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Technology and Employment in Soft-Drinks Industry in India

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ORIGIN AND GROWTH

The first aerated drink was started with marble bottles in India some 50 years ago. Then gradually these bottles were replaced by the crown corks. 'Gold Spot' was regarded as the very first branded soft-drink in the country.[1] Later on, 'Pepsi-cola' a multinational product entered the Indian scene. The Coca-Cola Export Corporation (CCEC) entered into India during 1950.[2] This has brought about dramatic changes in the product, organisational structure, technology, etc. There was no competing brand with this international drink. The CCEC by giving franchise rights helped the growth of the industry. This is a classic example of how a multinational company operating in a low priority area manages to get away with runaway growth.[3]

The Parle Exports are mostly responsible for developing the indigenous soft-drink industry by putting up, to start with, semi-automatic plants in important towns and then gradually extending their know-how to put up automatic bottling units for bottling their own products by the local people on the lines of Coca-Cola. Parle Exports may be regarded as the first Indian multinational company in the field.[4] The Parle could not penetrate into the market due to the competition of the world famous Coca-Cola.

The net outflow of crores of foreign exchange prompted the Janata Government to stipulate certain conditions on the CCEC.[5] As the company would not like to conform to the 'Indianisation' rules, it had to leave the country. At the instance of the Government, Modern Bakeries entered the soft drinks market with 'Double Seven' as substitute to 'Coca-Cola' In fact, several firms which were already in the market have expanded their sales and stepped into the vaccum.

The growth and development of Coca-Cola and Parle have prompted small entrepreneurs to go in for semi-automatic plants as the consumers became brand and quality conscious. After 1977, units which were manufacturing earlier with Coca-Cola came out with their own brands and know-how. Further, they have developed franchise rights for their brands and started encouraging local units to operate under their franchise.

Thus instead of the core company merely developing a product and brand name and trying to get franchise offers, the Indian firms marketed the product themselves and thus selling both franchise and success story. As a consequence of growing demand for soft drinks the number of units has increased to 213 during 1984-85.[6] Though the industry is scattered all over the country, the locational pattern is urban biased.

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The origin and growth of soft drinks industry presents a typical case of how an indigenous, widely dispersed 'Cottage' industry based on hand-made technology gets transformed into a regionally concentrated, large-scale automatic manufacturing activity through the international 'demonstration effect.' Until nineteen fifties soft drinks industry presented a picture of large number of independent small bottlers whose market was highly competitive localities of urban and semi-urban areas with some spill over to nearby rural markets. The atomistic structure of production units went with almost the total absence of selling costs and with very low retailer margins.

Further, there was a switch from large number of producer-seller dominated structure to a few producers, large number of dealers/distributors and widespread network of retailers. Structural transformation is marked by huge advertisement costs, dealer commissions and the lure of very high retailer's margins. The range of the market of a manufacturing unit increases from a small town and its neighbouring villages extending over a few kilometres to a metropolis and its entire hinterland extending over several hundred square kilometres. Ultimately, the process of transformation has resulted in the anihilation of the entire small scale 'hand-made' technology. Thus, the industry presents a typical picture of oligopoly with all the characteristics of idle capacity and exhorbitant selling costs.

MANUFACTURING PROCESS

Semi-Automatic Process

Empty bottles are first washed with ordinary hand brush by manual labour in the washing room. Then the bottles are fed into bottle washing machine for final cleaning. Water is softened in the tank by mixing lime, soda ash for bleaching and alum for quick settlement to about 30-40 ppm and stored in a overhead tank. The water is filtered through activated carbon in the filtering machine by which pure water is obtained and the same will be passed through chilling plant to chill the water so that it can absorb Co_2 gas easily. Water will be passed and mixed with Co_2 gas in the aerated water machine to which fillers are coupled.

Syrup is made in SS tank according to the formula and flavoured chemicals are added to make the required syrup. The syrup is mixed well with the help of stirrer and taken to the filling room where 30-40 ml of syrup is filled in each bottle by the syruper with the labour force. The syrup filled bottles will be filled with aerated water upto 200 ml by labour. These bottles will be taken by the labour for corking.

Automatic Process

The water used in the process is completely treated for removing the hardiness and the chemical and bacterial contents in it by different processes of ion exchange, hardiness remover and chlorination. Chemicals like alum, lime and bleaching agents are added to water. The treated water will pass through sand filter as well as the activated carbon filter, and in the process chlorine will be removed. The water will go through the chilling unit for cooling temperature, ranging from 40-45°F. After being brought to that temperature, the water will go to carbonation. The carbonated water is prepared by dissolving carbon-dioxide in chemically treated water.

