State of Technology and Productivity in Pakistan's Manufacturing Industries: Some Strategic Directions to Build Technological Competence

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Historically, Pakistan's economic growth record, especially of the manufacturing sector, has been quite satisfactory. However, since the late 1980s Pakistan has been facing a slow growth of manufacturing industries, particularly of the large-scale manufacturing units. This has led some economists to express the apprehension that perhaps de-industrialisation is taking place in the country. A careful analysis of the causes of this sluggish growth suggests that one of the main contributory factors is the slow growth in total factor productivity (TFP)—the best overall measure of competitiveness. What has caused this productivity slow-down? For Pakistan there is clear evidence of a relationship between the growth in total factor productivity and the ailing S & T apparatus. The results presented in the study also lend support to the hypothesis that knowledge capital, human capital, openness, and government policies are crucial determinants of total factor productivity growth. Given a liberal economic environment in the country, which is essential to improve efficiency and productivity, the paper offers four strategic directions in order to improve the status of the S & T system in Pakistan: (1) augment the public sector S & T apparatus with the private sector funding and oversight; (2) take measures to upgrade scientific research institutions to the international standard; (3) streamline the technology creation, absorption, and diffusion system; and (4) enhance the demand for S & T in industries. These strategic directions are designed in such a manner that they work together towards a series of phased reforms, which can create incentives and market-based mechanisms to enhance the technology system without relying on a radical shift in the governance element of the bureaucracy.

1. INTRODUCTION

Historically, Pakistan's economic growth record, especially of the manufacturing sector, has been quite satisfactory. However, since the late 1980s Pakistan has been facing the problem of slow growth of manufacturing industries, particularly of the large-scale manufacturing units.[1] This has led some economists to

[1]Large-scale manufacturing covers the registered manufacturing establishments employing 10 or more workers.

express the apprehension that perhaps de-industrialisation is taking place in the country. A careful analysis of the causes of this sluggish growth suggests that one of the main contributory factors is the slow growth in total factor productivity (TFP)—the best overall measure of competitiveness.[2] We can see from Table 1 that productivity growth slowed down significantly during 1990s. What has caused this productivity slow-down? The answer to this question may enable the policy-makers to control and reverse this declining trend.

Most theoretical and empirical studies claim that both technology demand and technology supply are important determinants of productivity growth. For example, while Solow (1956) shows that technological improvement is important, the endogenous growth models emphasise that human capital and knowledge capital leading to improvements in technology creation, adoption, and absorption are important determinants of productivity growth.[3] Furthermore, Lichtenberg (1994) argues that the return on investment in research and development, leading to technological development, is substantial. The results of other empirical studies also indicate that technological change leading to a rise in efficiency of resource use is an important determinant of productivity growth.

Now, as global economic change led by the IMF and the WTO is dismantling of the system of protection and regulation, Pakistani enterprises, both large and small, are scrambling for better access to appropriate technologies to boost their productivity and competitiveness. Furthermore, as the private sector sees the WTO deadline of year 2004 looming, it is clamouring for effective government strategies to cope with the situation.

The demand for technology is rising sharply but the existing science and technology apparatus (called S & T hereinafter) in the country is ill-equipped to assist Pakistani firms to tackle the economic challenges posed by the changing global economic environment. It faces the following major problems: (1) laboratories are underfunded; (2) scientists are underpaid; (3) market-oriented research is rarely conducted; (4) technicians are poorly trained; (5) the absorptive capacity of the innovation system is limited; and (6) S & T governance is ineffective.

Thus, on the one hand, due to lack of competition, most of the domestic industries have not been motivated to introduce appropriate modern technologies;

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[2]The approach to measure TFP depends critically on the assumption of cost minimisation, competitive factor markets, and constant returns to scale. Furthermore, it is also sensitive to the definition and measurement of input, level of disaggregation in input measurement, the factors netted out, and the assumptions regarding the shares of primary factors of production. In the empirical literature, alternative methods are used to estimate the TFP. However, these methods rest on the assumption that equilibrium conditions hold for every data point and ignore the dynamic issues, lagged adjustment process of inputs, and the role of price expectations. For a comparative analysis of the empirical methods, see Norsworthy (1984).

[3]See, for example, Arrau (1989); Bruton (1995); Dehlman Ross-Larsen and Westphal (1985); Denison (1967); Lichtenberg (1994); Romer (1986) and Solow (1956).

and, on the other hand, because of the weaknesses of the S & T system and a poor diffusion system, the private sector largely ignores the existing technology apparatus available in the country. The industrialists opt instead for the turn-key technologies readily available in the international market. As a result, whatever little technology is produced in the country hardly reaches industry.

Despite its weaknesses, however, the existing S & T apparatus in Pakistan represents a valuable capability and a starting-point to build an effective and efficient technology-based economy which can help Pakistan's manufacturing industries leap-frog into the global market. A large pool of relatively skilled workers available in the country and a larger pool of science and technology (S & T) personnel are ready to take part in a "reverse brain drain" once the economic fundamentals and governance in the country begin to improve.[4]

It must be recognised that, for Pakistan, the process of industrialisation and productivity growth depends critically on the process of acquiring technological competencies and on the quality and rate of innovation, which in turn depend on the ability to absorb and apply the technology available from internal and external sources.[5] If technology adoption and absorption capabilities are not developed in Pakistan, the country runs the risk of languishing in a permanent state of dependence without liberating the wealth-creating potential of its growing labour force and other productive resources.

The main objective of this paper is to review the productivity trends in the large-scale manufacturing industries and analyse the significance of the existing research and development (R & D) capability of Pakistan in explaining productivity growth. Given the importance of R & D activities to boost productivity and competitiveness, the recommendations in this paper are largely directed at meeting the demand for improved technology, and ensuring that more effective institutions are in place to manage this transition towards better and appropriate technology. Furthermore, while proposing strategic directions, special consideration is given to institutional inertia, bureaucratic hurdles, and lack of political commitment.

