On the Estimation of the Growth of Technical Manpower in India

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1. Let us assume that there are E_0 engineers (or scientists) in a country at the end of year O. In that year, the outturn of engineers (or scientists) is e_0. In general, we may write E_t and e_t respectively for the stock at the end of and outturn during the tth year. Not all engineers in the stock E_0 will complete the first year ; some will retire, some will join other occupations or go abroad and some will die or become unfit for service due to ill health. Thus there will be a continuing attrition of the stock ; let the annual rate of attrition be r per cent. At the end of the first year, the stock will, therefore, be $E_1=(1-r)E_0+e_1$, and in general, we may write

$$E_t=(1-r)E_{t-1}+e_t \qquad \ldots \qquad \ldots \qquad (1)$$

This expression enables us to work out an estimate of stock for year x given an estimate of stock for year y provided we have data on outturn for the period covered by year x and year y. Using some past data on stock, it is thus possible to work out an estimate of stock for a recent year. Also, if some recent estimate of stock is available, the expression may be used to derive an estimate of stock for a past year.

2. Estimates of stock of both engineers and scientists in India for the year 1955-56 have been worked out by the Perspective Planning Division (PPD) of the Planning Commission.[1] The same sources further give data on outturn of engineers or scientists for the period 1915-16 to 1955-56.[2] One can, therefore, make use of the 1955-56 stock and the given data on outturn to work out estimates of stock of engineers

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1 Engineers in India, Number and Distribution, Manpower Studies, No. 5, October 1957 (mimeographed), and Scientists in India A Statistical Study, Manpower Studies No. 10, July 1959, (mimeographed).

2 Conceptually, outturn should include inflows from other countries and other occupations. But available data usually relate to persons qualifying as engineers (or scientists) during a year.

and scientists in 1915-16, making a reasonable assumption about the rate of attrition. This procedure, however, yields very surprising results, as will be seen from table (1) below.

Table 1 : Stocks of engineers and scientists in India in 1915-16

Particulars	rate of attrition per year (p.c.) 2.5	3
(0)	(1)	(2)
engineers	30,892	47,760
scientists	7,096	12,046

The estimates of stock used for 1955-56 are 71,900 for engineers and 23,283 for scientists. It is difficult to conceive of such large stocks of engineers and scientists in India in 1915-16 because the rate of annual outturn of engineers and scientists in 1915-16 were respectively 429 and 136, and these rates were probably lower before 1915-16.[3] Even in seven or eight years after 1915-16 the rates of annual outturn did not rise materially. Thus, even the lower figures of stock obtained by using a rate of attrition of 2.5 per cent (i.e. on the assumption that effective lives of engineers and scientists are as long as 40 years) does not appear to be consistent with the probable rates of outturn prior to 1915-16.

3. This puzzling result may be due to any one of the following three reasons. The rate of attrition used may be still lower, though a small reduction in this probably would not improve matters. Secondly, the annual estimates of outturn may not be correct, or may not be strictly consistent with the notion of stock used. Finally, the estimates of stock for 1955-56 may be high.

4. However, a good deal of care has been taken by the PPD to work out the estimates of stocks, making use of both annual estimates of outturn and data given in National Registers of Scientific Personnel with reasonable adjustments whenever necessary. Thus, it is difficult to think of these figures as off the mark. While it is not clear whether the migrants to Pakistan have been included in the annual data of outturn used to build up the stock estimates, we have considered these figures as excluding migrants. If the figures include migrants, the outturn and stock figures will be even less consistent. Net inflow of technical personnel from abroad will have a tendency to bring the stock and outturn estimates more consistent. Appropriate adjustments have been made by PPD for this. However, small changes in assumptions here cannot be dimensionally important. One may probably feel

3 See Appendix Table.

that the assumption about attrition made by PPD is on the low side, but this alone again may not solve the dilemma posed here. There does seem to be a possibility that the stock figures for 1955-56 includes many people without adequate engineering and scientific education, and the figures of outturn stock do not represent exactly the same category of people.

