A comparative analysis of shifting of doctorates

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Taking stock of the science technology (S&T) workforce plays an imperative role in the advancement of S&T. Productivity of doctorates (Ph Ds) in the field of science and engineering/ technology influences the development in S&T competitiveness. Shortage of out-turn in S&T stock can slow down the process of growth and advancement; and if shortage arises, it may persist for a long time. As emerging trends of education and S&T manpower out-turn are indicating a shift in doctorates, an analysis of these trends will be appropriate for reshaping the future of tomorrow and for taking the desired course of action. In the present study the emerging trends among five disciplines, namely science, engineering/technology, arts, commerce and education in India are analysed with the help of mathematical models. The results show a shift towards commerce, arts and education and a decline in science doctorates, with engineering/technology reaching the stage of saturation.

SCIENCE and technology (S&T) manpower is an important indicator of technological growth and competitiveness of a country. Every year, thousands of post-graduates and doctorates (Ph Ds) in different subjects and disciplines from academic institutions contribute towards growth and development on the national as well as international level. Recently, the economic reforms have rigorously affected the pattern of higher education in India. In the changing economic milieu, economic liberalization has opened the doors to a global marketplace for highly educated personnel. Besides, it has also influenced the flow of doctorates from one discipline to another. This kind of shift may create an imbalance in education in future. To overcome this dilemma, suitable employment of the S&T personnel is required. This lies in the effectiveness of planning the manpower requirement in desired areas of S&T, to create a base for scientific and industrial research. The present analysis is essential to focus efforts on the emerging trends in the field of higher education. A sufficient knowledge of S&T manpower is important for the formulation of S&T policy and the development of S&T plans and programmes.

Several changes have occurred in the current trends in higher education that need to be understood as a part of the picture. A long-standing concern for India has been its brain drain. In addition, interdisciplinary shift of students is a matter of serious concern. This may affect the structure of S&T manpower because science and engineering, as a discipline, are posing a slow growth rate[1]. Further, the decline in Indian science[2] is now a central issue in higher education. Therefore, the objective of this article is to analyse the relative shift of new doctorates in the field of science, engineering/technology, arts, commerce and education. This analysis may provide important information about the future pattern of emerging trends among the S&T manpower and particularly, the supply of new doctorates. The estimates for future trends of doctorates produced will help in policy formulation and proper planning. Indian S&T manpower is ranked as the third largest in the world; for this reason India is taken as a case study. This also implies that India has the potential to emerge as a significant player in the global technology market. Correspondingly, the findings may provide a helpful map to navigate the emerging trends of new doctorates produced in different disciplines, by analysing the interdisciplinary shift of Ph D students.

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Methodology and analysis

The framework of the study is to analyse the interdisciplinary shift of doctorates among five different disciplines, namely science, engineering/technology, arts, commerce and education. Data used in this study belong to doctorate degrees awarded during the period 1974 to 1999 (ref. 3). The data pertaining to doctorate degrees awarded in science, engineering/technology, arts, commerce and education are listed in Table 1. To analyse the data and for making future projections, a mathematical model proposed by Fisher-Pry[4] is applied. This model is studied and applied extensively for the analysis of competition among competing technologies. The model may be expressed in the following mathematical form:

$$\log\left(\frac{f}{1-f}\right) = a + bt,$$

where f is the share of the new technology at any time t, and a, b are model parameters. The model is based on the following assumptions:

- Technological advances can be considered as competitive substitutions of one method of satisfying a need for another.
- If a substitution has progressed as far as a few per cent, it will proceed to completion.
- The rate of fractional substitution of new for old is proportional to the remaining amount of the old left to be substituted.

Assuming that the competition between different commodities is similar to competing technologies and behave in the similar manner, technology substitution model is applied for the study. Studies show that substitution tends to proceed with a constant percentage annual growth increment or exponentially in the early years, and to follow a logistic (*S*-shaped) curve.