The schematic details of the paper are as follows: Section 2 briefly reviews the historical perspective of the productivity growth in the large-scale manufacturing sector of Pakistan. The section also explores the determinants of the TFP-growth in the large-scale manufacturing sector. State of technology and related issues are discussed in Section 3. The proposed strategic directions to enhance productivity through reforms in the S & T apparatus are outlined in Section 4. The conclusions are given in the final section.

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[4]The view was expressed by the majority of researchers during a survey of R & D institutes (RIs), conducted for DRI-McGraw Hill (1998).

[5]Dehlman, Ross-Larsen, and Westphal (1985) emphasise that for technological growth it is not necessary to innovate domestically. In fact, the time lags involved in the R & D efforts to innovate and the success of these innovations may slow down the growth process, initially.

2. HISTORICAL PERSPECTIVE ON PRODUCTIVITY GROWTH

The role of technological improvements in promoting economic growth is well-documented. The empirical studies divide growth of output into two components. One component is attributed to the growth of primary factor inputs like capital and labour. The other component (the residual) is attributed to technological change [see Solow (1956)].[6] In recent endogenous growth models, long-run economic growth is driven primarily by accumulation of human capital and knowledge capital, leading to improvements in technology. The accumulation of knowledge is treated as a prerequisite for economic growth and the level of innovation activity in a country [see Romer (1986); Dahlman, Ross-Larsen, and Westphal (1985) and Lichtenberg (1994)]. According to Lichtenberg (1994), there is substantial return on investment in R & D, contributing to "intellectual capital" formation. He argues that the rate of return to investment in R & D is higher than the corresponding return to tangible investment. The empirical studies, discussed by Lichtenberg, also show that return to knowledge capital, represented by the R & D activity, is higher at the macro level because it reflects the private rate of return to knowledge accumulation and the return to spillover effects of technological progress within country. Romer (1986) emphasises that stock of human capital leads to increasing returns to scale, and the investment in human capital has a social pay-off greater than private returns. Lucas (1988) suggests that, in addition to individuals' own capital, the average level of human capital in a country also affects workers' productivity, and it can change the comparative advantage of a nation.[7] Similarly, Chawdhry, Islam, and Kirkpatrick (1988) emphasise that human capital is expected to lead to the emergence of comparative advantage in high-tech and high value-added industries which contribute to economic growth significantly. They explain that human capital formation, in particular the rapid expansion of engineers and technicians, was a critical element in the goal of attaining productivity growth rate of about 8 percent per annum for the large-scale manufacturing sector of Malaysia and Singapore.[8]

Keeping in view this brief theoretical and empirical perspective, the relationship between productivity growth and technological improvements in the large-scale manufacturing sector is examined. For this purpose, the following issues are discussed in this section: (i) a growth-accounting framework to compute partial and total factor productivity; (ii) an outline of factors contributing to total factor productivity growth in the large-scale manufacturing sector of Pakistan; (iii) data-related issues; (iv) analysis of trends in partial and

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[6]Denison (1967) applied the accounting framework and used data for nine developing countries to decompose output growth into changes in approximately thirty different quantitative and qualitative factors.

[7]Learning-by-doing is also considered a part of the human capital accumulation.

[8]However, it is not clear whether he is referring to total factor productivity or labour productivity.

total factor productivity in the large-scale manufacturing sector of Pakistan during 1972–97; and (v) discussion of empirical estimates of the relationship analysing the impact of human and knowledge capital, openness, and import of technology on total factor productivity growth.

(i) Model

In order to compute partial and total factor productivity, we apply the growth accounting framework pioneered by Solow (1956). This framework is based on a production function of the following form:

$$Q = AF(K,L) \qquad \dots \qquad \dots \qquad \dots \qquad \dots \qquad \dots \qquad \dots \qquad (1)$$

$$P_l = Q/L \qquad \dots \qquad \dots \qquad \dots \qquad \dots \qquad \dots \qquad \dots \qquad (2a)$$

$$P_k = Q/K \qquad \dots \qquad \dots \qquad \dots \qquad \dots \qquad \dots \qquad \dots \qquad (2b)$$

Where: Q=Output (value-added in the large-scale manufacturing sector)

K = Capital stock
L = Labour force
P_l = Labour productivity
P_k = Capital productivity
A = Hicksian efficiency parameter.

Taking the log of both sides of Equation (1), and differentiating with respect to time, we get the following growth equation:

$$G_q = G_a + r\,G_k + w\,G_l \qquad \dots \qquad \dots \qquad \dots \qquad \dots \qquad \dots \qquad (3)$$

By rearranging Equation (3), we can write:

$$G_a = G_q - r\,G_k - w\,G_l \qquad \dots \qquad \dots \qquad \dots \qquad \dots \qquad \dots \qquad (4)$$

While G_q, G_k, and G_l are rates of growth of output, capital stock, and labour force, respectively, r and w represent the shares of capital and labour inputs in total output. G_a represents total factor productivity growth, i.e., the growth in the productivity of total factor input.

Since TFP-growth (G_a) is necessary for sustainable economic growth in a country, it is important to explore its determinants in Pakistan's large-scale manufacturing sector. The models developed by Lichtenberg (1994) and Bruton (1995) identify the following variables as major determinants of productivity growth: stock and growth in human and knowledge capital, spillover of national and foreign R & D activity, and openness. Following Bruton (1995), we write:

$$G_a = \alpha_0 + \alpha_1(G_1) + \alpha_2\,(G_2) + \alpha_3\,(G_3) + \alpha_4\,(O) + \alpha_5\,(P) + \varepsilon \quad \dots \qquad \dots \qquad (5)$$

where:

G_1 = growth in knowledge capital;
G_2 = growth in human capital;
G_3 = growth in technology imports;
O = openness;
P = changes in economic policies.

