Tape Code for Information Interchange

Perforated tape is an input/output medium for computers. It is available in many widths, ranging in size from 5/8 inch to 1 inch wide. Character code bits, lying across the width of the tape, are represented as "on" by a perforation in the tape.[17] "This standard specifies the representation of the American Standard Code for Information Interchange (X3.4) . . . in perforated tape . . . The perforations shall be arranged in eight longitudinal tracks, one for each of the seven information levels and one for parity."[18]

Parity is used as a validity check of character coding in computer data processing. The parity of a coded character is the number of on bits inclusive of a following parity bit. Parity is specified as even or odd, with the parity bit available to be turned on if the bits in the character code proper do not sum to a number of the specified parity. When parity is other than that specified, it indicates that a bit has been lost and that the character is invalid.[19] This standard also specifies even parity.[20]

X3.9-1966 Fortran

It is extremely difficult for most humans to write a program using a computer's machine language. There have therefore been developed higher level languages which are simpler for humans to utilize. The instructions of these higher level languages must be translated by software programs into the binary bits of a computer's machine language before they themselves can be stored and executed.[21]

Higher level languages are of two types -- 1) those oriented to individual computer design and circuitry and 2) the even higher level of the problem oriented language. There are hundreds of problem oriented computer languages.[22]

Fortran is one of the two most popular of the problem oriented computer languages.[23] As the Fortran language bears a marked similarity to algebra, it is most useful for programs involving extensive mathematical calculations.[24] The program which translates the instructions written in the Fortran language into lower level instructions is called the Fortran processor.[25] The Fortran processor is incapable of reacting positively to inputs that are different than those which are expected.[26] For example, if a Fortran processor expects the mathematical operation of addition to be denoted by a "+" as in the instruction Y = C + I, it would not be able to recognize the mathematical operation of addition if it were to be denoted by "plus," as in the instruction Y = C plus I. However, one could also conceivably construct a Fortran processor which recognized the symbol "plus" and did not recognize the symbol "+". Fortran processors which are then identical in their capability to recognize concepts, are not then necessarily identical in their capability to recognize different symbols representing these identical concepts.

"This standard establishes the form for and the interpretation of programs expressed in the FORTRAN language for the purpose of promoting a high degree of interchangeability of such programs for use on a variety of automatic (computer) data processing systems. A processor shall conform to this standard provided it accepts, and interprets as specified, at least those forms and relationships described."[27]

X3.10-1966 Basic Fortran

The larger the computer system, the broader is the set of Fortran statements capable of being accepted and translated by the system's Fortran processor. "To obtain efficient operation on small computing systems, it is desirable to omit certain less commonly used parts of the FORTRAN language," thus obtaining Basic Fortran.[28]

> All programs written in American Standard Basic FORTRAN are valid American Standard FORTRAN programs. The existence of two standards, however,

restricts interchangeability in that programs written to run on a processor that accepts American Standard FORTRAN will not, in general, be acceptable to Basic FORTRAN processors.[29]

X3.11-1969 General Purpose Paper Cards for Information Processing

Punched paper cards are a computer input-output medium.[30] 7-3/8 by 3-1/4 inches are the dimensions of the most common card size used by both computers and electronic accounting machinery, the latter being data processing equipment which antedates the computer.[31] This standard specifies the quality of paper and the dimensions, these being the same as those previously given, for punched paper cards.[32]

X3.12-1970 Vocabulary for Information Processing

> The purpose of this standard is to present an organized body of concepts and their corresponding terms relevant to the field of information processing, and to identify relationships among the concepts and among terms.[33]

X3.14-1969 Recorded Magnetic Tape for Information Interchange (not yet available) - 200 CPI. See X.3.22-1967.

