The Developing Economies, XXXI-3 (September 1993)

PRODUCTIVITY, EFFICIENCY, AND NEW TECHNOLOGY: THE CASE OF INDIAN MANUFACTURING INDUSTRIES

BUDDHADEB GHOSH
CHIRANJIB NEOGI

INTRODUCTION

VERY few areas of research in economics have produced so many path-breaking papers—both theoretical and empirical—as the issue of appropriate factor proportions (or, so to say, the technological question in industry) for the developed as well as the less developed countries (LDCs).[1] Interestingly enough, economists in the developed countries have long been persuaded about the role of R & D in fostering technological advances in industry which in turn help achieve faster productivity growth.[2] The governments in most of the LDCs like India bothered little about the long-run cost of outright introduction of advanced capital-intensive technology, and did not pay any heed to their domestic factor endowment and efficiency of resource use. Moreover, it has long been proved by economists that technological change is not neutral with respect to country, commodity, nor factor use.[3] Increasing interest in advanced technology under prevailing institutional frameworks stems, among other things, mainly from three important considerations.[4] First, to get rid of the short-run cost of R & D and related uncertainties, given the scarcity of capital, outright import of foreign technology is always preferred. Second, by doing so, the LDCs have been able to introduce wide varieties of new products for their rising middle class. Third, with increasing reliance on capital-intensive methods the producers have been able to bypass to some extent the traditional labor troubles in industry.

A variant of this paper was presented at a seminar organized by Economic Research Unit, Indian Statistical Institute, Calcutta, on March 1991. We are thankful to Professors N. Bhattacharya, D. Coondoo, R. Mukherjee, and Manoranjan Pal for their valuable suggestions. We also benefited from discussions with Professor Mihir Rakshit.

[1] Some of the brilliant surveys on the literature in this area are [30] [34] [49] in general, and [27] for India.

[2] A nonconventional approach to the choice of technology by long periods of trial and error can be found in [24]. Moreover, numerous attempts have been made to measure the contributions of R & D to productivity growth, e.g., [16] [33]. Although they have used technological advance in a neoclassical context, the ultimate result is that the entire "residual" part cannot be explained by spontaneous technological advance.

[3] Some of the important works in this area are [13] [26] [4] [45] [43] [46].

[4] Although economists dealing with the issues of foreign technology and domestic technological development are divided into various opinion groups, the following works largely cover these viewpoints: [38] [29] [46] [39] [10] [48] [28].

The Indian scene as a testing ground of the aforesaid hypothesis has become highly relevant mainly for three reasons. First, one of the important features of India's industrial change from the fifties to the sixties was the relatively increasing emphasis on foreign capital. The devaluation episode of the mid-sixties was supposed to work in favor of the inflow of foreign capital. Thereafter "indigenization" followed in the name of "import-substituting industrialization" [6] [7]. But the seventies saw the beginning of indiscriminate import of foreign technology even beyond the capital goods sector. And the "sheltered market" phenomenon was the main feature of trade liberalization policy until recently.[5] Second, from a micro perspective, the import of foreign technology has had a rather limited (and in some cases, negative) impact on domestic technological effort except for a selected few big industries.[6] Third, hardly any broad macro studies have so far been attempted on Indian industry with significant foreign collaborations in order to verify the question of efficiency of resource use in industry. What is more, the increasing diminution of industrial efficiency is very much evident in the Seventh Five-Year Plan document which laid tremendous emphasis on the "sunrise" industries. They include telecommunications, computers, microelectronics, ceramic composites, and biotechnology. It was proposed to attain the goals of self-sustaining industrial growth and technological development through, among other things, the adoption of effective promotional measures to raise the productivity of resources. It was also explicitly mentioned that the protection from international competition of the earlier semi-insular phase had given rise to high manufacturing costs, which have been inhibiting both expansion in the domestic market and rapid export development. Manifestly, an appropriate environment was promised to be created so as to encourage and promote greater efficiency, higher productivity and faster industrial growth [21].

There is no denying the fact that the question of efficiency is inextricably related to the appropriateness of the chosen technology, and more often than not the fault may lie in the institutional preparedness for scientific management which is necessary for the smooth functioning of the new technology. Beyond the proximate sources, from a broader technological perspective they may be certain features of the entire economic environment in a country that have a generally facilitating or retarding influence on growth. In this context, productivity changes at the industry level may be a resultant of a general efficiency fall at the macro level. According to Nelson, "it can be argued that slow productivity growth is itself one of the causes of poor employment and price performance of the economies" [34, p. 1056].

However, technological change in industry may be broadly defined to include (i) advances in technological knowledge embodied in new capital goods imported from developed nations, which may be taken into account by collaboration agreements undertaken between domestic and foreign industries, (ii) adaptive changes

[5] The new three-year EXIM policy, expansion of the open general list, the seventh and eighth five-year plans, and most importantly, the New Industrial Policy of 1991 clearly bear testimony to the thrust towards economic liberalization. Also consult [42] [20].

[6] For detailed elaboration, see [3] [11] [31] [28].

to be introduced by the firms in the importing LDCs which are required to make the technology suitable for local conditions (including both process and product differentiations), and (iii) special tools and information about the techniques of scientific management.

We will be dealing with the first aspect of technological change in regard to its power and ability to improve the productivity of labor. Like any other LDC, India is characterized by acute scarcity of capital, and awareness of how to make efficient use of existing resources through proper adjustment of policy variables is sadly lacking [37]. It is well known that if one of the two factors, capital and labor, increases at a very fast rate relative to the other, then the productivity of the other factor must increase at a reasonably fast rate. In other words, sustenance of industrial growth depends crucially on the efficiency with which the accumulated capital stock per unit of physical labor (or, so to say, overhead tools and machineries with which to work) and human capital are utilized in an aggregative sense. This paper is concerned with the performance of some selected ("sunrise") Indian industries (which are categorized in the Appendix Table I) in terms of labor productivity (*LP*) in relation to capital coefficients. Or, in other words, we try to study the effect of technological advancement as reflected in strictly rising capital intensities on the productivity of labor. Within the framework of the present study, the results are significantly conclusive: in a macro sense, inefficient use of resources is the order in the electronics, electrical, and chemical industries.

The organization of this paper is as follows. Section I deals with the data and the concept and measurement of efficiency. Section II briefly outlines the pattern of changes in output and input coefficients. Section III concentrates on the efficiency of input use in twenty-nine industries, where, according to the Reserve Bank of India (RBI), the largest foreign collaborations (among the entire manufacturing sector) have been made for importing advanced technology, in a comparative static framework over different time spans. In Section IV, an attempt is made to identify the factors determining labor productivities in Indian industry. Finally, a summary and policy implications are given in Section V.