5. If this surmise is correct, then it is worthwhile to try to build up estimates of current stock which are exactly comparable with the data on outturn presented in the PPD papers. This can be done by making use of relation (1), and using a hypothetical figure for the base period stock.[4] If we want to estimate stock for 1955-56, on the basis of an estimate of stock for 1915-16 and the data on outturn for the intervening years, the magnitude of stock chosen for 1915-16 will have little effect on the estimate of stock for 1955-56 for attrition rates of 2.5 per cent or 3 per cent because even for 2 5 per cent rate of attrition, since the intervening period is 40 years, none in the original stock of 1915-16 will survive in 1955-56, and the estimates of stock in 1955-56 will depend only on the data of outturn. This is brought out in table (2) presented below for 3 per cent rate of attrition which we consider as more realistic.

Table (2) ; Stocks of engineers and scientists in 1955-56 based entirely on outturn data and hypothetical figures of base period stock.

Year	Stock of engineers at attrition rate of 3 per cent and with assumed base period stock		Stock of scientists at attrition rate of 3 per cent and with assumed base period stock	
	$10e_o$	$2e_o$	$10e_o$	$2e_o$
1915-16	4290	858	1360	272
1955-56	59,056	58,038	20,126	19,802
PPD estimates for 1955-56	71,900	71,900	23,283	23,283

6. The position, however, does not substantially alter if we take 2.5 per cent as the rate of attrition instead of 3 per cent used in table (2). The differential effects of these two rates of attrition have been presented in table (3) below for base period stock equalling 10 times the base period outturn ($E_o=10e_o$).

7. A study of tables (2) and (3) indicates that the procedure adopted by us results in a wide departure from the PPD estimates in the case of engineers, while the difference is much smaller in the case

4 Annual figures of outturn of engineers and scientists and annual estimates of their stocks calculated under different assumptions are given in the Appendix Table for the period 1915-16 to 1960-61.

of scientists. The differences are reduced when either a lower attrition rate or a higher estimate of base period stock is adopted. In fact, for scientists, a base period stock of $10e_n$ coupled with a 2.5 per cent rate of attrition gives a figure not far off the PPD estimate.

Table (3) : Stocks of engineers and scientists at 3 per cent and 2.5 per cent rates of attrition and with assumed base period stocks of $10e_0$.

Year	stock of engineers at		stock of scientists at	
	3 per cent attrition	2.5 per cent attrition	3 per cent attrition	2.5 per cent attrition
1915-16	4290	5290	1360	1360
1955-56	39,056	62,163	20,126	21,118
PPD estimates for 1955-56	71,900	71,900	23,283	23,283

8. Since we are interested in the estimates of the stock of engineers and scientists over the decade 1950-51 to 1960-61, we may do this following different procedures. One way will be to accept the PPD estimates for 1955-56 and obtain the annual estimates by working forward and backward with relation (1). The other procedure will be to start with a hypothetical base (say, $10e_0$) 1915-16 and work out the series from this using the entire data on outturn. The results of this calculation are presented in table (4) below, for the attrition rate of 3 per cent applied in both the methods. We have also presented figures calculated according to the second method using a rate of attrition of 2.5 per cent.

Table (4) : Stocks of engineers and scientists in India during the period 1950-51 to 1960-61 calculated according to different methods.

Year	engineers			scientists		
	worked from 1955-56 estimates : attrition 3 p.c.	worked from 1915-16 stock : attrition 3 p.c.	2.5 p.c.	worked from 1955-56 estimates : attrition 3 p.c.	worked from 1915-16 stock: attrition 3 p.c.	2.5 p.c.
1950-51	54,971	40,010	42,279	17,109	13,432	14,210
1951-52	57,322	42,811	45,223	18,005	14,438	15,264
1952-53	60,210	46,135	48,700	19,145	15,685	16,562
1953-54	63,022	49,370	52,102	20,264	16,908	17,842
1954-55	67,202	53,960	56,870	21,724	18,469	19,464
1955-56	71,900	59,056	62,163	23,283	20,126	21,188
1956-57	77,330	64,871	68,196	25,040	21,978	23,114
1957-58	82,930	70,845	74,411	27,121	24,151	25,368
1958-59	90,075	78,353	82,184	29,289	26,408	27,716
1959-60	100,134	88,763	92,890	31,968	29,174	30,581
1960-61	110,232	99,202	103,670	34,980	32,270	33,787