X3.15-1966 Bit Sequencing of the USA Standard Code for Information Interchange in Serial-by-Bit Data Transmission

In the Standard Code for Information Interchange characters are represented by strings or groups of 7 bits -- b_1, b_2, b_3, b_4, b_5, b_6, b_7.[34] In transmitting these bits serially using data communications facilities the choice must be made as to with which end of the string of bits one should begin transmission.[35] "This standard specifies . . . the bit sequence . . . shall be . . . b_1 through b_7 in ascending consecutive order. Also, a parity bit, if transmitted is to follow . . . b_7."[36]

The use of a parity bit is a means of checking for the loss or destruction of a bit in transmission.[39] As in the representation of the Standard Code for Information Interchange on perforated tape, this involves specifying that the group of bits comprising a character's code shall be either of even or odd parity.[38]

X3.16-1966 Character Structure and Character Parity Sense for Serial-by-Bit Data Communication in the American National Standard Code for Information Interchange

There are two commonly used methods for transmitting computer data with electronic communications equipment. These are 1) the start/stop method and 2) the synchronous method. In the start/stop or asynchronous method the set of bits comprising a character code, including the parity bit, is both preceded and followed by an extra bit which is transmitted to inform the receiving terminal of the commencement and termination of a character's transmission. In the synchronous method, transmission of data is regular, "the receiving station is kept in step with the transmitting station by a special timing circuit."[39] The stop and start bits are therefore not necessary.

This standard then specifies the following:

I. For Synchronous Data Communication
    A. "The character structure . . . shall consist of eight bits (seven character code bits and one parity bit) having equal time intervals"
    B. "Parity . . . shall be odd."
II. For Asynchronous Data Communication
    A. "The character structure . . . shall consist of 10 signal elements." (seven character code bits, a parity bit and start and stop bits)
    B. "Parity . . . shall be even."[40]

X3.17-'66 American National Standard Character Set for Optical Character Recognition

Optical character recognition devices are computer input peripherals which can read characters directly from the printed documents. Characters are read in the following manner: a) light is reflected from the character to a photoelectric device which converts it into an electronic representation of the character.

b) the electronic representation is matched against stored character patterns to identify the character of the printed document.[41]

"This standard prescribes the shapes and sizes of alphanumeric characters and symbols to be used in Optical Character Recognition systems."[42] Such standardization of characters is necessary to ensure that the electronic representation produced by a printed character will match the internally stored character patterns when the equipment and printed documents are produced by different and otherwise uncoordinated organizations.

X3.18-1967 One-Inch Perforated Paper Tape for Information Interchange

The one-inch width is one of the available widths for perforated paper tape.[43] Perforated paper tape is of two types, chad and chad free. In chad free tape the perforations have been fully punched out, while in chad tape the perforated paper circles remain hinged to the tape.

In perforated paper tape the "on" bits can be sensed by either electromechanically or photoelectrically completing a circuit. In the former the perforations permit wire brushes to make contact with a metal roller. In the latter the perforations permit light to make contact with a photoelectric cell. Various codes for representing information on perforated paper tape exist.[44]

For data to pass from the paper tape to the computer, a necessary condition is that the size of the paper tape and the location and size of the perforations must be compatible with that of the computer peripheral paper reading equipment. This standard specifies the dimensions of the perforations on one inch wide chad free paper tape.[45] These dimensions also hold where the tape is constructed of materials other than paper.[46]

"The tape shall be used for recording up to eight levels of information across the tape."[47] The seven character code bits of the Standard Code for Information Interchange (X3.4) and a parity bit can therefore be accommodated.

X3.19-1967 Eleven-Sixteenths Inch Perforated Paper Tape for Information Interchange

This standard specifies the dimensions of the perforation on 11/16 inch wide chad free paper tape. "This tape shall be used for recording up to five levels of information (bits) across the tape."[48] The seven bits of the American National Standard Code for Information Interchange can therefore not be accommodated, although a "4 bit subset consisting of the 4 low order bits" and the parity bit can be accommodated.[49]

X3.20-1967 Take-Up Reels for One-Inch Perforated Tape for Information Interchange

For one-inch wide perforated paper tape, "this standard covers the physical dimension of . . . reels . . . so that reels of perforated tape may be interchanged among machines of various manufacturers,"[50] a necessary condition for communication among computer systems having paper tape peripheral equipment.