I. CONCEPT AND METHODOLOGY

A. *The Data*

The period of our analysis is chosen to be between 1974–75 and 1986–87 mainly for two reasons. First, continuous annual data are available from the *Annual Survey of Industries (Factory Sector)* [18, various issues] for this period. Second, this period marked widespread development of "new" products in industries (classified in the Appendix Table I) which were significantly opened up to international linkages through explicit import of capital-intensive technology. As a corollary to this, Indian industries embarked upon the path of technology upgradation leading to explicit preference for capital-intensive techniques. Information about technology in general and foreign technology in particular is too scanty for a comprehensive empirical verification. But the recent surveys by the RBI

[41] [42][7] have shown that from the industrywise breakdown over the years 1977 to 1981 about 95 per cent of total technical collaborations were undertaken in the manufacturing industries. And out of these more than 75 per cent were earmarked for only three broad industries, namely, (1) manufactures of electrical machinery, appliances, and supplies and parts, (2) manufactures of machinery, machine tools, and parts, and (3) manufactures of chemical and chemical products. Thus, capital-intensive technology through foreign collaborations has entered Indian industries in recent years.[8] A period of twelve years is assumed to be enough for our purpose to check the extent of the impact of new technology on the productivity of the relatively stagnant factor, here labor. However, technological issues like import of know-how and/or techniques are basically embodied in our analysis and not separately dealt with. To be specific, adoption of advanced capital-intensive techniques is proxied by increasing capital/labor ratios (K/L) in the industries.

The major source of our data is the *Annual Survey of Industries (Factory Sector)* (ASI) [18], which includs firms of all types as defined by ASI.[9] All monetary figures are converted into real terms with the help of appropriate deflators: (i) capital formation deflators from various issues of *National Accounts Statistics*, and (ii) commodity groupwise indices of wholesale prices (new series) from the *Indian Labour Journal*.[10]

In the absence of any meaningful information about hourly labor time in manufacturing industries, labor is measured here in terms of (i) number of workers engaged as production workers, and (ii) total number of employees including skilled and supervisory personnel in each of the industries. It may be admitted that measurement of the stock of capital always poses some problems. We have here followed the Perpetual Inventory Accumulation (PIA) method originally propounded by Goldsmith [17]. Most of the researchers who have dealt with capital stock in Indian industries have preferred to use the gross fixed capital stock (GFCS) perpetuated from the base year and converted into real terms. Some of the important works using this method with Indian data are [22] [12] [44] [1]. Accordingly, K/L is defined as the amount of GFCS (real) per unit of labor at

7 The survey [42] covers 564 companies in the private sector and 26 government companies. The total number of approvals over the eleven-year period 1974 to 1984 works out to be 4667. See [41] [42].

8 Moreover, as reported in R & D statistics [19] [20], despite the growth in R & D capabilities a large number of industrial houses depend on foreign technology from West Germany, the United Kingdom, Switzerland, Japan, France, and Italy. The industrial groups concerned are mainly those considered by us.

9 "Annual Survey of Industries cover all factories registered under sections 2m(i) and 2m(ii) of the Factories Act of 1948, which refer to the factories employing 10 or more workers and using power, or those employing 20 or more workers but not using power on any day of the preceding 12 months" [18, 1986–87 edition, p. 1]. An elaborate description of the industrial database of the Indian economy can be found in [1].

10 Capital stock is deflated by using implicit capital formation deflators obtained from National Accounts Statistics, Government of India. The commoditywise wholesale price indices are used to convert the values of output into real terms.

a point of time [$(K/L)_1$ for production workers and $(K/L)_2$ for all employee]. Labor productivity ($Y/L = LP$) is defined as the ratio of value added and laborers [$(LP)_1$ for production workers and $(LP)_2$ for all employees].

B. *Concept and Measurement of Efficiency*

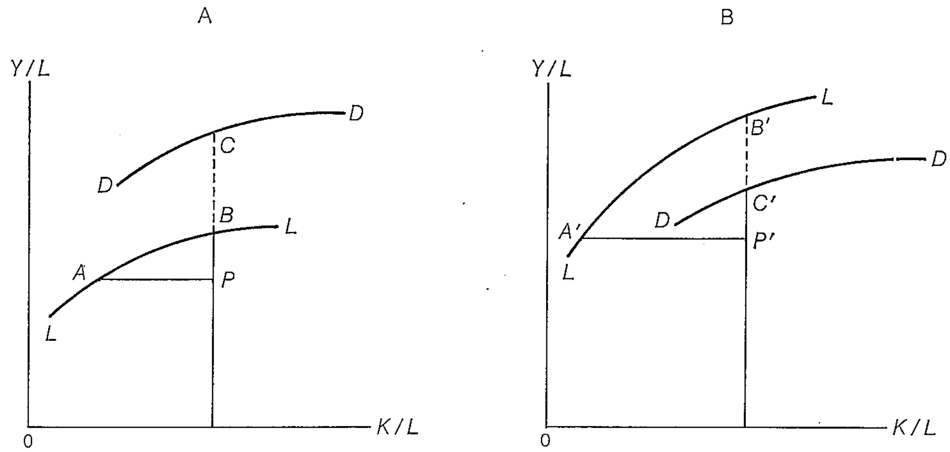
Although methodological differences persist, there is broad agreement among the developments in the field of frontier production function and efficiency over the last few decades. One of the pioneering works in this area is by M. J. Farrell [14] who constructs an envelope of isoquants for the industry where the industry production function is conceptually a frontier of potential attainment for given input combinations. In existing literature, there are two different but interrelated techniques of measuring firm as well as industry efficiency. One is to proceed by estimating the average production function of industry and the other by using the frontier production function (FPF), where the concept of "best practice" method is used to locate the maximum potential output of firms using different input combinations at the prevailing state of technological knowledge. The question of technical efficiency (TE) of firms has been a subject of considerable debate in economics. For example, Mueller points out that "Once all inputs are taken into account, measured productivity differences should disappear except for random disturbances. In this case the *frontier* and *average* functions are identical. They only diverge if significant inputs have been left out in the estimation" [32, p. 731]. Though there are some conceptual problems in defining the term "average" as used in deriving the average production function, the method of average industry production function is highly useful when there is a dearth of firm-level data covering a reasonably long time span [2]. Timmer [47] estimates the TEs of industry from the disturbance terms as defined in his model, and derives the correlation coefficients of the efficiency indices. Judging the values of the coefficients, he shows that if the frontier is almost a neutral transformation of the average function, the two indices (resulting from OLS residuals and *LP* techniques) can give rise to the same result.[11]

In the industrially advanced nations, technological change is the consequence of innovation or adoption of new technology developed by the "best practice" firms. Hence, the concept of efficiency is relative to those firms. But for an LDC, where most of the firms are structurally inefficient, the "best practice" method is neither prevalent nor useful. In the present context, where we are dealing with industry-level data, the concept of average production function is quite appropriate for measuring changes in efficiency between different time periods.

In this study, a technique is said to be efficient (inefficient) when there is an upward (downward) shift of the productivity locus due to the adoption of new technology. Figure 1 graphically represents the concept of efficiency and inefficiency respectively resulting from new technology adoption in a comparative static framework. In Figure 1A, the curve *LL* is the labor-productivity locus

[11] Among other recent contributions to efficiency measurement using stochastic and deterministic methods of estimating frontiers, [36] [23] [25] may be noted. For a literature survey, see [15].

