Small-Scale Industry and Technology in India: The Case of the Computer Industry

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ABSTRACT. This article finds that small firms in newly industrializing countries can serve as a conduit for technical change. Small firms in India's computer industry have helped narrow the technology gap between the domestic industry and its international counterpart. Successful innovator firms have grown larger. Changes in government policies were essential for the maturation of the nascent Indian high-technology industry.

I. Introduction[1]

Newly industrializing economies are confronted with a particular challenge to their future economic prosperity. Accelerating technological change in the microelectronics sectors in industrial nations continuously erodes the comparative advantage derived from relatively cheap labor which industrial latecomers could in the past exploit for their own benefit in trade. This raises the specter of increased marginalization of economically underdeveloped nations in the competition for world markets in high quality, customized, design- and technology-intensive products. Unless ways are found for these countries to acquire the technological capabilities needed to narrow the technology gap that separates them from the industrialized countries, newly industrializing nations risk losing world market share in manufactured products.

Recent contributions to the literature on industrial organization by Acs and Audretsch (1987, 1988, and 1989) have examined the relationship between technical change, firm size, and industry structure in the United States. These studies used detailed innovation events instead of the more traditional measures of technical change such as patented inventions and R&D expenditures. Moreover, they are the first attempt to introduce firm size as an explanatory variable of technical change. As the evidence from industrialized countries suggests, in some sectors small firms are a more significant conduit for technical change than are large ones. This is particularly true in the microelectronics industry. More generally, technical change is more rapid in less concentrated industries, in other words, in those sectors in which competition among firms is strong. But this is no proof that a linear relationship between technical change and industry structure necessarily exists. Kamien and Schwartz (1982) suggest that a U-shaped function may be more appropriate.

I have found no study that establishes a relationship between firm size, industry structure and innovation events in newly industrializing countries in any industrial sector. This article will explore the question of the extent to which small- and medium-scale firms can serve as agents of technology transfer and acquisition in an economically developing country and thus contribute significantly to technical change and future competitiveness. It attempts to demonstrate that small firms in India's computer industry helped narrow the technology gap between domestic and international enterprises in the industry between 1976 and 1986. The article has as its second objective an inquiry into government policy conditions in India which initially inhibited and then stimulated small-scale (and medium-scale) enterprise advances in technology. When government allowed entry into the computer industry and provided access

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for small-scale enterprises to sources of international technology and thus to technological opportunities in the home market, it is hypothesized, the technology gap narrowed over time.

The major impediment to such an investigation into technical change in microelectronics industries of economically developing nations is the complete absence of data bases that would reveal dynamic changes in industry structure and government policies, and that would indicate innovative activity specific to particular sectors and firms of a country. Therefore I had to build from the ground up a database on which to base this empirical evaluation.

I proceed to use this information as follows: First, I trace the movement of firms from one firm size category to another for an entire decade. Second, I characterize the technology prevalent in the international computer industry for the last 40 years. The nature of computer technology helps explain movement between firm size categories. Technology traits of computers are also useful for the construction of a technology gap measure. Third, I examine the role small- and medium-size firms played in the introduction of concrete computer technology innovations in India. Fourth, a rudimentary historical account of industrial policy pursued by the Government of India (GOI) with respect to computer firms will help explain the rapid decline in the technology gap measure in 1978/79 and the subsequent gradual decline in the measure from 1982 to 1986. Fifth, I offer some policy considerations, and finally I sum up the findings of this article.

II. Development of size structure of India's computer industry, 1976–1986

Table I provides a picture of the Indian computer industry's entry and exit movements. I have followed the movements of those companies that are officially considered to have been in production (a total of 37). Other establishments, most likely of very small size, have existed in India and continue to do so, since by 1985 over 300 Industrial Licenses (IL) and Letters of Intent (LI) had been issued by the government to computer firms. I do not have adequate information on these firms, assuming they ever went into production.