(ii) Determinants of TFP-Growth

The economic rationale behind the above-cited determinants of TFP-growth is as follows.

(a) Accumulation of Knowledge Capital (G_1): The rates of innovation and technology adoption and absorption are closely linked to the accumulation of knowledge capital. The growth rate of knowledge capital is expected to raise innovation activity and, consequently, productivity in an economy [see Romer (1986); Dahlman, Ross-Larsen, and Westphal (1985) and Lichtenberg (1994)]. Lichtenberg (1994) argues that investment in research and development (called R & D hereinafter) is important for the process of "intellectual capital" formation. He mentions that R & D investment has been increasing at a faster rate than investment in physical capital. The empirical results of these studies show that return to R & D investment is much larger than the corresponding return to tangible investment. Furthermore, Lichtenberg also argues that the "….positive partial correlation between a nation's productivity and its own privately-funded R & D indicates that a country benefits more from its own R & D than other nations do."

(b) Accumulation of Human Capital (G_2) is expected to raise the wealth-creating potential in an economy. This relationship between economic growth and human capital formation is well-established. For example, Schultz (1994) argues that "...human capital is an important determinant in modern economic growth and a central factor in explaining differences in per capita income across countries". He suggests that new growth theories should incorporate education, on-the-job training, and health as indicators of human capital formation. Similarly, Lucas (1988) argues that accumulation of human capital through formal schooling and learning-by-doing improves the productivity of factor inputs and comparative advantage for export expansion, which, in turn, lead to economic expansion. Arrau (1989); Edwards (1998) and Romer (1986), also emphasise the productivity-enhancing role of human capital formation.

(c) Transfer of Technology (G_3), often proxied by technology imports, is an important source of productivity growth in developing countries. It is often argued that the R & D expenditure in developed economies may have a spillover effect on the R & D of a developing country [See Dahlman, Ross-Larsen, and Westphal

(1985) and Lichtenberg (1994)]. According to Dahlman, Ross-Larsen and Westphal (1985), it is not necessary to innovate domestically to have rapid economic growth. The transfer of technology could be more effective provided that acquisition capabilities are developed in the country. They argue that "…inventing products and processes is not at the centre of the technological development needed for successful industrialisation. It is at the fringe. What is central is acquiring the capabilities needed for efficient production and investment".

(d) Openness (*O*) is expected to have a positive effect on productivity growth. A number of empirical studies support this assertion. For example, Pack (1988) emphasises that free trade removes inefficiencies and consequently raises productivity. Edwards (1998) uses nine different measures of openness to examine the impact of openness on the growth of TFP and concludes that there is a positive relationship between productivity growth and openness. He concludes that "…regressions reported here are robust to the use of openness indicator, estimation technique, time period, functional form, and suggest that more open countries have indeed experienced faster productivity growth".

(e) Changes in Economic Policies (*P*): Prolonged political unrest and frequent changes in policies are expected to lead to sluggish productivity growth. Political unrest discourages firms to take an interest in improving their capabilities and to use better and modern technologies. Furthermore, *ad hoc* and inconsistent economic policies often create the credibility problem. Consequently, long-term decisions about investment and acquisition of technology have a negative effect, restricting productivity growth. Thus, pursuing bad policies and/or frequent changes even in good policies are expected to have an adverse effect on productivity growth.

(iii) Data Issues

The main data sources for the estimation of the model are: *Pakistan Economic Survey* (various issues), unpublished data from the records of the Pakistan Council of Scientific and Industrial Research (PCSIR) and of the Patent Office, Irfan and Mahmood (2000), and Pakistan (1994). The study covers the 1972–1997 period.[9]

The data on initial stock of physical capital (for 1964) and labour (for 1970–91) are taken from Kemal and Ahmed (1992). For subsequent years the data series for capital stock is constructed by adjusting capital stock for depreciation and adding annual fixed capital formation. The data for constructing fixed capital series and for

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[9]The analysis of total factor productivity covers the period from 1972 to 1997. However, due to non-availability of data for foreign patents granted for the pre-1980 period, the sample period is restricted to 1980–1997 in some equations.

labour force are taken from various issues of *Pakistan Economic Survey*. Taking 1980-81 as the base year, the output index and labour and capital productivity indices are computed.[10]

Various estimates of knowledge capital (G_1), viz., growth rate of development expenditure on industrial R & D activity (G_{11}) and growth rate of R & D manpower (G_{12}) are used as a proxy for knowledge accumulation in this study.[11] Alternatively, the output of the technology infrastructure can be measured in terms of the processes developed. In this study, we ignore the processes developed for two reasons: (a) continuous time series data are not available; (b) a larger fraction of this scientific activity results in the publication of papers in the scientific journals only. Thus, we include G_{11} and G_{12} as indicators of knowledge capital. The Planning Commission and the PCSIR are the major data sources. For G_{11} we include only the development expenditure, and for G_{12} we include the work force with the Ph.D. and Master's degrees in science subjects and technical workers directly involved in R & D activity.[12]

The stock of human capital can be estimated in a number of ways. We can either use enrolment in higher educational institutions or accumulated expenditure on the development of human capital as indicators of accumulation of human capital. For simplicity, we use lagged enrolment in the professional colleges and in vocational and technical institutions as an indicator of the rate of accumulation of

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[10]In order to construct these indices we assume the Solow framework. The labour force data are taken from *Pakistan Economic Survey* (1998). Capital stock series is constructed under the assumption of a constant rate of depreciation equalling 7 percent. Alternatively, capital stock series can be constructed assuming non-linear depreciation. However, in this study we are ignoring this issue. The estimates for the shares of capital and labour in total output are taken from Irfan and Mahmood (1999). The study reports that the shares of labour varied between 19–22 percent during 1970–97. Correspondingly, the share of capital varied between 81–78 percent. This is not a surprising result given high capital intensity in the large-scale manufacturing sector of Pakistan.