Fig. 1. Model for Measuring Efficiency



prior to the adoption of new technology at time t_0. After adoption, the curve shifts to *DD* at time t_1 with corresponding higher values of *Y*/*L*. Let *A* be the observed position of an industry on the old curve *LL* which shifts to *C* on *DD* after adoption. This movement from *A* to *C* can be divided into two parts. The first is from *A* to *B* which means that capital deepening process leads productivity to increase to *B*. But after adoption, productivity rises to *C*. Naturally the segment *CB* represent the gain in productivity due to efficient use of inputs with the help of advanced technology.

On the other hand, any downward shift of the locus is the consequence of inefficient use of inputs. The movement from *A*′ to *C*′ in Figure 1B is composed of two parts: *A*′ to *B*′ and *B*′ to *C*′. Here as a reverse case of Figure 1A, the drop in productivity from *B*′ to *C*′ is due to inefficient use of inputs even when productivity rises by *P*′*C*′. Thus, a rise in productivity does not necessarily mean efficient use of inputs when technology adoption augments the capital/labor ratio.

C. *The Model*

This phenomenon of efficiency can be shown empirically from the relationship between observed *LP*s and *K*/*L* ratios across industries for different points in time. The analysis is basically a macro relationship between *LP* and *K*/*L*. In this context, it may be mentioned that the linear homogeneous production function exhibiting constant returns to scale is equivalent to a function of one variable in per capita terms, i.e., $LP = Y/L = f(K/L)$ where *LP* is output per labor.[12] In our case, due to the presence of heteroscedasticity at higher values of *K*/*L*, we have opted for the following functional specifications involving logarithms of the variables. And to capture the intertemporal shift, we have used temporal dummy

[12] This phenomenon is tested in Section III for twenty-nine industries.

variables. The empirical test employs multiple regressions of two nonlinear equations of the forms.

$$\log(LP) = \alpha + \beta_1 \log(K/L) + \beta_2 [\log(K/L)]^2 + \beta_3 D, \qquad (1)$$

$$\log(LP) = \alpha + \beta_1 \log(K/L) + \beta_2 [\log(K/L)]^2 + \beta_3 D + \beta_4 [\log(K/L)] D, \qquad (2)$$

where D represents the temporal dummy with $D = 1$ for later years and $D = 0$ for other.

The standard form of the production function dictates that the value of β_1 should be greater than zero while the value of β_2 should be negative. If the function shifts upward (a special case where it moves in a northeasterly direction), the value of β_3 will be positive. But if $\beta_3 < 0$, this implies a downward shift of the productivity locus. Whether it shifts in a southeasterly or southerly direction, the production process becomes inefficient in both the cases. Finally, β_4 represents the slope dummy of the curve. If $\beta_4 < 0$, it implies that for large values of K/L the process becomes more inefficient. Positive values of β_3 and β_4 imply opposite results.

II. MANIFESTATIONS OF EFFECT OF NEW TECHNOLOGY

A. *Relative Rates of Growth of Output and Input Coefficients*

The annual growth rates of output, K/L and LP are presented in Table I. As evident from this table, the annual average growth rate of output in real terms between 1974–75 and 1986–87 ranges from 0.28 per cent in the case of manufacture and repair of drills, coal-cutting, earth-moving machineries, cranes, conveyors, and other heavy machinery and equipments to 59.68 per cent in manufacture of electronic computers, control equipments and parts. Although it is quite natural for the latter industry to have achieved the maximum growth rate in a phase of very rapid computerization throughout the economy, almost all the industries have grown at rates far higher than the historical Hindu growth rate of 5 per cent per annum [40].

For reviewing the question of the pace of output growth as one proceeds to the eighties, we have divided the period into two parts: 1974–75 to 1979–80 and 1979–80 and 1986–87. The strikingly common feature of periodic output growth across industries is that growth rates have fallen in the latter period in as many as nineteen industries out of twenty-nine. Only in three industries have growth rates strictly risen in the latter period and in all the rest the second-period growth rates have either remained constant or increased very marginally.

One of the interesting features of these industries over the period is that average annual growth rates of K/L [both $(K/L)_1$ and $(K/L)_2$] have significantly exceeded those of real output in as many as twenty-six industries. Moreover, in most of the industries the growth rate of the K/L ratio itself has risen in the latter period [seventeen industries for $(K/L)_1$ and twenty-one industries for $(K/L)_2$].

The question of efficiency as used in this study can be primarily understood from the extent of productivity gain over the period relative to rising machineries

TABLE I

AVERAGE ANNUAL GROWTH RATES

Serial No.	Period	Output	$(K/L)_1$	$(K/L)_2$	$(LP)_1$	$(LP)_2$
1	1	10.5863	14.8814	12.6861	3.8509	2.4232
	2	16.0428	20.6535	21.6208	4.8999	5.4310
	3	19.0114	27.9193	26.3585	5.0254	4.4680
2	1	14.1908	17.8526	14.7660	0.9252	−0.6478
	2	9.2785	9.8363	11.5142	5.7470	7.1404
	3	15.7996	19.2095	18.5079	3.6934	3.3964
3	1	9.9374	12.7742	12.2105	5.0610	4.6449
	2	1.1755	17.2355	15.3656	0.6609	−0.2257
	3	5.5968	22.2896	19.9711	2.7998	1.9884
4	1	9.6624	13.4090	9.8762	7.2137	4.4086
	2	8.9951	12.9617	13.0584	1.6104	1.6667
	3	12.1111	18.7834	15.7564	4.5718	3.1696
5	1	7.9036	7.0861	8.1358	−4.1084	−3.5534
	2	5.5344	10.7045	9.8802	−1.0647	−1.5008
	3	8.0411	11.4851	11.6721	−2.3282	−2.2759
6	1	13.4108	20.2978	15.7823	6.0652	3.2880
	2	11.5045	19.8273	24.0934	−2.6503	−1.1952
	3	17.3689	33.0468	32.5425	0.8529	0.7470
7	1	11.5634	5.6811	6.3686	−0.5254	−0.0289
	2	4.5535	18.9342	17.6305	−0.0178	−0.5777
	3	9.4899	16.2927	16.0603	−0.2518	−0.3239
8	1	5.9168	10.5699	10.7291	−6.0541	−5.9916
	2	−1.5577	8.8814	9.1601	−4.1645	−4.0431
	3	1.5943	12.6936	13.0594	−4.2221	−4.1598
9	1	63.0803	40.8139	38.3682	31.0284	28.9985
	2	2.8780	5.5694	6.8669	−4.0434	−3.3742
	3	36.5290	29.1799	29.9181	8.0902	8.4059
10	1	8.2883	−3.3664	−4.5430	−2.6086	−3.8522
	2	3.7699	14.6657	14.4651	0.3500	0.2486
	3	6.8648	4.7482	3.5690	−1.0450	−1.6750
11	1	13.6434	5.2623	5.4118	4.7275	4.8734
	2	0.8584	15.6575	14.6161	6.0287	5.3222
	3	7.1375	13.5217	12.9235	6.3489	5.9530
12	1	−5.1374	7.0560	6.5516	0.4992	0.1344
	2	7.1046	16.5777	13.3320	5.6998	3.5979
	3	0.2752	15.9622	13.0245	3.3915	2.0150
13	1	7.6441	25.3926	21.1443	7.8616	5.3842
	2	5.6713	13.3039	14.7813	1.9972	2.8693
	3	7.9825	29.7976	27.8156	5.2111	4.5291
14	1	5.4214	17.1486	15.8209	7.6904	6.7339
	2	0.2549	38.5582	37.8300	1.5765	1.3580
	3	2.6841	50.0392	47.0083	4.7900	4.1347
15	1	9.8770	11.2793	9.4697	4.6990	3.3156
	2	4.5916	10.3254	10.7392	5.4457	5.7774
	3	8.4962	14.5283	13.4389	5.9278	5.2601