For purposes of this article, small- and medium-scale enterprises are distinguished from large-scale establishments by the number of persons they employ, unless otherwise specified. Small-scale businesses are defined as those that provide work for up to 50 full-time employees (workers), medium-size ones as those that engage up to 200 persons, and large firms those that create employment for over 200 employees.[2] Table II classifies the 34 observed companies in the Indian computer industry (excluding IBM) according to their size category for each fiscal year between 1975/76 and 1985/86. However, some caveats are in order here. For some smaller firms the number of employees in some years was unavailable. It is my judgement that those firms would fall either into the 'small' or 'medium' categories. In some cases, when I lacked employment figures for a year but knew of a firm's employment size in previous periods, I assumed that it remained in the same category, unless I had definite information to the contrary. I have also assumed, based on the continued rapid output growth of the computer industry during the period under examination, that firms generally did not shrink in size, with some known exceptions. Subsidiaries of large industrial

TABLE I
Industry structure over years (entry, exit, merger)

Year	Number of firms			IL and LI issued (cumul.)
	Entry	Exit	Cumulative	
1969	2	0	2	3
1975	1	0	3	3
1976	3	0	6	3
1977	1	0	7	3
1978	2	1	8	12
1979	2	0	10	18
1980	4	0	14	24
1981	7	0	21	43
1982	6	0	27	49
1983	6	0	33	54
1984	1	1	33	137
1985	2	0	35	300
1986	0	1	34	300

Sources: Notifications of Industrial Licenses (IL) and Letters of Intent (LI); Government of India, Dept. of Electronics, *Electronics Information and Planning*, Vols. 1–13; *Dataquest*, various issues; Statistics Investigation Bureau (1974); Kumar (1984); Grieco (1984).

TABLE II
Firm size-categories

Year	Total firm size-categories				
	Firm (nos)	Small-firm (nos)	Medium-firm (nos)	Large-firm (nos)	Unknown size (nos)
1975/76	1	0	0	1	0
1976/77	2	0	0	2	0
1977/78	5	2	0	3	0
1978/79	8	2	2	4	0
1979/80	11	3	2	4	2
1980/81	18	3	6	5	4
1981/82	25	5	7	6	7
1982/83	30	3	9	9	9
1983/84	32	5	14	10	3
1984/85	34	4	16	11	3
1985/86	34	4	12	18	0

Small $\leqslant$ 50 employees; medium $\leqslant$ 200 employees; large $>$ 200 employees.
Sources: Company interviews, brochures and annual reports; GOI, Bureau of Public Enterprises, *Public Enterprises Survey*, annual issue; "The Dataquest Top Ten," *Dataquest* (March 1984): pp. 32—65; "The Dataquest Top 10," *Dataquest* (March 1985): pp. 45—67; "The Top Ten," *Dataquest* (Aug. 1986): pp. 11—49.

houses (DCM, ORG, NELCO) were always classified as large-scale firms.

With computer firms thus classified as to size between 1975 and 1986, a continuous movement of firms from small to medium to large-scale in terms of employment size becomes readily apparent (see Table II). Small firms and to some extent medium-sized firms are thus transitory creatures, seeking to mature and reach large-scale status. The reason for this drive to become large in terms of employment can be found in the nature of the computer industry technology.

This observation in Table II of a strong trend towards large-scale employment in the Indian computer industry is supported by a more rigorous analysis of market-share 'transition-probabilities' in the Indian computer industry for the period 1976 to 1986. For that period we observed a total of 201 movements of Indian computer firms from one market-share size-category to another (Table III). Market-share size-categories are defined using a seven-category system for the purpose of the transition probability analysis. Category zero serves as entry point for new firms and as terminal point for firms that exit the industry. When firms enter the industry they move from category zero to another category with some observed probability. Categories one to six rank firms according to their market share for each fiscal year as follows:

- one equals a market-share of 0.01—3.99 percent;
- two equals a market-share of 4.0—7.99 percent;
- three equals a market-share of 8.0—11.99 percent;
- four equals a market-share of 12—15.99 percent;
- five equals a market-share of 16—19.99 percent;
- six equals a market-share of 20 percent and more.

From the observed movements of firms from one market-share category to another for each year (1976—86) I estimated transition-probabilities. Table III shows those estimated transition-probabilities.[3] From the then defined probability matrix, I generated a steady state size-distribution for firms ('limiting probabilities'). This size-distri-

TABLE III
Estimated transition-probability matrix for the period 1976—86

'Interstate' transition observations

States	zero	one	two	three	four	five	six	total
zero	0	30	1	1	1	1	0	34
one	2	109	5	2	0	0	0	118
two	0	3	4	2	1	0	1	11
three	0	0	5	3	3	0	0	11
four	0	0	1	4	1	1	0	7
five	0	0	0	1	1	3	1	6
six	0	0	0	0	1	2	11	14
								total 201