X3.21-1967 Rectangular Holes in Twelve Row Punched Cards

There are two means by which card readers, a computer input device, can sense the existence of the punched card code; these are wire brushes and photoelectric cells. In the former the punched hole permits an electrical impulse to pass from the brush to a metal roller. In the latter the hole permits a light to pass and activate a photoelectric cell.[51] Punched holes are either round or rectangular, the latter type being predominant.[52]

For punched cards to be acceptable to a card reader, viz., for communication with the computer to occur, both the size of the card and the size and shape of the punched hole must be compatible with the design of the card reader. To facilitate punched card communication among computer systems having card readers produced by different manufacturers, "this standard specifies the size and location of rectangular holes in the twelve-row 3½ inch wide punched card."[53]

X.22 - 1967 Recorded Magnetic Tape for Information Interchange

A magnetic tape is a strip of plastic that has an iron oxide coating. Bits can be produced on the tape by passing an electric current close to the tape. This changes the magnetic field of that portion of the tape near which the current has passed. A bit pattern can in turn be then sensed by having the magnetic field induce an electrical current in a tape reading device. Different equipment manufacturers have established different coding systems. The width of the tape also varies, normally being either 1/2 inch, 3/4, or 1 inch in width.[54]

"This recorded magnetic tape standard is intended to implement the USA Standard Code for Information Interchange (X3.4) . . . on magnetic tape for interchange among information processing systems . . . for the ½-inch tape width."[55] This is accomplished by specifying the format of the code bits,[56] and also their physical characteristics.[57] Physical characteristics of the tape itself and the reel are also specified.[58]

X3.23-1968 Cobol

Cobol is, like Fortran, a problem oriented computer language.[59] It also shares with Fortran the distinction of being one of the two most popular of these high level languages.[60] Unlike Fortran, Cobol was developed specifically for business data processing applications.[61]

This standard "establishes the form for and the interpretation of programs expressed in COBOL for the purpose of promoting a high degree of interchangeability of such programs for use on a variety of automatic data processing systems."[62] The significance of the development of this standard for computer product standardization is comparable to that of the X3.9 Fortran standard; a standard for a popular problem oriented programming language has been established. This facilitates interchange of programs written in this language among the computer systems of different manufacturers.

X3.24-1968 Signal Quality at Interface between Data Processing Terminal Equipment and Synchronous Data Communication Equipment for Serial Data Transmission

Synchronous data communication is one of two techniques by which computer character code bits are transmitted.[63] "This standard is applicable to the exchange of binary data signals and timing signals across the interface (i.e., boundary) between data processing terminal equipment and synchronous data communication equipment."[64] It specifies the frequency and acceptable distortion levels for these two types of signals.[65]

X3.25-1968 Character Structure and Character Parity Sense for Parallel-by-Bit Data Communication in the American National Standard Code for Information Interchange

When a character is transmitted parallelly rather than serially, each character code bit is transmitted simultaneously over individual communication channels.[66] This standard assigns the bits of the standard code for information interchange (X3.4) to channels, using a bit i to channel i (i = 1, 2 . . . 8) assignment. The standard also specifies parity.[67]

X3.26-1970 Hollerith Punched Card Code

The Hollerith punched card code is, as its name suggests, a code for representing characters by means of punched holes in a card. It uses combinations of holes within a column to represent a character, one character per column, eighty columns per card.[68] Due to its widespread use it has "acquired the status of a de facto standard."[69] With the exception of one character, the set of Hollerith characters is a subset of the standard code for information interchange (X3.4). The original Hollerith characters' codes were retained for this subset and new punched code combinations were assigned to the remaining set of characters in the standard code for information interchange.[70]

X3.27-1969 Magnetic Tape Labels for Information Interchange

Magnetic tape is both an input/output and an auxiliary memory medium for computers.[71] "It is a common practice to record some identification information on each reel of tape. External labels have a limited life span and are subject to loss or various kinds of errors."[72] This standard presents formats for internal magnetic tape labels.

FOOTNOTES

[1] ANSI was formerly called the United States of America Standards Institute.

Davis, Gordon B. Computer Data Processing (New York: McGraw-Hill, Inc., 1969), pp. 556-557.

[2] Business Equipment Manufacturers Association, Annual Report 1969 (Washington, D. C., 1970), Appendix: Member Companies.

[3] American National Standards Institute. Catalog 1971 (New York, February 15, 1971), p. 57.

[4] Davis, Computer, p. 526.