TALE I (Continued)

Serial No.	Period	Output	$(K/L)_1$	$(K/L)_2$	$(LP)_1$	$(LP)_2$
16	1	5.2559	22.4712	20.5609	3.4005	2.4211
	2	5.2529	14.2526	12.0992	4.9179	3.4690
	3	6.1462	28.3930	24.0418	4.7578	3.2567
17	1	8.5994	0.4361	−0.5098	4.4291	3.2625
	2	9.5326	40.7587	39.9461	5.2021	4.9145
	3	11.7503	22.7225	20.6163	5.5898	4.6700
18	1	8.4897	10.3036	9.5865	6.6004	5.9820
	2	6.8049	9.9743	9.3661	3.4361	2.9918
	3	9.4490	13.4466	12.3687	5.6293	4.9501
19	1	2.0699	14.7714	11.2674	5.0696	2.6469
	2	3.9686	17.8249	14.5700	3.6830	1.8616
	3	3.3577	24.9221	18.3495	4.9262	2.3832
20	1	6.0435	15.8776	8.6349	2.6210	−1.6717
	2	12.7760	16.5903	24.4999	4.8746	9.7828
	3	12.1632	24.7717	24.0124	4.2473	3.9677
21	1	7.8911	7.7924	7.2596	3.8614	3.4142
	2	4.7639	11.9485	11.1217	3.0416	2.4955
	3	7.4218	13.0383	11.9477	3.7994	3.1948
22	1	16.1686	8.4913	8.1133	5.4779	5.1452
	2	2.9906	22.1309	23.1161	1.6599	2.0913
	3	10.6350	21.9070	22.2509	3.7158	3.8484
23	1	9.8151	13.0745	12.7521	11.6181	11.3116
	2	6.2718	10.5844	10.4741	−2.7644	−2.8156
	3	9.8960	16.2046	15.8407	2.8360	2.6757
24	1	6.6777	8.5391	8.4559	10.8465	10.7563
	2	7.8791	15.2189	16.3295	2.5491	3.1826
	3	9.0245	16.3345	17.1566	7.2719	7.7842
25	1	9.5680	17.2842	15.2397	3.0543	1.8669
	2	22.7742	17.8490	16.1083	6.6353	5.5018
	3	23.7189	27.5555	23.6385	5.6373	4.1560
26	1	367.8603	28.5777	31.9355	38.3301	42.4114
	2	−12.6725	53.8636	32.3123	−9.2021	−10.8098
	3	12.3490	91.9242	65.4770	1.3403	−1.0579
27	1	30.0140	0.1678	−0.7089	2.1275	1.1485
	2	30.3847	12.8217	9.2199	9.9172	6.7015
	3	59.6771	7.0510	4.4262	7.0036	4.3872
28	1	23.7475	22.0087	19.5908	0.8809	−0.2161
	2	24.1836	21.6547	19.9277	5.9983	5.0236
	3	42.5366	37.2157	32.3851	3.8072	2.5702
29	1	23.4857	16.6944	13.8683	4.3081	2.5313
	2	9.2050	14.0943	12.6820	6.9864	5.9281
	3	22.7806	22.8962	18.9117	6.7226	4.8451

Notes: 1. Periods 1, 2, and 3 refer to 1974–75 to 1979–80, 1979–80 to 1986–87, and 1974–75 to 1986–87 respectively.
2. Serial numbers of industries correspond to ISIC as given in the Appendix Table I.

TABLE II
PAIRWISE CORRELATION COEFFICIENTS

	Output	$(K/L)_1$	$(K/L)_2$	$(LP)_1$	$(LP)_2$	*Emp*
Period 1:						
Output	1.00					
$(K/L)_1$	0.40**	1.00				
$(K/L)_2$	0.51*	0.98*	1.00			
$(LP)_1$	0.77*	0.65*	0.72*	1.00		
$(LP)_2$	0.82*	0.59*	0.70*	0.99*	1.00	
Emp	0.96*	0.32	0.41**	0.64*	0.69*	1.00
Period 2:						
Output	1.00					
$(K/L)_1$	−0.28	1.00				
$(K/L)_2$	−0.14	0.90*	1.00			
$(LP)_1$	0.69*	−0.25	−0.12	1.00		
$(LP)_2$	0.66*	−0.30	−0.06	0.94*	1.00	
Emp	0.77*	−0.51*	−0.37**	0.41**	0.37**	1.00

Note: The coefficients between $(LP)_1$ & $(LP)_2$ and $(K/L)_1$ & $(K/L)_2$ are automatically high according to definition.
* Represents significance at 1 per cent level.
** Represents significance at 5 per cent level.

and tools per unit of laborer which is reflected in an increasing K/L ratio. Some of the important features of productivity changes are noted here. First, there has been an absolute fall in *LP* in four industries from 1974–75 to 1986–87. Second, the growth rates of *LP*s in the remaining industries can be said to be very marginal compared to those of K/L (and also of output). Another feature is that productivity growth has fallen in the latter period in thirteen industries out of twenty-five (and, in four cases, an absolute decline is noted). Although very little improvement was achieved in the remaining twelve industries, this gain is very insignificant compared to the huge rise in capital cost incurred between the periods.

B. *Correlation Test*

Pairwise correlations of growth rates of all the variables, namely, output, K/L, *LP*, and employment (*Emp*) are calculated independently for both periods and presented in Table II. Some of the findings appear to be very interesting for our purpose. The coefficients between output and *LP* [both $(LP)_1$ and $(LP)_2$], output and employment, and finally between employment and *LP* (both measures) show a quite significant positive association in both the periods. But each of the coefficients has drastically fallen in the latter sub-period. The most remarkable decline in terms of magnitude is found between employment and productivity. In the first period, the association of K/L with *LP* is quite high and statistically significant, while that of K/L with output is not so high but statistically significant. The associations of K/L with output and *LP* in the latter period become negative but not significant. All these findings together may be taken to be an indication toward a growing mismatch between input and output growth in the industries reviewed here, a subject which is dealt with in greater detail in the next section.