'Interstate' transition-probability

	zero	one	two	three	four	five	six	Sum of 0 to 6
zero	0	0.8823	0.0294	0.0294	0.0294	0.0294	0	1
one	0.0169	0.9237	0.0423	0.0169	0	0	0	1
two	0	0.2727	0.3636	0.1818	0.0909	0	0.0909	1
three	0	0	0.4545	0.2727	0.2727	0	0	1
four	0	0	0.1428	0.5714	0.1428	0.1428	0	1
five	0	0	0	0.1666	0.1666	0.5	0.1666	1
six	0	0	0	0	0.0714	0.1428	0.7857	1

States	Limiting probabilities	Mean time to return
zero	0.0096	104.20
one	0.5645	1.771
two	0.1269	7.88
three	0.1047	9.55
four	0.0628	15.901
five	0.0436	22.938
six	0.0877	11.392

bution would be expected if the observed movements between size-categories continued indefinitely.[4] I found that in the long-run we can expect 43 percent of the firms in market size categories two to six, and the rest in category one with a slight possibility of exit (less than 1 percent). In 1985/86 any firm in the Indian computer industry with a market share of 4 percent or more employed more than 200 people, and thus has to be considered large-scale. The above exercise thus confirms my result from Table II, which says that, in 1985/86, 18 out of 34 operating enterprises were large in terms of employment size. The estimated 'limiting probabilities' allow us to say that at least 43 percent of firms in the Indian computer industry are likely to be large, that is, almost half of the industry's firms. This is very much in line with actual experience in the Indian computer industry.

III. Computer technology

The nature of international computer technology helps to explain the strong movement from small to large firm *employment* size categories in India. Research on the international computer industry shows that economies of scale have traditionally not played a significant role in the mini- and microcomputer industries.[5] The special nature of technological change in computer components, particularly semiconductors,[6] made it possible for firms to spin off capital-intensive component production processes. Computer manufacturers

then had to purchase the components from outside and concentrate on the assembly of in-house-designed computers in relatively labor-intensive shops.[7] Also the speed of technological progress in computers made it seem unwise to sink vast amounts of capital into production facilities which could not be adapted rapidly to new products and circumstances.[8]

India's technological developments in the computer industry can only be evaluated in the context of developments internationally, particularly in the US industry.[9] An adequate comparison of respective technical changes over time will yield information about the size of the technology gap between the domestic and international manufacturing firms. To make that comparison it is necessary to identify the main qualitative traits of a computer system, holding prices constant. Those characteristics are: a) the performance of the individual machine modules; b) the ways these modules are connected (design and architecture); and c) the manner in which the system is controlled by programs (i.e., microprograms[10] and operating systems).[11]

From this comparison of technological characteristics, both in the international and in the Indian computer industry, it became clear that computer hardware, software and architecture developments of the domestic industry have largely followed those in the international realm. The question I need to address here is exactly how closely in time India was able to follow. More specifically, to test the hypothesis that India's domestic mini- and microcomputer industry was able over time to narrow the technology gap between its computer systems and foreign ones, I have developed a convenient 'technology gap' measure which quantifies the time difference in the qualitative traits of computer systems over a ten year period.[12]

The results of this exercise are shown in Figure 1. With the entry of large and small firms in 1977/78, India drastically reduced its lag in computer technology. Between 1979 and 1982 the gap between India's computer technology and the internationally available technology widened again, before it narrowed again to about two years in 1985 and 1986. I explain the dramatic drop in the gap measure in 1977/78, as well as the later gradual decline, with important changes in India's industrial policy. The temporary increase witnessed between 1979/80 and 1981/82 can essentially be laid at the door of an intermittent freeze on innovation activity in large and small computer enterprises. Before moving to a detailed discussion of these government interventions, it is thus appropriate to determine what contribution small, medium, or large firms made to technical change in the Indian computer industry over the period 1978 to 1986.

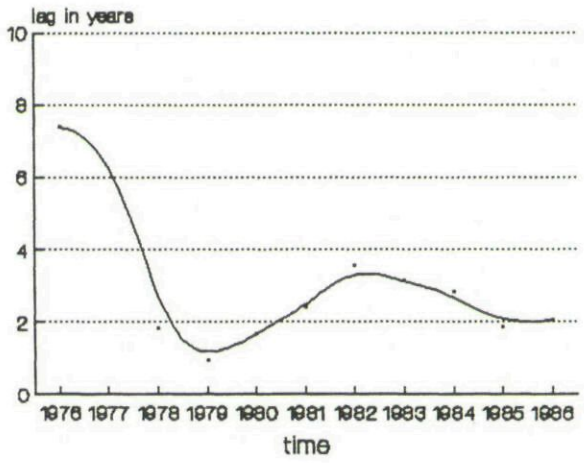

Fig. 1. Technology lag in years.