The sugar syrup used in the process is boiled by steam and dirt content in the sugar is filtered with a pressure filter and pumped to another vessel after it is cooled. Sugar and citric acid are dissolved in treated water in sufficient quantity to get the syrup which is filtered. The concentrate and some preservatives are added to the filtered solution. The mixture of finished syrup in required quantity and the carbonated water will give the soft drink.

The bottle washing machine is connected with a streamline and the boiler. Once the bottles are pushed into the bottle washer, the bottle comes out after getting filled with the aerated drink. The bottles are cleaned with caustic soda and other chemicals by stream inside the bottle washing machine and then the bottles come from the machines completely cleaned off inside and outside. These bottles move on automatically on a chain conveyor to the syrup unit where the concentrate is mixed with the sugar syrup and gets filled automatically to the required quantity and then moves to the filter where the carbonation takes place i.e., the water and CO_2 are simultaneously mixed and filled in the bottle while it moves on to crowning machine where the crown corks come out automatically and the bottles are crowned. Then the bottle moves on the conveyor to the collecting table where the bottles are packed into wooden shelfs and sent out to the market untouched by hand.

THE SAMPLE SURVEY

For the purpose of the empirical investigation, the sample units are selected from Andhra Pradesh. A sample of three automatic plants and seven semi-automatic plants are chosen purposively out of 15 and 25 respectively. The selected units are located in important centres of the State. The industrial data is collected through specially designed schedule by personal interview method.

STRUCTURAL RATIOS AND TECHNICAL CO-EFFICIENTS

The structural ratios and technical co-efficients pertaining to semi-automatic and automatic process have been computed from sample data and presented in Table 1.

Labour-Intensity

There are four indices viz., capital - labour (K/L), capital - output (K/O), Labour-output (L/O) and wages - value added (W/V) ratios in the literature to measure labour-intensity.[7] However, as the wage cost is included in emoluments, the emoluments - value added (E/V) ratio may be used instead of wages - value added ratio.

Table 1
Structural Ratios and Technical Coefficients

Ratio/coefficient	Semi-automatic process	Automatic process
Capital-labour (K/L) (Rs.)	15,391	39,642
Capital-output (K/O)	0.944	0.383
Labour-output (L/O)	0.00006	0.000009
Emoluments-value added (E/V)	0.433	0.293
Output-capital (O/K)	1.059	2.61
Output-labour (O/L) (Rs.)	16,304	1,03,455
Value added-capital (V/K)	0.274	0.576
Value added-labour (V/L) (Rs.)	4,217	22,845
Value added-output (V/O)	0.259	0.221
Surplus-capital (%)	16	40.402
Surplus-labour (S/L) (Rs.)	2,391	16,016
Surplus-output (%)	15	15.48

Source: Sample Survey.

The capital-labour (K/L) ratio shows that the semi-automatic process provides nearly two and a half times as much employment per unit of capital as the automatic process. Then a question arises as to why and how did a technology that does not seem to be dictated by the necessity and resource endowments of a country get embodied and embedded along with the indigenous technologies. The possible causes are: firstly, the government allowed the free entry of capital-intensive technology to India; secondly, the government at that time was not interested in the widespread acceptance and development of semi-automatic technology; thirdly, the success of Coca-Cola has prompted the entrepreneurs to start automatic plants on franchise lines even after the exit of Coca-Cola rather than the revival of handmade units; and finally, development of the taste of the public for hygienically manufactured and bottled soft-drinks.

The capital output (K/O) ratio indicates that the capital required per unit of output is 2.5 times higher in semi-automatic process than automatic one. The semi-automatic units are of recent origin and they confront the problems of initial production as well as marketing. In other words, these units are confronted with the problem of overcoming the rigidities in the supply of the other cooperating factors required to work with capital. Capital base is also not reduced in these units as a consequence of their nascent emergence. Hence, these are the rationale of higher capital-output ratio in the semi-automatic units. Over a period of time this ratio is bound to undergo a change and it may turn favourable to small units as in the case of other industries.