III. THE EMPIRICAL TEST OF EFFICIENCY

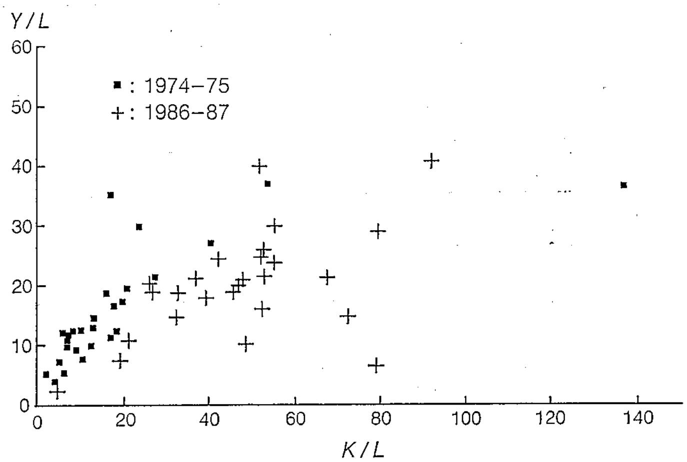
Economists' concept of technology is essentially an ex post economic characterization where technological possibilities depend on various economic and institutional factors. An appropriate technology in one country may not be suitable for some other country where the economic and institutional settings differ. Since the development of a scenario of possible technologies with various combinations of economic characteristics is practically impossible, an appropriate technology developed with a view to using the factors efficiently may not produce the same result when applied to some other country [24]. In the LDCs, the usual practice is to import advanced technology from the developed nations but adaptation of this technology to local conditions requires continuous research involving huge time and other expenditures.

We are now in a position to consolidate our findings in terms of the relationship between *LP*s and *K/L* ratios in Indian industries. Two scatter diagrams of the cross-section data on *LP* against *K/L* (one for production workers and the other for all employees) for two different years, 1974–75 and 1986–87, have been presented in Figure 2. As evident from these diagram, there seems to exist some homogeneity among *LP*s for the lower values of *K/L*, while the larger values a wide variation is observed. Another observation is that the points in both the scatter diagrams have shifted in a southeasterly direction over time. This shift indicates that (i) the industries have become more capital-using than before, and (ii) the productivities in general have fallen in the latter year relative to the *K/L* ratios. The immediate conclusion is that Indian industries are fast becoming more and more capital-intensive without any significant positive impact on productivities. Hence, the hypothesis of inefficiency as raised earlier is supported by these scatter diagrams.

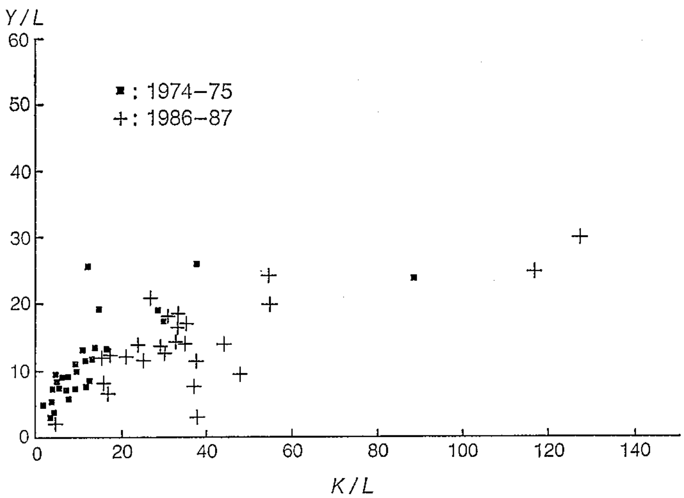
As defined in Section I, we have tried to unearth this phenomenon of inefficiency in terms of shifts of the fitted curves (for equations 1 and 2) showing the relation between *LP* and *K/L* for 1974–75 and 1986–87. As stated earlier, a functional relationship between *Y/L* and *K/L* is appropriate only when the production function is linear homogeneous. We have estimated the Cobb-Douglas production function for each of the three years twice, once imposing the homogeneity restriction, $\alpha + \beta = 1$, and once without this restriction. We have statistically tested the linear homogeneity property of the production function in our case using the data on all the twenty-nine industries. Appropriate *F*-tests based on the restricted and unrestricted error sum of squares have been performed separately for three different years, and for two types of employment figures. In all the cases, except for the final year, the null hypothesis, $\alpha + \beta = 1$, has not been rejected, as the *F*-ratios were found to be smaller than the corresponding tabulated values at the 5 per cent level of significance. However, when we drop only one observation, namely that for the twenty-sixth industry, from the final

Fig. 2. Scatter Diagrams of Cross-Section Data on *LP* against *K/L*

A. Production workers



B. All employees



Notes: 1. Each point represents an industry.
2. The units in each of the axes of both the figures are in Rs. thousand.
3. Three points from Figure 2A and one point from Figure 2B are omitted as outliers for the year 1986–87.

TABLE III

LOGARITHMIC RELATION BETWEEN *LP* AND *K/L* WITH A TEMPORAL DUMMY, 1974–75 AND 1986–87

Equations	Constant	Coefficients of Independent Variables				$\bar{R}^2$
		log (K/L)	$[\log (K/L)]^2$	D_1	log $(K/L)D_1$	
Production workers:						
(1)	−0.36	1.52	−0.11	−0.19	—	0.67
		(2.50)	(−1.53)	(−3.55)		
(2)	−1.38	2.07	−0.18	−1.09	0.20	0.68
		(2.87)	(−2.07)	(−1.67)	(1.39)	
All employees:						
(1)	0.11	1.33	−0.09	−0.11	—	0.61
		(1.99)	(−1.15)	(−3.47)		
(2)	−0.87	1.86	−0.16	−0.94	0.18	0.61
		(2.23)	(−1.57)	(−1.32)	(1.06)	

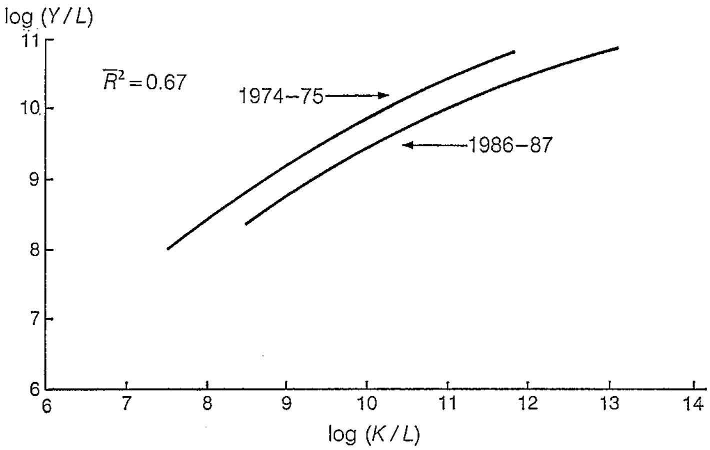
Notes: 1. Dependent variable=log(*LP*).
2. $D_1=0$ for 1974–75 and $D_1=1$ for 1986–87.
3. Figures in parentheses represent *t*-values.

year data set (reducing degrees of freedom by one), the *F*-ratio becomes very small so that there does not arise any doubt in accepting the null hypothesis in the final year. Table III presents the values of the coefficients for the equations with corresponding *t*-statistics and $\bar{R}^2$. For both types of workers we have found almost similar results in terms of the level of significance of the coefficients. The overall percentage explained by the independent variables is higher for production workers in both the equations relative to those of all employees ($\bar{R}^2$ being 0.67 and 0.68 for production workers as against 0.61 in both equations for all employees). The coefficients of the intercept dummy in equation (1) for both types of workers are negative and statistically significant. Moreover, the inclusion of the slope dummy gives a negative coefficient to the intercept dummy but the coefficients are not statistically significant. For the slope dummy they are positive, although not significant. Thus, there is no ambiguity in the downward shift of the productivity locus irrespective of the inclusion of skilled personnel in the definition of labor (as shown in Figures 3 and 4).