[11]Non-development expenditure in R & D includes mainly the wages and salaries of manpower. Since we are including R & D manpower as an explanatory variable, we exclude non-development expenditure. In order to compute the growth rate of G_{11}, first we compute initial value of stock of knowledge capital by summing up the depreciation adjusted R & D expenditure for the period of 1955–64, as follows:

$$KK_{1964} = \sum\nolimits_{-1955}^{1963}[-_{1955}(1-\delta)^{10} + E_{1956}(1-\delta)^9 + \ldots + E_{1962}(1-\delta) + E_{1963}]$$
$$\text{and } KK_{1965} = KK_{1964}(1-\delta) + E_{1964}$$

where KK is knowledge capital, E is development expenditure on R & D, and δ is rate of depreciation (Equalling 7 percent per annum). Once we get the initial stock of knowledge capital, we adjust the stock for depreciation and add R & D expenditure for each subsequent year to construct a capital stock series and then compute growth rate of knowledge capital. The human capital series is constructed by applying the same method. The rate of depreciation of knowledge and human capital is assumed to be the same as the depreciation rate of physical capital, i.e, 7 percent per annum.

[12] The supporting staff and non-development R & D expenditure may increase the productivity of the R & D sector. But we are ignoring it assuming that this component does not affect productivity growth directly. Furthermore, the depreciation rate of human and knowledge capital is assumed to be 7 percent per annum.

human capital (G_2). Various issues of *Pakistan Economic Survey* provide data on enrolment and on expenditure on education. In order to construct the stock of human capital, we apply the same methodology as for G_{11} (See footnote 10).

The number of foreign patents registered last year by The Patent Office in Pakistan is used as a proxy for the transfer of technology (G_3).[13] Alternatively, growth in the import of capital goods is another indicator of technology transfer. This is also an indicator of the spillover effects of international R & D activity on domestic productivity growth. The data on import of capital goods are taken from the *Pakistan Economic Survey* (various issues) and the data on the registration of foreign patents are taken from the records of The Patent Office. In addition to the spillover effects of international R & D activity, the spillover effects of domestic R & D activity in other sectors of the economy are also likely to have positive and statistically significant impact on productivity growth in the large-scale manufacturing sector. Growth rate of national expenditure on R & D (G_{32}) is included to capture this effect.

To examine the effect of globalisation or openness (O), we include the following variables: (i) the trade-output ratio (O_1) and (ii) export growth rate (O_2).[14] These measures are expected to determine the impact of increasing integration with the global economy on the competitiveness of Pakistan's large-scale manufacturing sector. The first measure of openness is the trade-GDP ratio, O_1. A rise in this ratio is expected to have a direct positive impact on productivity growth. Similarly, the export growth rate (O_2) is also expected to have a positive impact on productivity growth. In order to compute these measures of openness, the data are taken from *Pakistan Economic Survey* (various issues).

A dummy variable (P=1 for the years of nationalisation, P=0 otherwise) is included to capture the effect of policy changes on productivity growth.

In order to adjust output and capital stock for price changes, the manufacturing price index and the investment price indices are used. The R & D expenditure is deflated by the implicit GDP-deflator.

(iv) Productivity Trends

The output indices, constructed on the basis of value-added data, and productivity indices, i.e., capital and labour productivity, in large-scale manufacturing sector are reported in Appendix Table A-1.[15] The indices of partial

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[13]Assuming one-year lag in import and effective utilisation of imported technology, we include lagged inflow of foreign patents (granted). We tried 2 and 3 years' lag structure but decided to choose 1 year lag only as (i) the results did not change significantly; and (ii) the limited number of observations on foreign patents registered did not allow us to use a longer lag structure. Furthermore, the growth rate of the import of capital goods may be used as an indicator of technology transfer. However, the estimated coefficient of this variable was not statistically significant.

[14] For a detailed analysis of trade policy effects on productivity growth, see Edwards (1998).

[15] All the productivity indices are computed by utilising the 5-years moving average method.

(for capital and labour productivity) and total factor productivity show that during the last twenty-five years growth in the large-scale manufacturing sector was mainly a result of the growth in factor inputs, i.e., capital and labour inputs. Labour productivity (P_l) generally exhibits positive annual growth rate of 5.06 percent per annum, as productivity index increased from 66.59 in 1971-72 to 228.48 in 1996-97. The capital productivity (P_k) shows a mixed trend as it increased during 1972-76, slowed down during 1976–79, and thereafter showed a moderate increasing trend. For the whole period it increased from 102.20 in 1971-72 to 147.38 in 1996-97. This suggests a slower growth rate of capital productivity relative to the growth rate of labour productivity (See Table 1 and Appendix Table-A1). We also note that before 1980, P_l was lower than P_k, while P_l after 1980, was higher then P_k. The high growth in P_k could be a result of utilisation of excess capacity in the economy, more efficient use of capital and/or use of better capital equipment.[16]

The TFP-growth rate was 2.37 percent per annum for the period 1972–97, showing an improvement in competitiveness of the large-scale manufacturing sector during 1972–97 (See Table 1). This shows that approximately 41 percent of economic growth, during 1972-97, was a result of improvements in its competitiveness due to improvements in technology and other factors outlined above.[17] This also indicates that, despite the weak state of the science and technology apparatus and the low quality of human resources available in the country, productivity growth, on average, was significant. While it remains unclear exactly how the S & T system was contributing to the TFP growth, it is possible that it did make a difference. If so, then the low priority given to science and technology

Table 1

Growth Rates of Output and Productivity—Large-scale Manufacturing

Period	G_q	G_l	G_k	G_a (=GTF)
1972–75	2.83	1.72	2.20	2.08
1975–80	6.43	5.27	–2.50	–0.75
1980–85	9.26	8.31	4.14	4.84
1985–90	6.69	5.90	4.79	4.92
1990–95	4.17	4.60	0.51	1.36
1995–97	1.31	0.73	–1.75	–1.25
1972–97	5.73	5.06	1.48	2.37

Notes: G_q = Growth rate of output; G_l = Growth rate of labour productivity; G_k = Growth rate of capital productivity; G_a = Growth rate of total factor productivity.