[5] Davis, Computer, pp. 396-399.

[6] American National Standard X3.1-1969, "Synchronous Signaling Rates for Data Transmission," (New York: American National Standards Institute, 1970), p. 7.

[7] Chapin, Ned. An Introduction to Automatic Computers, Second Edition (Princeton: D. Van Nostrand Co., Inc., 1963), p. 38-40.

[8] American National Standard X3.2-1970, "Print Specifications for Magnetic Ink Character Recognition" (New York: American National Standards Institute, 1971), p. 9.

[9] American National Standard X3.3-1970, "Bank Check Specifications for Magnetic Ink Character Recognition" (New York: American National Standards Institute, 1971), p. 9.

[10] Bemer, R. W. "The American Standard Code for Information Interchange," Part 2, Datamation, September 1963, p. 39.

[11] American National Standard X3.4-1968, "Code for Information Interchange" (New York: American National Standard Institute, 1968), p. 3.

[12] Bemer, p. 39.

[13] Gupta, Roger. Electronic Information Processing (New York: The Macmillan Co., 1971), pp. 282-292.

[14] American National Standard X3.5-1970, "Flowchart Symbols and Their Usage in Information Processing" (New York, American National Standards Institute, 1970), Foreword, p. 3.

[15] American National Standard X3.5-1970, p. 7.

[16] Lee Louden, Robert K. Programming the IBM 1130 and 1800 (Englewood Cliffs, N. J.: Prentice-Hall, Inc., 1967) pp. 73-75.

[17] Bourne, Charles, P. Methods of Information Handling (New York: John Wiley & Sons, Inc., 1963), p. 75.
Chapin, pp. 31-32.

[18] American National Standard X3.6-1965, "Perforated Tape Code for Information Interchange" (New York, American National Standards Institute, 1965), p. 5.

[19] Davis, Computer, p. 130.

[20] American National Standard X3.6-1965, p. 5.

[21] Davis, Gordon B. Introduction to Electronic Computers (New York: McGraw Hill Inc., 1965), pp. 116-120.

[22] Davis, Computer, p. 363.

[23] Davis, Introduction, p. 120.

[24] Davis, Computer, pp. 347-350.

[25] Davis, Computer, p. 334.

[26] Stuart, Fredric. Fortran Programming (New York: John Wiley & Sons, Inc., 1969), p. 22.

[27] American National Standard X3.9-1966, "Fortran," (New York: American National Standards Institute, 1966), p. 7.

[28] American National Standard X3.10-1966, "Basic Fortran" (New York: American National Standard Institute, 1966), Appendix A6.

[29] American National Standard X3.10-1966, p. 26.

[30] Davis, Computer, pp. 304-306.
For a description of punched card input techniques see following introductory discussion to X3.21.

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[33] American National Standard X3.12-1970, "Vocabulary for Information Processing" (New York: American National Standards Institute, 1966), p. 7.

[34] American National Standard X3.4-1968, pp. 6-7.

[35] See Clamons, E. H. "Low-Order or High-Order, Which Bit First?" Control Engineering, August 1965, pp. 102-103, for a discussion of the substantive issues involved.

[36] American National Standard X3.15-1966, "Code for Information Interchange in Serial-by-Bit Data Transmission" (New York: American National Standards Institute, 1966) p. 5.

[37] Davis, Computer, p. 130.

[38] See earlier discussion of American National Standard X3.6.

[39] Davis, Computer, p. 397.

[40] American National Standard X3.16-1966, "Character Structure and Character Parity Sense for Serial-by-Bit Data Communication in the American National Standard Code for Information Interchange" (New York: American National Standards Institute, 1966), p. 6.

[41] Chapin, p. 36.
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[42] American National Standard X3.17-1966, "Character Set for Optical Character Recognition" (New York: American National Standards Institute, 1967), p. 9.

[43] See earlier introductory discussion to American National Standard X3.6.

[44] Bourne, p. 75.
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[45] American National Standard X3.18-1967, "One-Inch Perforated Paper Tape for Information Interchange (New York: American National Standards Institute, 1967), p. 5.

[46] American National Standard X3.18-1967, Appendix.

[47] American National Standard X3.18-1967, p. 5.