A nonlinear least square method is applied to estimate the model parameters using SYSTAT package[5]. Model parameters are obtained by quasi–Newton iterative technique for $\log(f/1-f) = a + b*t$ and fraction f separately (Tables 2 and 3). Using values of the parameters for fractions, forecasts have been made for the doctorate degrees awarded in different disciplines up to the year AD 2010. Using the projected values of fractions 'f', the percentage of doctorate degrees awarded in all five disciplines are calculated and listed in Table 4.

Results and discussion

S&T workforce is a major factor in economic and technical growth and has multi-dimensional effect on the economy.

Table 1. Doctorate degrees awarded in different disciplines

Year	Discipline				
	Science	Engineering/ technology	Arts	Commerce	Education
1974	1327	95	1093	58	60
1975	1515	163	1258	55	77
1976	1516	136	1282	41	82
1977	1671	152	1364	70	98
1978	1901	168	1677	96	92
1979	2044	134	1811	87	105
1980	2261	176	1831	118	120
1981	2792	189	2246	105	173
1982	2846	190	2347	173	178
1983	2892	160	2422	175	191
1984	2890	192	2678	177	187
1985	2922	210	2754	185	239
1986	2838	194	2886	263	219
1987	2814	224	2987	272	227
1988	2790	256	2830	235	211
1989	3044	238	3346	336	242
1990	2976	252	3242	301	205
1991	3002	260	3327	346	261
1992	3226	299	3489	409	254
1993	3386	323	3621	453	247
1994	3467	329	4039	515	308
1995	3657	337	3829	537	290
1996	3861	374	3957	612	295
1997	3498	298	4245	502	295
1998	3894	744	4058	541	342
1999	3896	696	4256	517	310

Technology, patents and education are the important indicators of science and economic development. Stock of higher S&T personnel in general and doctorates in particular, is one of the most significant indicators for overall development, advancement and technological competitiveness of a country. University Grants Commission (UGC) is a nodal agency for regulating the standard of higher education. UGC has been monitoring the growth of higher education to ensure that the trained manpower, with appropriate levels of professional training, skills and specializations, will grow according to the needs of the society and technological development. India has more than 250 central and state universities, a major source of Ph D-producing institutions. Apart from universities, Indian Institutes of Technology and different engineering colleges also award Ph D degrees. Higher education in terms of doctorates in science and engineering/technology is one of the major performers of research and development (R&D). Therefore, the Department of Science and Technology (DST) has also been trying to quantify S&T manpower and financial resources devoted to R&D in S&T by regularly launching a national survey.

Doctorate degrees awarded by Indian universities have been more or less constant or declining in recent years. The total number of research degrees (doctorates) awarded decreased from 11,107 in 1998–99 to 11,067 in 1999–2000. Among the degrees awarded in 1999–2000, the faculty of arts had the highest number with 4231 doctorates, followed by the faculty of science with 3832 doctorates. These two faculties together accounted for the highest proportion of total number of doctoral degrees awarded[6]. Comparative proportional shares of doctorate degrees awarded in each discipline are shown in Figure 1. From Figure 1, it may be noticed that the faculty of

Table 2. Parameter estimates for log function*

Discipline	Parameter		
	a	b	CRS
Science	0.070	– 0.019	0.874
Engineering/technology	– 3.327	0.009	0.075
Arts	– 0.359	0.008	0.452
Commerce	– 4.090	0.058	0.887
Education	– 3.624	0.013	0.513

Here log function represents $\log(f/1-f) = a + b*t$.