[16]However, due to non-availability of data it is difficult to adjust capital productivity estimates for changes in capacity utilisation.

[17]The TFP growth was modest as compared to the TFP growth in Korea (equalling 4 percent) during 1963–95 and the average TFP growth in industrialised countries (equalling 3.58 percent during 1950–73). [See Kim and Hwang (1997) and Bruton (1995)].

and human capital formation in development planning and the declining output of the innovation system during the last decade—mainly due to lack of political commitment—may be the prime reasons for the recent decline in productivity growth in the manufacturing sector.

(v) Determinants of TFP Growth: Analysis of Empirical Findings

The results of selected equations, designed to probe the determinants of TFP growth, are reported in Table 2. The coefficients of all the explanatory variables have expected signs.[18] The results show that growth in human capital and knowledge capital affects total factor productivity growth (G_a) positively. The growth in R & D

Table 2

Determinants of Total Factor Productivity Growth (G_a)

Explanatory Variables	Equation-1	Equation-2	Equation-3	Equation-4	Equation-5	Equation-6
Constant	−4.371	−4.889	−5.143	−3.684	−4.82	−0.793
	(0.437)	(2.049)	(0.882)	(1.582)	(2.046)	(0.612)
G_{11}	0.378	0.254	0.256	0.157	0.387	0.524
	(1.793)	(1.990)	(1.864)	(1.212)	(2.201)	(9.704)
G_{12}	0.417	0.403	0.401	0.488	0.231	–
	(2.126)	(2.543)	(2.409)	(3.14)	(1.024)	
G_2	–	0.952	0.948	0.767	0.515	0.082
		(2.813)	(2.627)	(2.706)	(1.022)	(0.384)
O_1	0.174	–	0.0087	–	–	–
	(0.153)		(0.048)			
O_2	–	–	–	0.047	–	–
				(1.935)		
G_{31}	–	–	–	–	–	0.0014
						(0.399)
G_{32}	–	–	–	–	0.008	–
					(1.165)	
P	−3.055	–	–	–	–	–
	(2.565)					
Adj.R-Squ.	0.353	0.405	0.376	0.474	0.415	0.857
F	4.279	6.452	4.610	6.407	5.260	35.055
N	24	24	24	24	24	17

Notes: *t*-values are reported in parenthesis.

G_{11} and G_{12} are, respectively, growth rate of expenditure on R & D and growth rate in scientific and technical manpower; G_2 is growth rate of human capital; G_{31} is annual change in foreign patents registered; G_{32} is growth rate of total economy-wide R & D expenditure; O_1 and O_2 are measures of openness; and P is dummy variable for policy change.

[18]Initially, alternative specifications of Equation (5) were estimated. The equation was estimated with lagged values of the explanatory variables and time trend as an additional explanatory variable. However, the inclusion of lagged values of explanatory variables did not change the results significantly and the coefficient of time trend was statistically insignificant. Thus, in the final estimated equations we dropped the time trend variable. The equations were selected on the basis of the theoretical arguments, provided above, adjusted *R*-square, and *t*-values of the estimated coefficients.

expenditure (G_{11}) has a positive and statistically significant effect on G_a. The growth rate of scientific and technical manpower (G_{12}) also affects productivity growth positively and significantly. Similarly, the coefficient of growth in national R & D (G_{32}) activity supports the view that spillover effects on productivity growth are positive. However, it is not statistically significant. Similarly, growth in human capital also contributes positively and significantly to productivity growth. These results confirm a positive role of growth in knowledge and human capital in productivity growth and improvement in competitiveness of the large-scale manufacturing sector of Pakistan.

All the coefficients of 'Openness' reveal a positive impact of globalisation and trade liberalisation on productivity growth. However, the coefficient of O_1 is positive but not statistically significant, whereas the coefficient of export growth (O_2) is positive and statistically significant. This shows that some direct measure for export expansion are more effective in improving the competitiveness of the economy. This result supports the Edwards (1998) conclusions that there is a significant positive relationship between openness and productivity growth.

The foreign patents registered, a proxy for transfer of technology, contributes positively but insignificantly to productivity growth. This shows that positive spillover effects (externalities) of foreign R & D activities on productivity growth are not very significant.[19]

The change in policy regimes, i.e., nationalisation of industrial units, had a negative and statistically significant impact on productivity growth. The magnitude and the significance level of the estimated coefficient shows that the effect of this variable is quite high; it suggests that privatisation should have a positive effect on productivity. However, this is not possible without establishing a stable and consistent economic policy framework to generate productivity growth in the large-scale manufacturing sector.

Concluding this section, we can say that knowledge capital, human capital, promotion of technology infrastructure, openness, and stable and consistent policies are important determinants of productivity growth in the large-scale manufacturing sector of Pakistan. To put the manufacturing sector on the high growth path there is a need for the accumulation of knowledge and human capital to encourage R & D activities, especially in the industries with large export potential. Such a strategy will not only raise the level of productivity but also enable the manufacturing sector, particularly export-oriented manufacturing, to improve its competitive strength in global markets. However, a complete understanding of the role of these sources of productivity growth requires a detailed understanding of the state of existing technology apparatus in the country, besides recommending a policy framework to improve its role in raising productivity in the economy.