The foregoing analysis suggests that the "sunrise" industries in India witnessed a significant technological metamorphosis in terms of capital use. But ironically, the high input coefficients in favor of capital did not produce any significant improvement in productivities. We can, therefore, conclude that these manufacturing industries are crippled by growing inefficiency despite a marginal improvement in labor productivities in a few industries. In a recent paper Coondoo, Neogi, and Ghosh [9] using the same technique have shown that Indian manufacturing industries as a whole have been suffering from growing inefficiency of resource use since the mid-seventies.

Fig. 3. Fitted Relationship between log(LP) and log(K/L) with Temporal Dummy: Production Workers

A. Equation (1)



B. Equation (2)

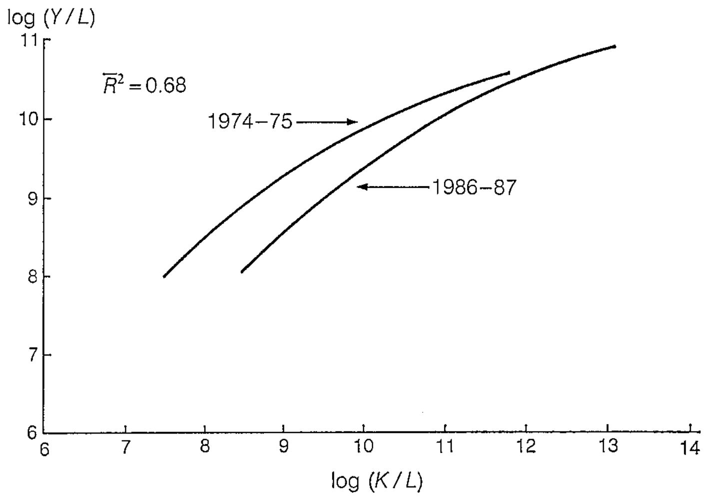
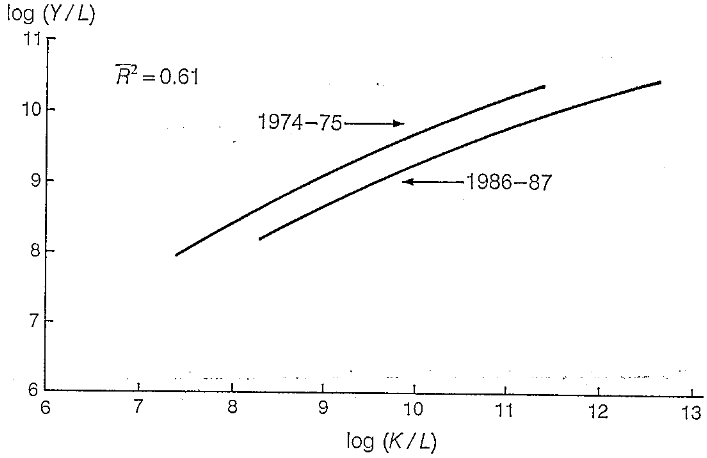
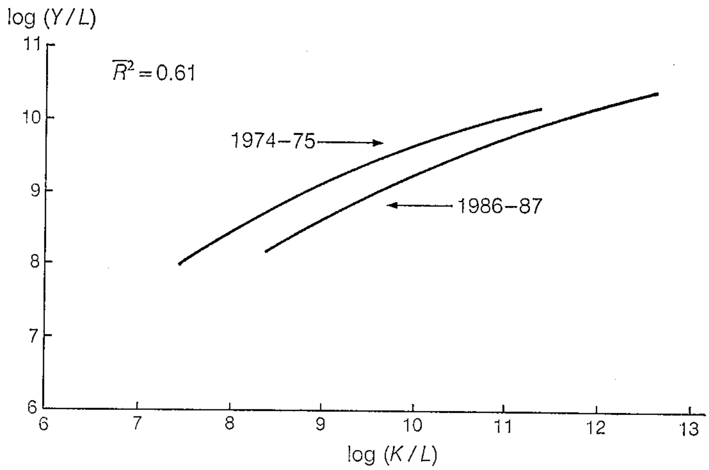


Fig. 4. Fitted Relationship between log(LP) and log(K/L) with Temporal Dummy: All Employees

A. Equation (1)



B. Equation (2)



IV. FACTORS INFLUENCING *LP*

The low efficiency in the manufacturing sector of the LDCs as pointed out by eminent scholars may be due to a number of factors. According to Clague [8], some important factors are (i) management quality, (ii) skill, (iii) external factors like reliability and quality of input supply, (iv) transportation and communication facilities, (v) rate of tariff protection, and (vi) degree of internal competition. Others have tried to trace a different set of causes as being responsible for the inappropriate factor proportions in the manufacturing of the LDCs [49]. But in view of the fact that efficiency here is defined in terms of intertemporal productivity changes, we have chosen a set of supply-side factors which can be proved to influence the level of and changes in productivity.

Labor productivity plays a vital role in the growth of output as we have already noted the high correlation between *LP* and output growth. According to this study, inefficiency may be the result of low labor productivities throughout the period. We have tried two types of regressions (linear and log-linear) with various combinations of the explanatory variables in order to identify the factors which determine *LP* in the aggregate. The dependent variable is *LP*—real value added per employee. The independent variables are (i) *K/L*, (ii) *SKILL*—measured by the ratio of skilled personnel (all employees minus production workers) to all employees, (iii) *PELEC*—electricity in physical units (KWH) per employees, and (iv) *SIZE*—average size of industries defined as total employees divided by number of factories. We performed these regressions only for the final year of our analysis and came up with some interesting findings. The results of all the regressions are presented in Table IV.

For the first set of equations, the most important variable (judged by the level of significance) in the determination of *LP* is *SKILL*. The next most important variable which appears to be statistically significant is either *PELEC* or *K/L*. Since *PELEC* and *K/L* are highly correlated, the presence of multicolinearity impelled us to test the regression either with *PELEC* or with *K/L*. However, the values of $\bar{R}^2$ remain unchanged in both cases. Interestingly, contrary to general belief, *SIZE* does not significantly influence *LP* in this analysis. The values of $\bar{R}^2$ indicate that this set of variables explains around 60 per cent of the variation in *LP* across industries.