Table 3. Parameter estimates for fraction f

Discipline	Parameter		
	a	b	CRS
Science	0.070	– 0.019	0.874
Engineering/technology	– 3.378	0.015	0.114
Arts	– 0.359	0.008	0.450
Commerce	– 3.975	0.052	0.875
Education	– 3.600	0.012	0.477

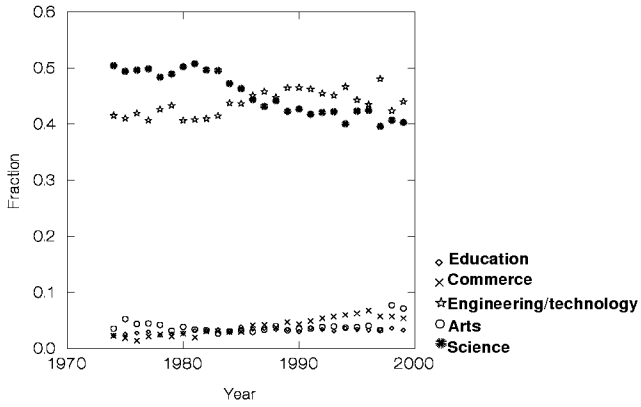

Figure 1. Share of doctorate degrees awarded.

Table 4. Projection of shares of different disciplines (in %)

Year	Science	Engineering/ technology	Arts	Commerce	Education
2000	39.30	04.70	46.20	07.00	03.40
2001	38.50	04.70	46.30	07.40	03.50
2002	38.00	04.80	46.50	07.80	03.60
2003	37.40	05.00	46.70	08.20	03.60
2004	36.90	05.00	46.80	08.60	03.70
2005	36.40	05.10	47.30	09.00	03.80
2006	36.00	05.20	47.50	09.40	03.90
2007	35.80	05.30	47.70	09.80	03.90
2008	35.30	05.40	47.90	10.30	04.00
2009	34.90	05.50	48.10	10.80	04.00
2010	33.50	05.50	48.30	11.30	04.10

science shows a relative declining trend among the studied disciplines. Faculties of education and arts exhibit marginal improvement and can increase in the future, while a steep sharpness in commerce indicates that a major swing is expected towards commerce. Engineering/technology on the other hand, is reaching a saturation level.

Results obtained in terms of logarithmic function for all five disciplines are given in Figure 2 *a–e*. Figure 2 *a* shows a substantial decline in doctorate degrees in science, whereas Figure 2 *b* shows that engineering/technology may reach a saturation level in future. It may be noticed from Figure 2 *c–e*, that arts, commerce and education have a probability for growth in future. Similarly, from Table 4 it may also be concluded that science is declining whereas commerce, arts and education are showing positive growth. However, science and engineering/ technology are expected to have a share of reach up to 34 and 6% respectively, whereas arts, commerce and education will have 48, 11 and 4% respectively, by AD 2010.

Concluding remarks

Information regarding out-turn of doctorates in India is an example of a change in attitude of researchers, where it may be noticed that science is not the academic preference among students. The analysis reveals that the major shift of new doctorates is towards commerce, while arts and education also show growth trends. Engineering/