IV. Small- and medium-scale computer firms and technology

What was the contribution of small-scale and medium-scale firms to India's narrowing of the technology gap? To find some answer to this question I analyzed literature which identifies essential innovations in the international (mainly US) micro- and minicomputer industries. This resulted in a list of key innovation events. The list then served as an objective guideline for the selection of essential technology changes in India's computer industry; these technology changes were then correlated to the names of particular Indian companies which originated them.

In establishing this list of Indian computer technology changes, I relied on several sources. One source was the Department of Electronics publication, which occasionally reports on technological developments in the industry, particularly in relation to the public computer enterprise ECIL.[13] A second source was computer trade

publications and journals, which regularly report on technological developments and publish evaluations of particular computer models.[14] The third major source was technical details given by interviewees.[15] This interview information was complemented by company brochures and by personal observation of computer products offered at the Annual Meeting of the Computer Society of India in Bombay, February 1987. Lastly I discussed technological developments in the Indian computer industry with independent computer experts.[16]

To the list of hardware innovations I added, as an indicator for sophistication in the computer *production* process,[17] changes in the layers of Printed Circuit Boards (PCBs) used in the assembly of Indian computer models. Here again I relied on publications and trade journals[18] as well as on the answers of interviewees. The result of this exercise was a list of essential process innovations in India's computer industry. Finally each one of these innovations I again associated with a particular firm.

The results are shown in Table IV. An initial period of innovative activity between 1977 and 1979 by small- and large-scale industry was followed by a lull in innovative efforts during the years 1980/81. This is one explanation for the initial rapid decline in the technology gap shown in Figure 1, followed by a temporary widening of the gap. In 1981/82 small- and medium-size firms temporarily became a driving force in innovation. The technology gap again started to narrow slowly in 1982/83. This was also the time when a new wave of small companies entered the Indian computer industry, as shown in Table I. Some of these entrants then kept growing in terms of employment and market share, and by 1985 had achieved large-scale status (see Table II on firm-size status). It is thus justified to conclude from our data that these were the same firms that then rekindled innovative activities as large-scale firms in the mid-1980s (see Table IV for these patterns). The effect of the combined growth and innovation dynamic, as expressed in my data base, is a sustained gradual decline in the technology gap after 1982/83 (Figure 1).

TABLE IV
Essential innovations and firm size

Year	Total	Innovations categorized by firm size		
	(nos)	Small firms (nos)	Medium firms (nos)	Large firms (nos)
−1976	3	0	0	3
1976/77	0	0	0	0
1977/78	2	*1*	0	*1*
1978/79	5	*2*	0	*3*
1979/80	1	*1*	0	0
1980/81	1	0	*1*	0
1981/82	3	*1*	*2*	0
1982/83	7	*3*	*1*	*3*
1983/84	5	*1*	*3*	*1*
1984/85	4	0	*1*	*3*
1985/86	5	0	*1*	*4*
1986/87	6	0	0	*6*
Sum	42	9	9	24
Percent	100.0	21.4	21.4	57.1

V. Industrial policy and technology

Two types of policies played a particularly important role in the ability of the Indian computer industry to exploit available technological opportunities and to narrow the technology gap: a) policies relating to industrial licensing and public sector reservations, and b) policies relating to import of raw materials, components, and computers as well as computer technology.[19]

First, India's computer policies influenced the rate of entry of new firms into the industry. Since the entry rate determines industry structure and thus influences the level of non-price competition, policies that restrict entry indirectly affect the speed of technological advance in the computer industry.[20]

My historical analysis of India's complex industrial licensing policy regime revealed that the government effectively prevented entry into the computer industry by both domestic and foreign private firms in the early 1970s, up to 1976. In the late 1960s the government had recognized the strategic importance of a domestic computer sector. Since foreign multinational corporations completely controlled the domestic scene in the 1960s and hence had control over computer technology, the government decided to establish the institutional framework within which a viable

domestic computer industry could flourish. The strategic importance of computer technology and the then very limited technological capabilities in the domestic private sector prompted the government to put indigenous computer production in the hands of a public sector enterprise, ECIL, in 1971.