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[19]In order to capture the effect of foreign technology transfer, we also included the growth rate of imported capital goods in the model. However, the estimated coefficient is not statistically significant.

3. STATE OF TECHNOLOGY APPARATUS

As mentioned earlier, together with factors of production, technology is inextricably linked with productivity and competitive growth of enterprises. International experience suggests that the most competitive and advanced economies are those that are at the forefront of the technological progress. The problem of industrial backwardness today in Pakistan is mainly due to slackness in productivity growth, which in turn is a result of technological underdevelopment. [20] For Pakistan, where highly skilled workers, capital, and foreign exchange are scarce, the growth of total factor productivity is of special significance. Given the population pressure in the country, there is a great need to accelerate productivity growth. Technological development is a key element in enhancing industrial productivity, and hence growth, which will make it possible to improve competitiveness and produce new products. The results discussed in the previous section established that human and knowledge capital and domestic R & D activity contribute significantly to productivity growth. Thus, it is important to examine the state of the technology system available in the country and suggest some measures to make it more effective.

Most of the problems in Pakistan are related to software rather than to the hardware side of technology. Functional linkages between various components of the S & T system (universities, research institutes, and industry) are missing. Technology infrastructure services are inefficient. International alliances of local research institutes (hereinafter RIs) are missing. Generally, RIs are facing funding, planning, and organisational problems.[21] Audit rules in RIs do not allow commercialisation of their products directly. Industrialists are either not quality-conscious or not aware of the benefits of better quality. Consequently, the private sector's participation in technological development is negligible. There is a weak conditioning of local customers in favour of better-quality products.

Besides these problems of the Pakistani S & T apparatus, there are other factors which hinder technology advance at different stages of technological development. These stages are Discovery, Development, and Deployment. All of these stages are important not only for effective utilisation of domestic innovations but also to extract due benefits from technology transfer. The problems attached to each stage are discussed below.[22]

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[20]The domestic R & D activity helps not only in domestic innovation processes but also in the acquisition and adoption of new technologies developed elsewhere.

[21]In 1990, Pakistan's total RIs funding was US$179,166 as compared to US$1,628,201 in India and US$2,137,899 in China. Ironically, even these meagre funds are used inefficiently in Pakistan due to cumbersome bureaucratic procedures.

[22]The discussion in this section is based on the findings of a survey of selected RIs in the country. Initially, we can concentrate on the improvements at the third stage, but for sustainable long-term productivity growth we can not ignore the first two stages.

Discovery: At this stage, exploration of basic scientific principles produces discoveries that appear to have potential application to industry and market needs. Discovery initiatives are supported as a means to enhance access to technology. The national innovation system in Pakistan, composed of universities, centres of excellence, and private industry, is very weak. Engineering innovation is rudimentary. Engineering capacity has been limited to basic maintenance and repair units. Patents are rarely produced because sponsored projects are generally not available from private industry or even from the public sector, and enforcement of intellectual property rights is weak. The weak performance is also a reflection of the weak knowledge base and poor technology infrastructure.

Development: In this phase, discoveries move from "proof of concept" to the stage of prototype product applications, through R & D. This determines whether the basic discovery has the potential to be developed into new products, or can improve present products, substitute manufacturing processes for previous approaches or reduce the cost and increase the quality of current processes. Pakistani RIs focus only on the development of indigenous technologies rather than tracking, undertaking, and absorbing international technological trends in the fields most relevant for domestic industry. No technology assimilation is taking place because no incentive is given to the participants in that process. Ironically, in manufacturing units, R & D usually means quality control—not the actual acquisition, adoption and/or development of technology.

Deployment: At this level, product prototypes are converted to production scale and are disseminated to users through the market distribution system. This work is usually done by industry. There is a lack of motivation in Pakistan's private sector to use local technologies. They prefer only the turnkey projects that provide efficient after-sale service with an option for technology upgrading. The private sector often imports outdated technologies. For instance, second-hand machinery is imported. This is mainly because support programmes to increase awareness of new technologies and best practices are lacking. Likewise, policy tools such as procurement, performance standards for products, and financial incentives that are considered helpful for technology deployment are lacking in the country.

In addition, the domestic S & T infrastructure faces the following problems.

Technology Facilities/Infrastructure: RIs and industries need the right kind of facilities for developing and carrying out technology activities at each technology level. These facilities include science laboratories, R & D facilities, testing and prototype service bureau, and technology parks or incubators' facilities for start-up firms as well as design, testing, and evaluation services. Infrastructure services essential for the proper functioning of the S & T system are highly inadequate and poorly organised in Pakistan. There is a lack of calibration, standardisation, and quality control of manufactured goods/equipment and a great dearth of competent consultancy organisations/firms in the S & T fields. S & T information services are rudimentary. There is also a dearth of reliable scientific statistics.

Technology Human Resources/Knowledge Base: Each technology level requires an adequate supply of technically trained and experienced people to carry out work at that level and to participate in the transfer of knowledge and information to other levels. In Pakistan, there is a great dearth of high-quality research personnel for S & T.[23] The quality of education is extremely low in science universities and colleges. The educational process, in general, does not encourage innovative activities. S & T at the grassroots level are not popular. Science in Pakistan is still regarded as an esoteric activity, peripheral to academic work. While the country faces a scarcity of qualified S & T staff, public policy actions provide no inducement to attract expatriate S & T Pakistanis back to Pakistan, so the brain drain of experienced and foreign-qualified people precipitates.

Above all, good governance is essential to efficient and effective running of RIs, and to attract quality staff. Inappropriate organisational structure, cumbersome financial and administrative procedures, and lack of professional freedom, implementation, co-ordination, and accountability can best describe the governance in Pakistan's S & T system.