The K/O ratio apparently supports the argument that the labour-intensive technology generates more employment per unit of output but sacrifices output. However, a closer scrutiny reveals that the seeming difference in K/O ratio between semi-automatic and automatic plants is due to the fact that it does not include any handmade technique that is comparable to the small-scale unit. What obtains is two ranges within capital-intensive technology, one semi-automatic and the other automatic. There are ominous tendencies that the high K/O ratio in semi-automatic plants may be a reflection of their inability to face competition from the automatic plants backed by the high power sales strategies of the larger producers. The very process of concentration of production in the hands of a few franchise peddling firms may spell a threat to the survival of semi-automatic independent units.

From the view point of labour-output (L/O) ratio, the semi-automatic plant generates employment per unit of output 6.7 times more than the automatic plant. In terms of emoluments - value added (E/V) ratio, it implies that the labour-intensity in semi-automatic technique is greater than mechanised technique. Thus there is a labour-intensity in semi-automatic process except from the view point of K/O ratio.

Productivity

Capital productivity is 1.06 in semi-automatic process while 2.61 in automatic process. Labour productivity in semi-automatic process is Rs. 16,304 whereas it is Rs. 1,03,455 in the automatic process resulting 6 times higher in the latter over the former. It may be said that the productivity is higher in automatic process compared to the other.

Value Added

A labourer generates value to the extent of Rs. 4,217 in semi-mechanised unit whilst it is Rs. 22,845 in mechanised unit. In other words, the value added-labour (V/L) ratio in the latter is 5.4 times greater than the former. The value added-capital ratio is 0.27 and 0.58 in semi-automatic and automatic techniques respectively. It shows that more capital is required to generate value in the former rather than the latter. A unit of output produces 0.26 in semi-automatic technique vis-a-vis 0.22 in the automatic technique. The resource use efficiency in terms of V/L and V/O ratios are in favour of the former while V/K for the latter.

Generation of Surplus

The percentage of surplus on capital is 16 in semi-automatic unit as against 40 in automatic unit. However, the percentage of surplus on output in both the cases is 15. A labourer generates surplus to a level of Rs. 2,391 in semi-mechanised firm but Rs. 16,016 in the other category. Further, there does not appear to be any reason to believe that employment generation at present would stimulate additional consumption much more than additional production. Such situation can occur only under circumstances where the overall savings is suboptimal but not in India where the savings ratio is fairly high. Besides, as considerations of growth are to be taken care of by the basic and heavy industries, consumer goods industry like soft-drinks is to be guided and developed more by considerations of equity.

OTHER FACTORS AFFECTING CHOICE

Apart from ratios and coefficients, other factors may influence and sometimes determine the technological choice. Hence, further analysed in terms of capacity utilization, skill intensity, consumption of power and fuel, market coverage, etc.

Cost of Repairs and Maintenance

In spite of all the limitations in the computation of repairs and maintenance cost, it is Rs. 0.04 in the case of automatic and Rs. 0.05 in the semi-automatic processes per unit of output.[8] Therefore, there is an inverse relationship between repair cost and mechanisation.

Capacity Utilization

As the goods are manufactured partly with machines and partly with labour in semi-automatic process, there is no scope to determine the installed capacity and so the comparison with automatic units as regards capacity utilization does not arise. The capacity utilization in automatic units is found to be 28 percent.[9] The reasons reported for under-utilization of capacity are: factories have worked for two shifts in some seasons and one shift in other seasons and closure in some period of the year; and seasonal variation in demand.

Emoluments-Labour (E/L) Ratio

The emoluments per worker per year in semi-automatic and automatic processes are Rs. 1,826 and Rs. 6,829 respectively.[10] The mechanised firm pays nearly four times higher than the semi-mechanised firm. The underlying causes for difference in emoluments between these techniques include variation in labour productivity, rural - urban living differences, skill differences, wage policy, trade-unionism, scale of production, etc.

Skill Composition

We notice from Table 2 that there is a significant difference in skill composition among firms. The skilled labour force in automatic process is 46 percent of the total workers as against 35 percent in semi-automatic process. In the case of semi-skilled labour, the former employed 39 percent whereas the latter 26 percent. The percentage of unskilled workers is 15 and 39 in mechanised and semi-mechanised techniques respectively. There is a positive relationship between the level of technique and the degree of skill.

Table 2
Average Skill Composition of Employment

Category of labourers	Semi-automatic process	Automatic process
Skilled	8 (35)	56 (46)
Semi-skilled	6 (26)	48 (39)
Unskilled	9 (39)	19 (15)
Total	23 (100)	123 (100)

Note: Figures in brackets indicate the percentage to total.