Even though the rate of attrition of 2.5 p.c. gives figures closer to those given in cols. (2) and (5), the choice, according to us, is really between those obtained from 1955-56 stock and those arrived at from 1915-16 stock using the same rate of attrition of 3 per cent. This is partly on logical grounds and partly because we think that 3 per cent is a more reasonable rate of attrition than 2.5 per cent. If this is granted, then we get a difference of about 11,000 for engineers and about 2700 for scientists for the year 1960-61. The differences are wider for 1950-51, being about 15,000 for engineers and about 3700 for scientists. Had we used the series based on 2.5 per cent attrition rate for scientists and thus reduced the 1960-61 difference and about 1000, even this would have resulted in a difference of the order of about 3000 in 1950-51. It is clear, therfore, that the two procedures give different results for the time horizon under study. This difference, in all probability, arises partly out of accepting a lower rate of attrition for PPD estimates and partly because of the possibility of inclusion in stock of persons who are not included in estimates of outturn. Thus, if the outturn estimates are inflated for such persons, it is conceivable that the two procedures would give closer results.

9. For making a somewhat deeper study of the problem, it is necessary to make certain assumptions about the rate of growth of the outturn. In the simplest case, we may assume that the annual outturn is constant and e in every year. Also, let the rate of attrition be r per cent and we denote $1-r$ by R. This gives,

$$E_n = R^n E_o + \frac{1-R^n}{1-R} e \qquad \ldots \quad \ldots \quad \ldots \quad (2)$$

If, however, we assume an arithmatical progression for the series of outturn given by

$$e_t = e_o + ta \qquad \ldots \quad \ldots \quad \ldots \quad (3)$$

then we have,

$$E_n = R^n E_o + \frac{1-R^n}{1-R} e_o + \frac{a}{1-R}\left[n - R\frac{1-R^n}{1-R}\right] \quad \ldots (4)$$

Lastly, if the outturn grows at the geometric rate of s per cent per year, and we denote $1+s$ by S, then we have,

$$E_n = RE_o + \frac{S^n - R^n}{S-R} Se_o \qquad \ldots \quad \ldots \quad (5)$$

These formulae help us to pose our problem. However, the actual series of outturn do not follow a simple law. A trend line with superimposed random disturbances may reflect the process of growth better, and it is necessary to take up this study. Once a growth law giving a reasonable fit is obtained, it should be possible to study some of the properties of the process in a more systematic way.

10. We notice, for example, that when worked back from the 1955-56 stock, the sequence of E_t diminishes for some thirty years monotonically (when attrition rate is taken to be 3 per cent) after which an increasing sequence ensues, which is almost monotonic in all our calculations. However, with large random disturbances about a trend, particularly when these compare dimensionally with magnitudes of both e and E, the picture cannot be expected to be very exact. But with any reasonable trend, the sequence of E_t will probably have specific turning points. This is a problem, which could be studied better when we get a satisfactory growth law. Apart from this, the law will be useful for working out projections needed for planning purposes, and also to obtain the estimates of the type given in table (4). We give below some illustrative calculations when the growth law given by equation (5) is supposed to hold.

11. Assuming a geometric law, when we start with a diminishing sequence first, we can find the conditions which satisfy the inequality $E_n > E_{n+1}$ which reduces to

$$\frac{E_o}{e_o} > \frac{S}{S-R}\left\{\frac{(S-1)\,S^n}{(1-R)R^n}+1\right\} \qquad \ldots \qquad \ldots \qquad (6)$$

This expression enables us to compute up to which value of n the sequence will be decreasing for given values of s, r, E_o and e_o. The following calculations bring this out for $s=0.1$, $r=0.03$.

E_o/e_o	the year from which the sequence starts increasing
33	0,1
40	1,2
50	3,4
100	0,10

To derive a value of s which will, say, double the stock in a given number of years, other things remaining the same, involves use of equations with high powers of s; such equations cannot be solved. But putting the values in the equation helps us to obtain a numerical solution. Given $E_o=72000$ and $e_o=6700$, with r at 3 per cent it can be calculated easily that s has to be of the order of 8 per cent for E_o to double in 10 years.