Thereafter, the so-called 'Minicomputer Panel', a study group set up under the auspices of the Electronics Commission, completed a study which concluded that ECIL by itself would be able both production-wise and technology-wise to meet domestic demand for minicomputers at least until 1975. From this report, policy makers concluded that foreign investment and collaboration were not necessary for the Indian computer industry in the near future. By its very existence the public sector company ECIL created a government interest in guarding its domestic near-monopoly from any threatening competition. With the enactment of the Foreign Exchange Regulation Act (FERA) in 1973, the Indian government possessed an effective tool to 'indigenize' operations of any foreign computer production holdouts, i.e., ICL and IBM. Potential domestic producers were kept out of the industry by the refusal of the administration to approve private production facilities.

By about 1976 it had become obvious that ECIL was not able to meet domestic computer demand at competitive prices and technology. Finally the forced exit of IBM from India during 1977 and 1978 further increased the gap between supply and demand in the market. The Janata government, at first unofficially and later officially, permitted private sector production in computers, with preference given to small-scale firms. The sharp reversal of licensing policies in 1978 was reflected in the rapid deconcentration of the industry (see Table I) and consequently in the narrowing of the technology gap in domestic computers from then on (see Figure 1). A gradual simplification of the production approval process for smaller and larger domestic firms throughout the first half of the 1980s has continuously increased the threat of entry by potential domestic competitors.

Second, India's computer policies regulated the access of domestic firms to sources of new computer technologies. Analysis of policies governing foreign collaboration with domestic computer firms shows that firms continuously found it difficult to access international technologies because of the prevailing restrictions put on collaboration agreements by the Indian Government.

In the 1960s imports of raw materials and components were seen as a source of technology for a large number of items that were not produced domestically. When a domestic component industry emerged in the 1970s, those inputs indigenously manufactured were put on a restricted import list. The rapid technology change in the international computer industry occurred, however, on the basis of an increasing variety of newly created sophisticated components, such as memory- and processor-chips and secondary memory storage devices. India's nascent component industry could not keep pace with many of these developments. This was recognized by the Department of Electronics in the early 1980s, and import regulations and procedures relating to computer parts and components were significantly simplified. Simultaneously tariff rates levied on crucial computer components were reduced. India so far does not have a significant capital goods sector which delivers production machinery needed for computer manufacture. Capital goods needed for hardware production have been on Open General License (OGL) throughout the 1980s, and thus relatively easy access to new technology in this area also has been assured for domestic computer manufacturers.

VI. Policy conclusions

The first element of industrial policy should aim at lowering costs of and increasing benefits of entry (financial and non-financial) for potential domestic manufacturers. Bureaucratic and regulatory barriers that prevent actual domestic entry have to be removed. Small-scale enterprises have made a significant contribution to technological advance in the Indian computer industry. But they were able to do so only after policy-determined deterrents to entry were removed. Policy makers should also pay attention to the possibility of an established foreign-owned monopolist preempting the domestic market (i.e., through predatory pricing, use of brand name, exploitation of good-will) and thus inhibiting entry by domestic firms. Hence a successful industrial strategy for building up a

domestic high-technology industry includes the regulation of activities of competing foreign multinationals, in the initial stage. Such control will allow domestic small-scale firms to enter and in due time to go down a learning curve and grow. It will allow domestic small-scale firms to achieve sufficiently large production runs for the home market when increasing returns to scale play a role in a particular high-technology industry (economies of scale do not always play a role, as we have seen is the case of the computer industry). Most importantly, an initial period of protection of domestic entrants from the onslaught of foreign competitors allows domestic manufacturers to build up sufficient R&D capacity. Before any protection is withdrawn, domestic manufacturers must be in a position to develop and adapt products for targeted niche markets in which the country in question has a potential competitive advantage. A concomitant effect of such policy of protection from foreign competition is that it raises the initial benefits of entry for potential domestic manufacturers.

Needless to say, any temporary protectionist policy has to consider the institutional constellation of a country. Government has to make clear right from the beginning that protection is temporary and barriers will be lifted after a certain specified period. Groups which have a potential vested interest in the continuation of protection may thus be prevented from claiming any right to continuing shelter.