Source: Sample Survey.

Nature of Employment

This industry does not provide continuous employment as it is seasonal. There are significant seasonal variations in the employment factor. All the units worked for about 230 days on an average per year.[11] The daily working hours varied from season to season. There are no piece-wage workers in the industry. The percentage of monthly paid workers is 57 in semi-automatic process and 84 in automatic process (see Table 3). The daily wage workers constitute 43 percent in the former while 16 percent in the latter. There is a positive association between capital-intensity and monthly paid workers and an inverse relationship between the former and daily wage workers.

Table 3
Tature of Employment

Category of workers	Semi-automatic process	Automatic process
Monthly wage	13 (57)	103 (84)
Daily wage	10 (43)	20 (16)
Total	23 (100)	123 (100)

Note: Figures in brackets indicate the percentage to total.

Source: Sample Survey.

Sex Composition of Employment

Sex-wise composition of work force is presented in Table 4. Male workers dominate the scene of employment with 90 percent in automatic firms and 87 percent in semi-automatic plants. The residual is accounted for women workers. The share of these workers is relatively low in both

Table 4
Age and Sex Distribution of Workers

Category of workers	Semi-automatic process	Automatic process
Men	20 (87)	111 (90)
Women	3 (13)	12 (10)
Total	23 (100)	123 (100)

Note: Figures in brackets indicate the percentage to total.

Source: Sample Survey.

the techniques due to mechanical operations. Therefore, the nature of employment does not differ significantly between the techniques.

Consumption of Power and Fuel

Table 5 gives the consumption pattern of fuel and power. The energy-output ratio is 0.01 in the semi-automatic process while 0.02 in the automatic process. The annual cost of power and fuel per labourer is Rs. 208 and Rs. 1,844 in the former and the latter respectively. Thus the energy-output and energy-labour ratios are directly related to the mechanisation of the technique.

Table 5
Consumption of Power and Fuel

Technique	Energy-output ratio	Per labourer per annum Rs.
Semi-automatic	0.013	208
Automatic	0.018	1,844

Source: Sample Survey.

Market Coverage and Distribution Cost

This industry is the child of advertising, supported by an extensive distribution network. It is only vigorous promotion which can successfully launch and cultivate a market for a flavour. Besides advertisement, promotion involves the use or creation of distribution agencies in prospective centres. Agents and retail outlets are involved in the chain of distribution between the producer and consumer. Thus the drink is sold through both direct and indirect channels as it is a consumer goods item.

Hence, the manufacturer has to employ indirect channels of distribution due to frequent purchases; consumers are spread over the market; low per unit value of the product; large number of consumers; and small quantity of purchase, etc.

The core company has allotted the market to eight firms at the time of entering into franchise agreement. The other sample firms can sell any where they like without any geographical restriction. The distribution cost per crate is Rs. 1.74 in the automatic plants whereas Rs. 2.00 in the semi-automatic ones.[12] However, the distribution cost[13] in the cost of production is 15 percent in both the techniques. The distribution costs apparently look reasonable at 15 percent. But, if we consider the exhorbitant retailers' margin, which is in the range of 60 to 65 percent of the ex-factory price of the product, the real picture of selling cost becomes clear. In fact it is this lure of high margin to retailers that has ruined the small handmade producer and reduced him into retail seller for a commission.

Knowledge about the Techniques

The formula of production of essence is a guarded secret and this imposes a barrier for the free entry of firms into this industry.. The huge selling costs associated with established brands dread the entrepreneur to step in. Hence, the persistence of oligopolistic pattern and therefore, the problems that accompany it.

CONCLUSION

The soft drinks industry provides an instance where a rupee of capital generates more employment in the relatively less capital-intensive semi-automatic technique compared to the automatic technique. But the capital required per unit of output is more in the former than the latter. Thus, it leads to the proverbial conflict between the employment maximization and output maximization. Here it may be necessary to recall that the output in this context is of non-essential category and employment is one that requires all the priority. Therefore, there is a need for assigning of the proper weight-age to employment and output, which may still favour a technique which can generate more employment. With proper fiscal measures, production in the semi-automatic units can be improved so that even the stigma of higher K/O ratio would be overcome.