Appendix Table 1 : Outturn and stocks of engineers and scientists in India calculated under different assumptions

Year	Outturn of		engineers					scientists				
	engineers	scientists	3 per cent attrition			2.5 p.c. attrition		3 per cent attrition			2.5 p.c. attrition	
			base $10e_o$	base $2e_o$	worked back	base $10e_o$	worked back	base $10e_o$	base $2e_o$	worked back	base $10e_o$	worked back
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
1915-16	429	136	4290	858	47760	4290	30982	1360	272	12046	1360	7096
16-17	430	183	4591	1262	46757	4613	30639	1502	447	11866	1509	7102
17-18	451	181	4904	1675	45805	4949	30325	1638	615	11692	1652	7106
18-19	484	163	5241	2109	44914	5309	30052	1752	764	11504	1774	7092
19-20	477	169	5561	2523	44043	5653	29779	1868	906	11328	1899	7084
20-21	503	160	5897	2950	43224	6015	29539	1972	1039	11148	2012	7067
21-22	528	159	6248	3390	42445	6393	29330	2072	1167	10972	2121	7050
22-23	485	187	6546	3773	41666	6718	27083	2197	1319	10830	2255	7061
23-24	567	205	6917	4227	40983	7115	28924	2336	1484	10710	2404	7090
24-25	560	206	7299	4690	40343	7527	28792	2472	1644	10595	2550	7119
25-26	1050	251	8130	5599	40182	8389	29123	2649	1846	10528	2737	7192
26-27	1183	313	9069	6614	40159	9362	29579	2883	2104	10525	2982	7325
27-28	1142	367	9939	7558	40096	10270	29983	3154	2408	10576	3274	7509
28-29	1207	471	10848	8538	41000	11220	30442	3540	2807	14730	3663	7793
29-30	1339	521	11862	9621	40236	12279	31021	3955	3244	10929	4092	8119
30-31	1364	509	12870	10696	40393	13326	31611	4345	3656	11110	4499	8425
31-32	1515	539	13997	11890	40096	14518	32337	4754	4085	11316	4926	8754
32-33	1481	535	15060	13014	40956	15636	33011	5146	4499	11511	5338	9071
33-34	1572	579	16180	14196	41299	16817	33759	5571	4941	11745	5784	9424
34-35	1655	622	17350	15425	41715	18052	34571	6026	5415	12015	6261	9811
35-36	1679	565	18509	16641	42142	19280	35387	6410	5818	12219	6669	10131

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
1936-37	1617	584	19571	17759	42494	20415	36121	6802	6227	12436	7086	10462
37-38	1687	577	20671	18913	42906	21592	36906	7175	6617	12640	7486	10778
38-39	1606	599	21657	19952	43225	22658	37591	7559	7017	12860	7898	11108
39-40	1643	613	22650	20996	43571	23735	38296	7945	7419	13087	8314	11444
40-41	1802	610	23773	22168	44066	24944	39142	8317	7006	13304	8716	11768
41-42	1960	637	25020	23463	44704	26280	40125	8704	8209	13542	9135	12111
42-43	2167	685	26436	24926	45529	27790	41290	9128	8648	13821	9592	12494
43-44	2012	699	27655	26190	46175	29107	42271	9553	9088	14105	10051	12881
44-45	2104	747	28929	27508	46893	30483	43320	10013	9562	14429	10547	13306
45-46	2322	786	30383	29005	47808	32043	44561	10499	10061	14782	11069	13760
46-47	2459	824	31931	30594	48832	33701	45908	11008	10583	15162	11616	14241
47-48	2927	901	33900	32603	50244	35785	47689	11579	11166	15608	12227	14787
48-49	2644	925	35527	34269	51429	37534	49143	12157	11756	16065	12846	15343
49-50	3017	939	37478	36258	52903	39613	50933	12731	12342	16522	13464	15899
50-51	3656	1083	40010	38826	54971	42279	53318	13432	13055	17109	14210	16585
51-52	4001	1409	42811	41662	57322	45223	55988	14438	14072	18005	15264	17580
52-53	4608	1680	46135	45020	60210	48700	59198	15685	15330	19145	16562	18821
53-54	4619	1694	49370	48288	63022	52102	69339	16908	16564	20264	17842	20045
54-55	6071	2068	53960	52910	67202	56870	66854	18469	18135	21724	19464	21612
55-56	6715	2211	59056	58038	71900	62163	71900	20126	19802	23283	21188	23283
56-57	7587	2456	64871	63884	77330	68196	77690	21978	21664	25040	23114	25157
57-58	7920	2832	70845	69887	82930	74481	83668	24151	23846	27121	25368	27360
58-59	9633	2982	78353	77423	90075	82184	91209	26408	26113	29289	27716	29658
59-60	12761	3558	88763	87861	100134	92890	101690	29174	28888	31968	30581	32475
60-61	13102	3971	99202	98327	110232	103670	112250	32270	31992	34980	33787	35634