An almost similar set of results is obtained when the equations are taken in log-linear forms. The values of $\bar{R}^2$ have been improved in all the equations compared to their linear counterparts. However, combining both the results it is evident that *SKILL* has played the most vital role in determining *LP*. Since Indian industries have become modernized with the advent of capital-intensive technology, the role of skilled personnel has become indispensable to cope with these sophisticated tools and machineries. Besides skill, electricity as a component of infrastructural facility—a prerequisite for industrial growth—has also played an important role in determining *LP*. Though there is high correlation between *PELEC* and *K/L*, there is no justification for treating electricity as a substitute

TABLE IV

ESTIMATED COEFFICIENTS OF REGRESSIONS ON *LP*

Type	Intercept	Independent Variables				$\bar{R}^2$
		K/L	*SKILL*	*PELEC*	*SIZE*	
Equation form: Linear Dependent variable=*LP*						
(1)	−1.27	−0.08 (−0.78)	62.21 (3.12)	0.42 (1.57)	0.05 (1.14)	0.59
(2)	−0.78	—	52.26 (3.42)	0.21 (4.68)	0.04 (1.10)	0.60
(3)	2.74	−0.07 (−0.70)	59.41 (2.98)	0.42 (1.55)	—	0.59
(4)	3.01	—	50.58 (3.31)	0.23 (5.56)	—	0.61
(5)	3.35	0.09 (5.18)	40.43 (2.50)	—	—	0.58
Equation form: Log-linear Dependent variable=log(*LP*)						
(1)	4.32	−0.44 (−2.00)	1.23 (5.12)	0.49 (4.12)	0.24 (1.81)	0.76
(2)	2.72	—	0.87 (5.15)	0.27 (5.03)	0.19 (1.38)	0.74
(3)	4.96	−0.37 (−1.62)	1.13 (4.63)	0.47 (3.86)	—	0.74
(4)	3.47	—	0.84 (4.91)	0.29 (5.48)	—	0.74
(5)	1.99	0.43 (3.57)	0.59 (2.39)	—	—	0.62

Note: Figures in parentheses represent *t*-values.

for *K/L*. They are rather highly complementary in fostering industrial growth. Hence, electricity independently explains a significant proportion of *LP*. Another finding appears to be that the coefficient of *K/L* in the first log-linear equation is negative and significant. A similar finding for Indian industries has been earlier reported in [12]. The negative coefficients of *K/L* may be due to the following factors. (i) As defined by ASI, fixed capital includes not only investment in plant and machinery with which the laborer works but also a part of unproductive investment in land, building, and other assets of the companies. Hence, rising *K/L* does not always help increase productivity and efficiency. (ii) A mere rise in fixed capital without any concomitant rise in working capital may not lead to higher capital utilization and efficiency. (iii) Moreover, capital coefficients (both *K/Y* and *K/L*) have been rising at very high rates in all Indian industries irrespective of their technological status. In other words, this may be due to an inappropriate mix of capital and labor in the industries considered here.

V. SUMMARY AND IMPLICATIONS

This study examined (i) the impact of advanced technology which is proxied by rising K/L ratios in Indian industries on the efficiency of factor use, and (ii) the factors influencing labor productivities across industries. First, increasing use of overhead capital has not produced any significant improvement in productivities. Second, whether one considers skilled personnel or just production workers in the definition of labor, in both cases the downward shift of the productivity locus suggests that inefficient use of resources has become the order in Indian "sunrise" industries in recent years. Third, the most important factors that influence labor productivities in an aggregative sense are skill, the capital/labor ratio, and/or electricity; interestingly, firm size does not play any significant role in determining productivity.

These findings have important implications for technology policy in developing countries. The adoption of new technology which is essentially capital-intensive might result in efficient use of resources if the appropriate technology could be found out through R&D. Most of the industries considered here produce goods which are relatively new in Indian markets. While it is true that such goods could be introduced mainly with the help of foreign technology, the government must reorient licensing procedures (as prescribed in the recent IMF package in connection with the New Industrial Policy of 1991 and related liberalization policies intended to solve India's current balance-of-payments disequilibrium) in such a way as not to waste the scarce factors just in the name of new technology or new commodities. In fact, the question of adaptability to the domestic factor endowment must be made an inseparable part of the new industrial policy. But the present day LDCs are not wholly free to choose their production strategies. It is sometimes argued that structural transformation through the advent of new technology-intensive industries is due mainly to an extraneous policy intervention rather than a policy of internal dynamism [35]. And naturally, the role of R&D is undermined in Indian industries.

To sum up, this study suggests that, unless a well-defined industrial policy in consonance with indigenous factor endowment and technological potential is launched, overall industrial development including efficient utilization of resources cannot be achieved even with moderate growth of output.

REFERENCES

1. AHLUWALIA, I. J. *Industrial Growth in India: Stagnation since the Mid-Sixties* (Delhi: Oxford University Press, 1987).
2. AIGNER, D. J., and CHU, S. F. "On Estimating the Industry Production Function," *American Economic Review*, Vol. 58, No. 4 (September 1968).
3. ALAM, G. "India's Technology Policy and Its Influence on Technology Imports and Technology Development," *Economic and Political Weekly*, Vol. 20, Nos. 45–47, Special Number, 1985.
4. ARROW, K. J. "The Economic Implications of Learning by Doing," *Review of Economic Studies*, Vol. 29 (3), No. 80 (June 1962).