Under these circumstances and constraints, there is only one strategy which can achieve the difficult task of reforming the S & T apparatus and, thus, improving productivity in the manufacturing industry. That is: transfer considerable responsibility for leadership and financial support of the S & T apparatus from the government to a public-private collaborative system, wherein the private industry has the leading role in applied research and government-sponsored RIs focus on basic research. A blueprint of this strategy is outlined in the next section.

4. STRATEGIC DIRECTIONS TO ENHANCE PRODUCTIVITY BY REFORMING S & T APPARATUS

In this section we lay out strategic directions to reform the ailing S & T apparatus in Pakistan while keeping in view the institutional inertia, bureaucratic stonewalling, insufficient private sector involvement in R & D activities, and historical lack of political commitment for science and technology.[24] Thus, the proposed policy should be such that it bypasses the existing bureaucracy and places financial and managerial autonomy in the hands of the private industry, whose survival depends most crucially on efficient and effective RIs.

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[23] In 1996, RIs in Pakistan employed 1843 persons with the PhD degree. In 1993, S & T staff in Pakistan was 93 per one million persons, whereas in India this ratio was 178 and in Malaysia it was 900. [See United Nations (1982, 1987, 1993)].

[24] Reform of RIs should by no means be considered as a total substitution of local technology with imported technology. We anticipate that Pakistani industry will continue to rely on imported technology. Pakistani RIs are expected to play a vital role, less in the development than in the selection and implementation of appropriate technologies.

Keeping in view the problems associated with productivity growth and technological progress in Pakistan, we propose four interrelated strategic directions which should become a part of a long-term technology development plan. The following strategic directions are proposed:

1. augmenting the public sector S & T apparatus with the private sector funding and oversight;
2. measures to upgrade RIs to the international standard;
3. streamlining of the technology creation, absorption, and diffusion system; and
4. enhancing the demand for S & T in industries.

Strategic direction 1 is a clear response to the current stalemated technology policy response in Pakistan. In this regard we propose three policy reform directions so as to achieve a fundamentally different dynamic relationship between RIs and the private sector. Here the ultimate goal is to make the existing RIs more market-oriented and to make private firms more aware of what the system has to offer to make them more competitive. The three policy reform directions include:

(i) setting up of cluster councils so as to define the commercial needs for R & D services and serve as a focal point for private sector interactions with the S & T apparatus;[25]

(ii) formation of a funding mechanism that draws funds from specific (cluster) industries and disburses them through cluster councils, with complete autonomy from the government; and[26]

(iii) defining the technology development policy in relation to the overall industrialisation strategy.

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[25]For the information of cluster (wide groupings of related industries) councils we suggest the following steps. (a) Identify specific industrial clusters and form working groups for each cluster. (b) Cluster working groups will establish applied research priorities for each industry, thereby expressing "demand" for R & D activities. (c) Establish councils for each cluster with spending authority to provide incentives for targeted research activities in selected RIs. (d) Councils will have full authority to make disbursements from cluster S & T funds without interference from government apparatus (i.e., financial autonomy). (e) During the first two years, most expenditures will probably take the form of incentives to RIs to develop specific products or processes (essentially contract research). (f) Over time, councils may also choose to contribute additional resources to augment laboratories and staff.

[26]Since each cluster can benefit from applied research activities in its field, it is justified to require a financial contribution to support such R & D. We suggest the following steps for the creation of the S & T Cluster Fund. (a) A cess will be applied to all industries, starting with the existing well-defined clusters, and will ultimately cover all economic activities. (b) Monies raised will be used exclusively to establish the S & T Trust Fund, which can only be applied to research activities under the direction of cluster councils. (c) A financial contribution to support R & D will be required from each cluster benefiting from applied research activities in its field. Under the existing system, the researchers have little means to respond to the actual requirements of industry. (d) Transparency procedures will be established to ensure that these funds do genuinely focus on benefiting the cluster. (e) Procedures for reorganisation (consolidation, etc.) of RIs will also be established.

We also propose some policy reform directions in strategic direction 2, i.e., for the upgradation of the supply-side of the research apparatus. The success of the suggested policy actions hinges on a successful adoption of the cluster approach described above. These measures will improve the quality of the existing science and technology apparatus through better procedures, programmes, and funding. The proposed policy reform directions are as follows.

  (i) Provision of efficient research infrastructure and support services, supported by cluster councils.

 (ii) Upgradating of management capabilities of S & T staff through on-the-job training and interaction.

(iii) Creating strategic alliances with international RIs through networking and joint participation in research projects.

(iv) Attracting expatriate Pakistani researchers back to Pakistan by improving economic fundamentals and governance in the country.

 (v) Attracting foreign direct investment in key industries, by creating an investment-friendly climate in the country that will act as a catalyst to promote cluster development in higher technology areas.

(vi) Developing technology resources in the country.

Strategic direction 3 concerns the technology diffusion system, i.e., efforts to enhance the technology standards, the quality control awareness, and the technology extension system. It is often realised that knowledge exists within the country but the potential users are unaware due to a lack of institutions to diffuse these technologies effectively. Improved standards, appropriate regulatory climate, and greater utilisation of information technology are all expected to enhance the delivery side of the technology system. We suggest here some initiatives that need to be undertaken to ensure that the research that is carried out actually reaches, and is absorbed by, the industry. Policy reform directions should be the following.

  (i) Imposing higher technology standards, especially on export-oriented products, by strengthening the metrology, standards, testing and quality agency (MSTQ) in Pakistan.

 (ii) Effective implementation of measures to protect intellectual property rights.

(iii) Introducing effective diffusion of information technology applications at all levels of industry, possibly using the funds collected through cluster councils.

Strategic direction 4 seeks to augment the demand for technology. This effort is in many respects the ultimate tool to ensure that technology development becomes a self-sustaining, highly productive aspect of Pakistan's economy. Policy reform directions in this regard include the following.

 (i) Enhancing co-ordination between RIs and industry.