From the point of surplus, the automatic technique has a comparative advantage and is conducive to the mobilization of savings. While resolving the conflict between surplus and employment one should consider that the savings are not sub-optimal in the country. Considerations relating to minimization of repair costs, skill-intensity as also less energy intensity favour labour-intensive technique. However, there is a need to make the optimum use of capital invested in both the sector and therefore, capacity utilization in the mechanised sector needs to be improved. The choice of techniques seems to be, therefore, not a question of either, or; it is question of utilising the capacity to the optimum.

Further, there is a need for a closer look into the cost structure of the soft drinks industry which has brought along with the imported technology, the techniques of high cost-high power marketing technology. This is a case where the choice of inappropriate product has brought along with it not only inappropriate production technique but the whole range of franchise dominated parasitic 'commission culture'. An erstwhile small producer is more contented in his position as a retailer because of the disproportionately high margins allowed to him. Though the Government of India could make the CCEC to pack up and withdraw from the country, the whole gamut of production and distribution practices that came with the corporation are very much there. There is a need to correct certain socially inappropriate practices left behind and here structural ratios should be viewed in the specific context of social distortions caused by certain trends in the industry.

Thus, there is no place for capital-intensive technology in this industry. The inappropriate choice should be understood in the light of the political economy of technology choice. Control over resources often decides the choice rather than the social costs and benefits. Those who have control over resources seek technological avenues where profits are likely to be high and huge. Public policy, in the interests of generation of more employment opportunities as well as raising the level of output, requires effective government intervention in industries like soft drinks to ensure an appropriate choice of technology.

On the whole the findings of the present study leads to the inference that the small scale units using labour-intensive techniques minimise the social opportunity cost and maximise efficiency in production. The promotion and development of these enterprises lead not only production of more output per unit of capital in future but also nearer the employment oriented strategy of development. There is adequate proof to show that given the political will, a proper combination of fiscal measures and direct control can steer the industrial structure towards a more appropriate pattern. Further, it proves that industrywise analysis of the economic and technical factors along with the related forces operating in the market and society are likely to be of invaluable use in the evolution of a more thorough and effective industrial strategy.

FOOTNOTES

1. J. Ramanathan, "Soft-drinks War Hotting Up", Industrial Times, Vol. 24, No. 25, December 1982, p. 6.

2. J. Ramanathan, "After Coca-Cola, What ?", Capital, Vol. 179, No. 477, August 1977, p. 225.

3. P. Govind, "The Soft-Drink Culture", Industrial Times, Vol. 21, No. 23, November 1979, p. 5.

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6. Government of India, Annual Survey of Industries, 1984-85, (New Delhi: Central Statistical Organisation), 1988, p. 90.

7. A.S. Bhalla, "The Concept and Measurement of Labour-Intensity", in Technology and Employment in Industry (ed.), A.S. Bhalla, Geneva, I.L.O., 1981, p. 25.

8. Computed from sample data.

9. Ibid.

10. Computed from Table 1.

11. Computed from sample data.

12. Ibid.

13. Here the expenses incurred by the agent as well as the retailer and also their profit margins and other selling expenses of the manufacturer are excluded while computing the distribution cost.

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Fitting Weibull Distribution

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INTRODUCTION

Different statistical distribution functions are widely used to model biological systems. For modeling expected survival or size distribution of crops in a stand, the following distributions have been frequently used:

1. Beta distribution.
2. Gamma distribution.
3. Normal distribution.
4. Weibull distribution.
5. Log-normal distribution.
6. Johnson's S_B distribution.

The above distribution functions vary in their applicability to represent the biological systems of interest. Choice of function depends upon kind of data available, knowledge of the system to model, and the different possible shapes that the distribution can assume. One simple method of choosing a few probable models to begin with is to plot the data (histogram, graph, etc.) and compare to probable shapes of different distributions. Beta and Johnson's S_B distributions are flexible i.e., they can assume different shapes depending upon values of parameters, compared to the other distributions listed above. These models are, however, difficult to fit, especially when advanced computing facilities are not available. The Weibull distribution is comparatively less flexible than the Beta and Johnson's S_B distributions, but it is easy to fit as it can be written in the closed form and parameter estimation is also simple. The Weibull distribution is a useful distribution to model biological phenomena provided the data is not sensored.