5. BAGCHI, A. K. "Export-led Growth and Import-Substituting Industrialisation," *Economic and Political Weekly*, Vol. 12, Nos. 6–8, Special Number, 1977.
6. BHAGWATI, J. N., and DESAI, P. *India, Planning for Industrialization: Industrialization and Trade Policy since 1951* (London: Oxford University Press, 1970).
7. BHAGWATI, J. N., and SRINIVASAN, T. N. *Foreign Trade Regimes and Economic Development: India* (New Delhi: Oxford and IBH Publishing Co., 1975).
8. CLAGUE, C. "The Determinants of Efficiency in Manufacturing Industries in an Underdeveloped Country," *Economic Development and Cultural Change*, Vol. 18, No. 2 (January 1970).
9. COONDOO, D.; NEOGI, C.; and GHOSH, B. "Technology-Intensive Industrialisation in LDCs: Experience of Indian Industries," *Economic and Political Weekly*, Vol. 28, Nos. 8–9, February 20–27, 1993.
10. DESAI, A. V. "The Origin and Direction of Industrial R & D in India," *Research Policy*, Vol. 9, No. 1 (September 1980).
11. ————. "Indigenous and Foreign Determinants of Technological Change in Indian Industry," *Economic and Political Weekly*, Vol. 20, Nos. 45–47, Special Number, 1985.
12. DHOLAKIA, B. H. "Measurement of Capital Input and Estimation of Time Series Production Functions in Indian Manufacturing Industries," *Indian Economic Journal*, Vol. 24, No. 3 (January–March 1977).
13. ECKAUS, R. S. "The Factor Proportion Problem in Underdeveloped Areas," *American Economic Review*, Vol. 45, No. 4 (September 1955).
14. FARRELL, M. J. *"The Measurement of Productive Efficiency," Journal of the Royal Statistical Society*, A, No. 120, Part 3 (1957).
15. FORSAND, F. R.; LOVELL, C. A. K.; and SCHMIDT, P. "A Survey of Frontier Production Functions and of Their Relationship to Efficiency Measurement," *Journal of Econometrics*, Vol. 13, No. 1 (May 1980).
16. GRILICHES, Z. "R & D and Productivity Slowdown," *American Economic Review*, Vol. 70, No. 2 (May 1980).
17. GOLDSMITH, R. "A Perpetual Inventory of National Wealth," *Studies in Income and Wealth*, Vol. 14 (1951).
18. Government of India, Ministry of Planning, Department of Statistics, Central Statistical Organisation. *Annual Survey of Industries (Factory Sector)* (Calcutta).
19. Government of India, Ministry of Science and Technology. *R & D Statistics, 1980–81* (New Delhi, 1981).
20. ————. *R. & D in Industry, 1984–85* (New Delhi, 1985).
21. Government of India, Planning Commission. *The Seventh Five Year Plan, 1985–90*, 2 vols. (New Delhi, 1985).
22. HASHIM, B. R., and DADI, M. M. *Capital Output Relations in Indian Manufacturing: 1946–64* (Baroda: Maharaja Sayajirao University of Baroda, 1973).
23. HULTEN, C. R. "Productivity Change, Capacity Utilisation and the Sources of Efficiency Growth," *Journal of Econometrics*, Vol. 33, Nos. 1–2 (October–November 1986).
24. ISHIKAWA, S. *Essays on Technology, Employment and Institutions in Economic Development* (Tokyo: Kinokuniya Co., 1981).
25. JEFFERSON, G. H. "China's Iron and Steel Industry: Sources of Enterprise Efficiency and the Impact of Reform," *Journal of Development Economics*, Vol. 33, No. 2 (October 1990).
26. KALDOR, N. "A Model of Economic Growth," *Economic Journal*, Vol. 67, No. 268 (December 1957).
27. KATHURIA, S. "Market and Innovation: A Survey of Empirical Studies of Schumpeterian Hypothesis for Developed Countries and India," *Economic and Political Weekly*, Vol. 24, No. 34, August 26, 1989.
28. KATRAK, H. "Imports of Technology and the Technological Effort of Indian Enterprises," *World Development*, Vol. 18, No. 3 (March 1990).
29. KATZ, J. M. "Industrial Growth, Royalty Payments and Local Expenditure on Research

and Development," in *Latin America in the International Economy*, ed. V. L. Urquidi and R. Thorp (London: Macmillan, 1973).
30. KENNEDY, C., and THIRLWALL, A. P. "Surveys in Applied Economics: Technical Progress," *Economic Journal*, Vol. 82, No. 325 (March 1972).
31. KUMAR, N. "Technology Imports and Local Research and Development in Indian Manufacturing," *Developing Economies*, Vol. 25, No. 3 (September 1987).
32. MUELLER, J. "On Sources and Measured Technical Efficiency: The Impact of Information," *American Journal of Agricultural Economics*, Vol. 56, No. 4 (November 1974).
33. NADIRI, M. I. "Sectoral Productivity Slowdown," *American Economic Review*, Vol. 70, No. 2 (May 1980).
34. NELSON, R. R. "Research on Productivity Growth and Productivity Differences: Dead Ends and New Departures," *Journal of Economic Literature*, Vol. 19, No. 3 (September 1981).
35. NEOGI, C. "Forces behind Structural Changes: A Quantitative Analysis of Indian Corporate Sector," *Artha Vijñāna*, Vol. 33, No. 4 (December 1991).
36. NISHIMIZU, M., and PAGE, J. M. "Total Factor Productivity Growth, Technological Progress and Technical Efficiency Change: Dimensions of Productivity Change in Yugoslavia, 1965–78," *Economic Journal*, Vol. 92, No. 362 (December 1982).
37. PATEL, I. G. "New Economic Policies: A Historical Perspective," *Economic and Political Weekly*, Vol. 27, Nos. 1–2, January 2–9, 1992.
38. PENROSE, E. "International Patenting and the Less Developed Countries," *Economic Journal*, Vol. 83, No. 331 (September 1973).
39. PILLAI, P. M. "Technology Transfer, Adaptation and Assimilation," *Economic and Political Weekly*, Vol. 14, No. 47, November 24, 1979.
40. RAJ, K. N. "Some Observations on Economic Growth in India over the Period 1952–53 to 1982–83," *Economic and Political Weekly*, Vol. 19, No. 41, October 13, 1984.
41. Research Bank of India. *Bulletin*, June 1974.
42. ————. *Foreign Collaborations in Indian Industries: Fourth Survey Report* (Bombay, 1985).
43. ROSENBERG, N. *Perspective on Technology* (Cambridge, Mass.: Cambridge University Press, 1976).
44. ROYCHOUDHURY, U. D. "Industrial Breakdown of Capital Stock in India," *Journal of Income and Wealth*, Vol. 2, No. 2 (April 1977).
45. SEN, A. K. *Employment, Technology and Development* (Delhi: Oxford University Press, 1975).
46. STEWART, F. *Technology and Underdevelopment* (London: Macmillan, 1977).
47. TIMMER, C. P. "Using a Probabilistic Frontier Production Function to Measure Technical Efficiency," *Journal of Political Economy*, Vol. 74, No. 4 (July–August 1971).
48. United Nations, Economic and Social Commission for Asia and the Pacific. *Industry and Technology Development News: Asia and the Pacific*, No. 15 (N.p.: United Nations, 1984).
49. WHITE, L. J. "The Evidence of Appropriate Factor Proportions for Manufacturing in Less Developed Countries: A Survey," *Economic Development and Cultural Change*, Vol. 27, No. 1 (October 1978).

APPENDIX TABLE I

INDUSTRIAL CLASSIFICATION

Serial No.	ISIC	Name of Industry
1	310	Basic & industrial, organic & inorganic chemical.
2	311	Fertilizers & pesticides.
3	312	Paints, varnishes & lacquers.
4	313	Drugs & medicines.
5	314	Perfumes, cosmetics, lotions, toothpastes, etc.
6	315	Inedible oils.
7	316	Turpentine, resins & fibres, plastic goods, etc.
8	317	Matches.
9	318	Explosives, ammunition & fireworks.
10	319	Chemicals not elsewhere classified (including photo-chemicals, films, etc.).
11	350	Agricultural machinery, equipments & parts.
12	351	Drills, coal-cutting, earth-moving machineries, cranes, conveyors & other heavy machinery & equipments.
13	352	Primemovers, boilers, diesel engines, etc.
14	353	Machineries for food & textile industries.
15	354	Other industrial machineries.
16	355	Refrigerators, air conditioners, etc.
17	356	Nonelectrical machineries (general items).
18	357	Machine tools, parts & accessories.
19	358	Office computing & accounting machines.
20	359	Nonelectrical machineries (special items).
21	360	Electrical, industrial machineries & parts.
22	361	Insulated wires & cables.
23	362	Dry & wet batteries.
24	363	Electrical apparatus, appliances & parts.
25	364	Radio, TV & telecommunication systems as a whole.
26	365	X-ray apparatus, tubes & parts.
27	366	Electronic computers, control equipments & parts.
28	367	Other components & accessories.
29	369	Other electrical machineries & parts.