The experience of the Indian computer industry demonstrates that protection against foreign competition has to be accompanied by a high level of domestic competition. In a high-technology industry the entrepreneurial spirit of a firm thrives when it is able and allowed to vie for a technological advantage over other firms, and thus helps assure the firm's survival. To enhance the kind of (non-price) Schumpeterian competition "which strikes not at the margins of the profits and the outputs of the existing firms, but at their foundations and their very lives,"[21] industrial policies for a successful build-up of a high-technology industry in a newly industrializing country need to include, as another element, measures that help open up avenues to international and domestic technology sources. For example, the government of a newly industrializing country can play a facilitative role in an industry's access to key technologies embodied in imported parts and components, when this has been determined *a priori* as a crucial technology source.

VII. Summary

In the case of the Indian computer industry, small- and medium-scale enterprises played a substantial role in the acquisition of international computer technology. The entry of a large number of firms in the early 1980s provided a seed-bed from which some successful firms — success defined here in terms of innovation events — grew to considerable size, whereas other less successful ones remained small.

Governments can facilitate the maturation of a nascent high-technology industry in an economically developing country by a) providing infant industry (technology) protection, b) allowing at the same time for easy domestic entry into the industry, and c) giving ample opportunity to the industry to access international technology sources. The effect of industrial policy changes in the computer industry of India can be gauged by the changes in the size of the technology gap that persisted over the time period under study. The permission of entry, and thus the deconcentration of the industry in 1977/78, fostered the kind of domestic competition linked in the industrial organization literature to higher degrees of innovativeness. The pace of innovation in the Indian computer industry increased, and the technology gap between it and the international industry narrowed, under a second wave of firm entries combined with better access to international technology sources. Some small firms did move down the learning curve, increased their market share under infant industry protection, and led the innovative effort in the mid 1980s as mature, large domestic firms.

Notes

[1] The paper presents only part of the results of the author's field work at the Centre for Policy Research in New Delhi in 1987.

[2] These employment size definitions are also used in a recent comprehensive study on small-scale industry by Little, Mazumdar and Page (1987).

[3] Anderson and Goodman (1957), pp. 89—110, show that

stationary transition probabilities can be estimated from actual observation with maximum likelihood estimates.

[4] For methodological details see Padberg (1962), pp. 189—199.

[5] Dorfman (1987), pp. 22, 226—227; Grieco (1984), pp. 11, 66; Brock (1975), pp. 20, 52, 65—66.

[6] See Tilton (1971) on this point.

[7] Dorfman (1987), p. 227.

[8] This is the so-called Arrow effect, discussed first by John Kenneth Arrow. Tirole (1988), p. 392, calls it the 'replacement effect'. Essentially when a firm has a market monopoly and an established production facility, the profits from introducing new products are offset by reduced profits from obsolete products and the necessity to invest in associated changes in the production plant. See also Flamm (1989), p. 7.

[9] For details in computer technology developments, refer to the author's dissertation draft.

[10] A software program that defines a computer system's instruction set and is generally stored in Programmable Read-only-memory (PROM). For detailed treatment of micro-programming see Hayes (1985), pp. 690—701.

[11] Stone *et al.* (1980), p. 1.

[12] For details refer to the author's dissertation draft.

[13] Government of India, Department of Electronics (1974a), p. 479; idem (1978), p. 829; idem (1983), p. 487.

[14] *Dataquest*, all issues 1982 to 1988; "Looking Back over the Past Decade," *Computers Today* (January 1987), pp. 48—55; Bhasin and Soni (1987); Constellate Consultants (P) Ltd. (1983, 1984 and 1986).

[15] For details see database on Indian computer models available with the author.

[16] Mr. Gene Mundt of Control Data Corporation, interview with author, Minneapolis, Minn., August 20, 1987; Prof. Rajaraman, Indian Institute of Science, interview with author, Bangalore, February 10, 1987; Dr. Kenneth Flamm, Brookings Institution, discussion with the author, Washington DC, February 9, 1988.

[17] Based on statements by Mr. Ross Johnson, Control Data Corporation, in a telephone conversation, September 1986 and by Prof. Rajaraman given in his interview, February 10, 1987, that this serves indeed as a reasonable proxy for the state of production technology in India.

[18] Government of India, Department of Electronics (1974b), p. 856; "Looking Back over the Past Decade" (January 1987), pp. 48—51.

[19] For details refer to the author's dissertation draft.

[20] A theory of 'non-price competition' is outlined in the author's dissertation draft.

[21] Schumpeter (1942), p. 84.

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