[48] American National Standard X3.19-1967, "Eleven-Sixteenths Inch Perforated Paper Tape for Information Interchange" (New York: American National Standards Insti-ture, 1967), p. 5.

[49] American National Standard X3.6-1965, Appendix B2.

[50] American National Standard X3.20-1967, "Take-Up Reels for One-Inch Perforated Tape for Information Interchange," p. 5.

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[54] Bourne, pp. 76-77.

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[57] American National Standard X3.22-1967, p. 9.

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[63] See earlier introduction to standard X3.16.

[64] American National Standard X3.24-1968, "Signal Quality at Interface between Data Processing Terminal Equipment and Synchronous Data Communication Equipment for Serial Data Transmission" (New York: American National Standards Institute, 1968), p. 1.

[65] American National Standard X3.24, pp. 1-3.

[66] Chandor, Anthony; John Graham and Robin Williamson, A Dictionary of Computers (Baltimore: Penguin Books Inc., 1970), p. 291.

[67] American National Standard X3.25-1968, "Character Structure and Character Parity Sense for Parallel-by-Bit Data Communication in the American National Standard Code for Information Interchange" (New York: American National Standards Institute, 1969), p. 5; Appendix B, p. 8.

For an explanation of the use of parity in data transmission see the earlier discussions of American National Standards X3.15 and X3.6.

[68] Davis, Computer, pp. 24-25.

[69] American National Standard X3.26-1970, "Hollerith Punched Card Code" (New York: American National Standards Institute, 1970), Appendix A.

[70] American National Standard X3.26-1970, pp. 9-10.

[71] Laurie, p. 11.

[72] American National Standard 3.27-1969, "Magnetic Tape Labels for Information Interchange," (New York: American National Standards Institute, 1970), Foreword, p. 3.

APPENDIX

CORRESPONDENCE

The following letter was sent to me by Louis D. Wilson, a former employee of the Eckert-Mauchley Computer Corporation. For confirmation of Mr. Wilson's former employee status see Auerbach, A. A.; Eckert, J. P.; Shaw, R. F.; Weiner, J. R.; and Wilson, L. D.; "The BINAC," Proceedings of the Institute of Radio Engineers, January 1952, p. 12.

ANALYTICS
INCORPORATED

179 WASHINGTON LANE, JENKINTOWN, PA. 19046 ◻ (215) 885-4242

15 June 1971

Mr. Benjamin Slome
55 West 95th Street
New York, N.Y. 10025

Dear Mr. Slome:

The following is in answer to your questions in your letter of 27 May 1971.

There was only one Binac system built. It was built for Northrop Aircraft Corporation and was essentially a laboratory model. It was constructed at Eckert-Mauchly facilities at the South-East corner of Broad and Spring Garden Streets in Philadelphia. System test was started in this same facility and was completed in larger facilities at 3747 Ridge Avenue in Philadelphia.

The first few Univac I systems were also built at 3747 Ridge Avenue and production facilities were then established at 29th Street and Allegheny Avenue, Philadelphia in space in the "Pep Boys" building. Later on production was transferred to Remington Rand facilities in Elmira and Utica, New York.

I trust this is sufficient for your needs. I would be most interested in seeing your dissertation when completed since I have an active interest in the history of the field.

Yours truly,

ANALYTICS INCORPORATED

Louis D. Wilson

Louis D. Wilson
Vice President

LDW/nar

IBM World Trade Corporation

A2-3

821 United Nations Plaza
New York, New York 10017
(Code 212) 983-6600
Cable address: Inbusworld

September 23, 1971

Mr. Benjamin Slome
55 West 95th Street
New York, New York 10025

Dear Mr. Slome:

Following are your questions and our answers, per your recent request:

1. Q. What was the motivation for commencing computer production abroad?

   A. It was a marketing and manufacturing decision to produce computers in areas overseas, where we would also market the computers.

2. Q. Why was France selected as the initial production site abroad?

   A. Not only France was selected. During the same time Germany and the United Kingdom also started to produce the 650. The market requirements had reached a level where it was justified to manufacture computers overseas rather than export them from the U. S. In addition, these countries had technical capability to manufacture computers.