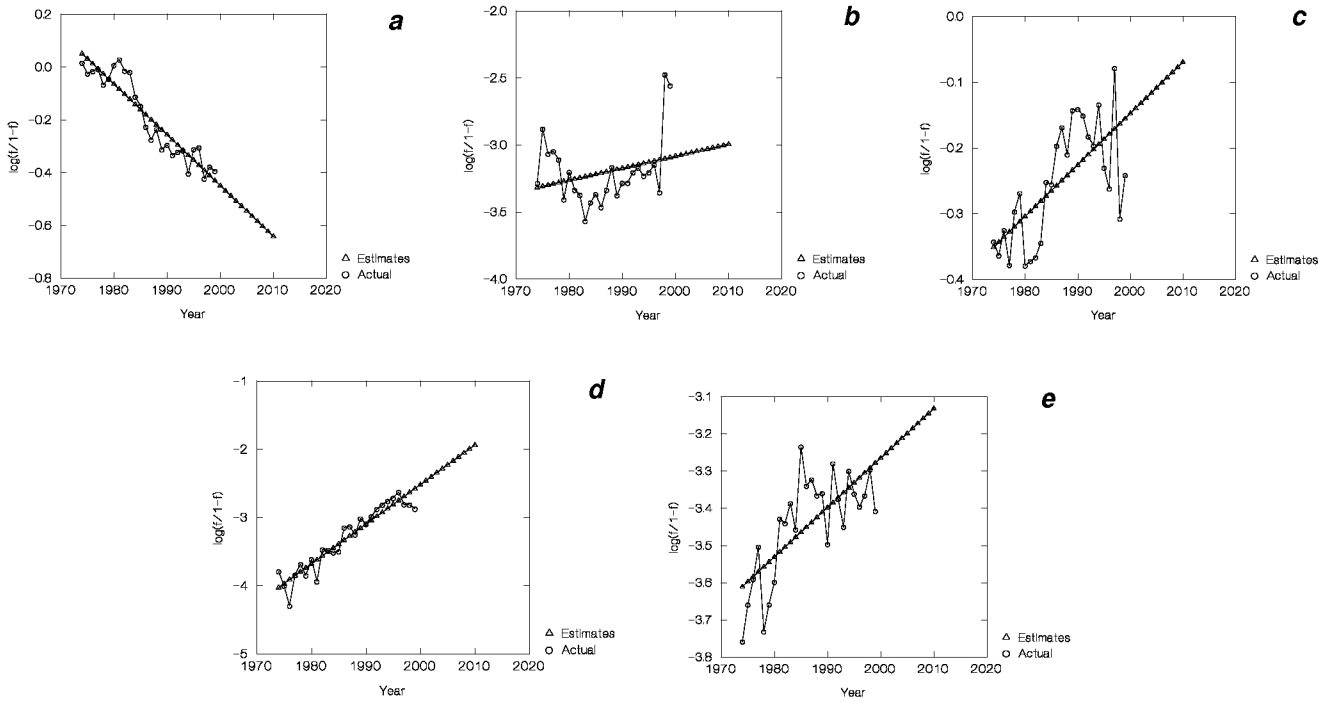

Figure 2. Actual and estimates for (*a*) science, (*b*) engineering/technology, (*c*) arts, (*d*) commerce and (*e*) education.

technology gives the impression of entering a saturation phase. It has also been pointed out by the AICTE[7] that advanced research has suffered and annual out-turn of Ph Ds in the field of science and engineering is declining. As a result the number of doctorates produced in science may decline in future, which can slow down the process of contribution to fundamental knowledge. If this decline continues, it may persist for a long time and will create a gap in supply and demand of S&T professionals. The imbalance and shortage of supply of doctorates in science will generate a vicious phase in the field of research and development, because technological developments depend to a large extent on scientific contributions. However, annual production of new doctorates in science has remained more or less constant. It may be because students of science have job opportunities in non-scientific fields. Further, increase in the number of doctorates in the commerce signifies that in the present scenario, commerce provides more job opportunities than science.

The swing of doctoral students from science and engineering to humanities may be attributed to carreer opportunities and economic incentives. Decline of doctorates in the field of science shows that the discipline provides lesser job opportunities in the changing economic perspective, because economic incentive affects higher education[8]. Lack of career choices is reducing/diminishing the linkage between students and scientific production. For this reason students are moving away from science and engineering/technology towards commerce and other disciplines. Another reason may be the government policies of private investment in higher education. These new policies can affect the growth of graduates and doctorates in the field of science and engineering/technology due to fees structure. Therefore, higher education in science and engineering/technology has to be made accessible to more people. To achieve these goals, emphasis must be given for improving public–private partnership. This may help, to some extent, overcome the problem of declining number of doctorates in science and engineering disciplines. Moreover, research in science should be encouraged not only to generate fundamental knowledge, but also to support technological developments. If these developments are ignored, a shortage of doctorates in science and engineering/technology may emerge in future.

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