(ii) Aggressively diffusing information regarding the required international product standards to educate potential exporters about the current gaps in standards.

(iii) Increasing competition within Pakistani industries.

(iv) Promoting entrepreneurial behaviour through on-the-job training and by developing industrial networks.

Interestingly, these four strategic directions are designed to work together to set in motion a series of phased reforms, which create incentives and market-based mechanisms to enhance the technology system without relying on a radical shift in the governance element of the bureaucracy.

5. CONCLUSIONS

The manufacturing sector of Pakistan, which provided the growth momentum to the economy in the sixties, has been exhibiting sluggish growth in recent years. The main reason for low growth is the slow-down in total factor productivity growth, which became negative after 1995. For Pakistan there is clear evidence of a relationship between the growth in total factor productivity and the ailing S & T apparatus. The results presented above also lend support to the hypothesis that knowledge capital, human capital, openness, and government policies are crucial determinants of total factor productivity growth. The share of knowledge and human capital in explaining the variance in productivity growth is almost 30 percent and 18 percent, respectively. Thus, the development of an efficient and effective technology apparatus is of utmost importance for the growth of industries.

Given a liberal economic environment in the country, which is essential to improve efficiency and productivity, the paper offers the following four strategic directions in order to improve the status of the S & T system in Pakistan:

1. Augment the public sector S & T apparatus with the private sector funding and oversight.
2. Take measures to upgrade RIs to the international standard.
3. Streamline the technology creation, absorption, and diffusion system.
4. Enhance the demand for S & T in industries.

Interestingly, all these strategic directions are designed in such a manner that they will work together to set in motion a series of phased reforms so as to create incentives and market-based mechanisms. They are aimed at enhancing the technology system without relying on a radical shift in the governance element of the bureaucracy.

Table A1

Indicators of Industrial Productivity and Its Determinants

Year	Vama	P_l	P_k	G_a	G_{11}	G_{12}	G_2	O_1	O_2	G_{31}	G_{kim}	G_{32}
1972	60.97	66.57	102.20	–	8.54	–2.65	6.96	11.55	16.45	–	–	–
1973	63.24	68.27	107.70	4.61	9.69	–3.55	6.28	22.43	9.04	–	8.79	–
1974	64.75	69.11	109.94	1.85	11.16	–4.04	5.29	27.84	27.76	–	9.72	–
1975	66.29	70.13	109.11	–0.20	11.51	–2.08	4.73	34.33	–7.94	–	21.62	–
1976	68.20	71.35	104.95	–2.42	10.91	–2.06	4.04	29.69	–0.34	–	13.64	–
1977	70.49	72.32	98.56	–4.47	9.36	–0.07	3.79	29.12	3.17	–	6.39	–
1978	74.73	75.37	93.85	–2.85	7.20	–0.49	3.69	26.91	1.48	–	7.83	–
1979	81.07	81.76	92.81	1.06	7.63	–0.42	3.63	25.93	–5.60	–	3.90	–
1980	90.51	90.70	96.14	4.92	8.48	0.42	3.71	33.39	35.31	412	3.78	–
1981	100.00	100.00	100.00	5.09	9.44	1.66	3.97	33.42	4.52	307	8.19	–
1982	110,20	110.90	104.72	5.73	8.82	1.90	4.59	30.16	–9.23	290	11.59	–0.79
1983	120.73	121.24	109.85	5.65	9.80	3.18	5.02	31.45	19.49	342	3.73	17.10
1984	131.29	128.85	114.11	4.27	9.09	8.61	5.62	31.33	–3.15	435	10.59	11.43
1985	140.95	134.98	117.77	3.46	8.51	3.73	5.77	30.47	–2.87	290	8.78	19.19
1986	152.53	145.19	123.81	5.50	7.73	6.06	6.17	32.31	31.30	460	5.94	5.93
1987	163.10	153.71	129.66	4.85	8.88	4.66	6.25	31.90	13.84	508	6.25	17.88
1988	173.32	162.06	135.59	4.65	9.42	3.63	6.23	29.58	–0.24	308	1.12	–3.15
1989	183.69	169.99	142.08	4.70	8.97	–1.81	6.79	31.22	11.47	498	–2.61	–4.12
1990	194.87	179.74	148.84	4.90	7.15	0.46	7.66	29.45	2.78	445	8.45	5.28
1991	204.55	184.71	153.46	2.97	5.57	–1.66	7.96	30.91	24.03	520	10.78	–21.03
1992	215.25	196.62	155.51	2.49	3.67	–2.21	7.92	35.94	15.49	432	4.18	1.82
1993	225.00	207.93	156.39	1.70	1.14	–2.80	7.79	36.50	0.52	475	6.89	14.15
1994	234.19	218.97	156.11	0.82	–1.63	–3.21	7.05	33.33	2.33	500	9.65	–6.97
1995	239.03	225.28	152.68	–1.19	–4.13	–2.48	6.47	32.10	–3.48	520	–3.60	–4.30
1996	243.74	230.17	148.97	–1.49	–0.25	–2.76	7.10	33.27	4.05	540	–3.60	–4.00
1997	245.31	228.48	147.38	–1.00	–0.09	–1.48	3.04	29.06	–1.85	262	–3.60	–3.00

Note: **VAMA=index of the value-added in large-scale manufacturing (5-year moving average); P_l=index of labour productivity (5-year moving average); P_k=index of capital productivity (5-year moving average); G_a=growth rate of total factor productivity (5-year moving average); G_{11}=growth rate of development expenditure on Research and Development; G_{11} =growth of manpower involved in R & D activity; G_2 = growth rate of enrolment; O_1=Trade–GDP ratio; O_2=export growth rate; G_{31}= foreign patents registered; G_{kim}=growth rate imports of capital; G_{32}=growth rate of national expenditure on R & D.**

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