3. Q. What are the domestic production figures for the 650 for all years preceding and following the commencement of production abroad?

   A. We consider that figure proprietary information.

4. Q. Why did IBM select Brazil and India as production sites for the IBM 1401?

   A. Brazil between 1962 and 1964 was in a depression. The Brazilian government closed the border and put restrictions on capital flow. It was a marketing and manufacturing decision to utilize the foreign exchange available in Brazil. In addition, we brought main frames into Brazil and had IBM in Brazil assemble the computers instead of importing completely built computers.

We started manufacturing in India because we wanted to contribute to the economy of that country. We are manufacturing 1401s in India because we felt the 1401 is a level of computer that the Indian marketplace could assimilate.

For your information, IBM Brazil and IBM in India have not exported computer main frames.

Our plant in Bombay, however, also manufactures 029 keypunch equipment and collators, calculating machines and reproducers. Unit record equipment is shipped to over 40 countries around the world including Australia, Canada and Germany, contributing as much as $2 million annually to India's balance of payments.

Sincerely,

Geoffrey Kean

GK/jd

A2-5

IBM World Trade Corporation

821 United Nations Plaza
New York, New York 10017
(Code 212) 983-6600
Cable address: Inbusworld

October 4, 1971

Mr. Benjamin Slome
55 West 95th Street
New York, New York 10025

Dear Mr. Slome:

Thank you for your letter of September 30.

The statement made by G. E. Jones in the article "Rio de Janeiro, South America Club Convenes," in the IBM World Trade News, May 1963, was true at that time. We exported very few main frames from Brazil. However, since that time we are exporting only data entry equipment from Brazil.

Re the dates of initial production of the IBM 650: As a concept Europe was preparing to produce a broader portion of our product line for its own market place. We were talking about the time period not the exact year when we referred to the initial production of the 650. The exact years you quoted from the "IBM FACTS BOOK" for initial production for the 650 in France, Germany and Greenock, are correct.

Sincerely,

D. J. Kamegietz
for Geoffrey Kean

GK:mw

IBM World Trade Corporation

A2-6

821 United Nations Plaza
New York, New York 10017
(Code 212) 983-6600
Cable address: Inbusworld

October 27, 1971

Mr. Benjamin Slome
55 West 95th Street
New York, New York 10025

Dear Mr. Slome:

Following are the answers to the questions you posed to us in your letter of October 24:

1. The IBM 1401 is still being produced in India.
2. IBM in India uses mostly imported parts for its 1401's.
3. The models manufactured in India are the IBM 1401R and the IBM 1401H.

Sincerely,

Geoffrey Kean

GK/jd

APPENDIX

Official United States Computer Trade Classifications

Exports

January, 1970 to present.

714.2002: Electronic computers, digital, main frame and central memory, including industrial process computers.

714.2008: Electronic computers, analog, main frame and central memory, including industrial process computers.

714.2012: Electronic computers, hybrid, main frame and central memory, including industrial process computers.

714.9204: Input-output and combination input-output devices and parts not elsewhere classified (n.e.c.) for electronic computers.

714.9208: Auxiliary storage devices and parts n.e.c. for electronic computers.

714.9212: Communication devices and parts n.e.c. for electronic computers.

714.9216: Parts and accessories n.e.c. for basic electronic computers.

(Schedule B Statistical Classification of Domestic and Foreign Commodities Exported from the United States, U.S. Bureau of the Census, 1/1/70.)

January, 1965 to December 1969.

714.2005: Electronic computers digital including process control computers.

714.2010: Electronic computers n.e.c. including process control computers.

714.9210: Parts and accessories n.e.c. for electronic data processing machines, other than typewriters.

(Sechedule B Statistical Classifications . . . , 1/1/65.)

Imports

Schedule A number 714.300: Accounting, Computing, and Other Data Processing Machines. This Schedule A number is composed of two Tariff Schedules of the United States Annotated (TSUSA) numbers, 676.1500 (Accounting, Computing, and other Data Processing Machines) and 676.3030 (Data Processing Machines).

(U.S. Foreign Trade Statistics, Classifications and Cross-Classifications, 1970, U.S. Bureau of the Census, February, 1971.)

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