THE MODEL

The Weibull distribution is a widely used mathematical distribution function in forest modeling. The probability density function (Equation No. 1) and probability distribution function (Equation No. 2) of a two-parameter Weibull distribution for random variable X are as follows:

$$f(x) = \frac{\alpha}{\beta}\left(\frac{x}{\beta}\right)^{\alpha-1} e^{-\left(\frac{x}{\beta}\right)^{\alpha}}, \quad x \geq 0,\ \beta > 0,\ \alpha > 0 \qquad - (1)$$

$$F(x) = 1-e^{-\left(\frac{x}{\beta}\right)^{\alpha}}$$

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Where,

$f(x)$ = Probability density function
$F(x)$ = Probability distribution function
α, β = Parameters
e = Exponential

The above distribution assume different shapes depending upon values of parameters α and β. Figure No. 1 shows different shapes a two-parameter Weibull density function can take.

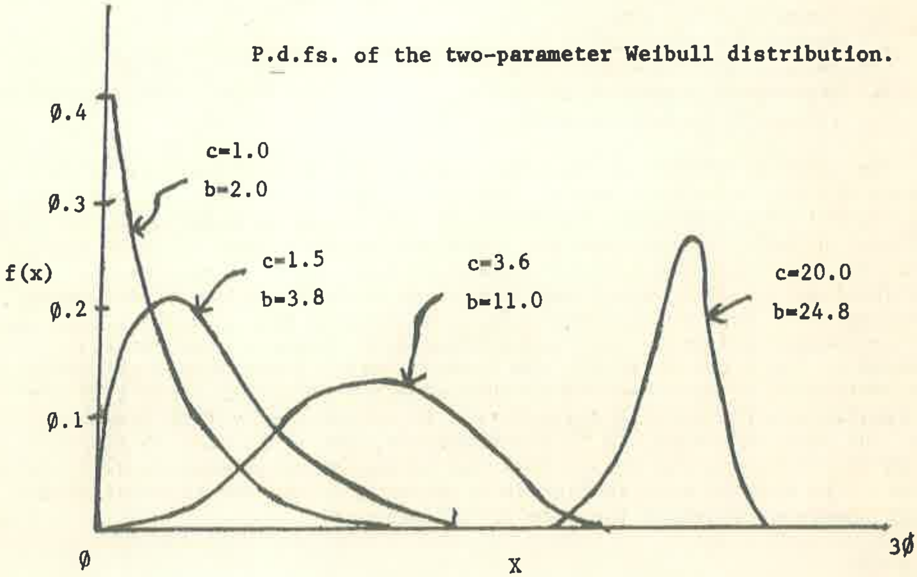

Figure No. 1

Parameters α and β are highly correlated. β is the scale parameter and α is the shape parameter. The value of β determines the spread of the curve over the X-axis and the value of α determines the shape of the curve. The above logic holds only when the value of one parameter is changed holding the other constant. Because the parameters are highly correlated, both the values have to be studied carefully before making any judgement.

FITTING THE MODEL

Once a distribution (or density) function is chosen to model the system of interest, it is important to obtain the best estimates of the parameters. Maximum likelihood estimators are frequently used. In the case of the Weibull distribution function, the maximum likelihood method is not preferred as it requires interative computations. Percentile estimators are used to estimate parameters of the Weibull distribition. Estimates of α and β can be easily obtained as:

$$\hat{\alpha} = \frac{-2.93487}{\text{loge}(x._{17n}/x._{97n})} \qquad - (3)$$

$$\hat{\beta} = e^{.5547 \text{ loge } (x._{82n}) + .4453 \text{ loge } (x._{40n})} \qquad - (4)$$

Where,

$\hat{\alpha}$ = Estimate of α

$\hat{\beta}$ = Estimate of β

$x._{17n}$ = The 17^{th} percentile value of x.

$x._{40n}$ = The 40^{th} percentile value of x.

$x._{82n}$ = The 82^{nd} percentile value of x.

$x._{97n}$ = The 97^{th} percentile value of x.

loge = Natural logarithm.

An Example in Forestry

An illustration is provided on how the Weibull distribution can be used to model the diameter distribution of a 5-year old sissoo stand in Chitwan, Nepal. When a forest crop is harvested, logs are sold at prices according to the size of the log.

i) Data

Table 1 shows the frequency distribution using raw data recorded in one 1/30th hectare plot from the stand mentioned above.

Table 1

Observed number of trees by dbh (diameter at breast height: 4.5 ft. above the ground level).

Dbh class (inch.)	No. of trees
1	0
2	6
3	16
4	19
5	8
6	2
7	2
8	2
9	0

Figure No. 2 shows a histogram drawn using the data as shown in Table 1.

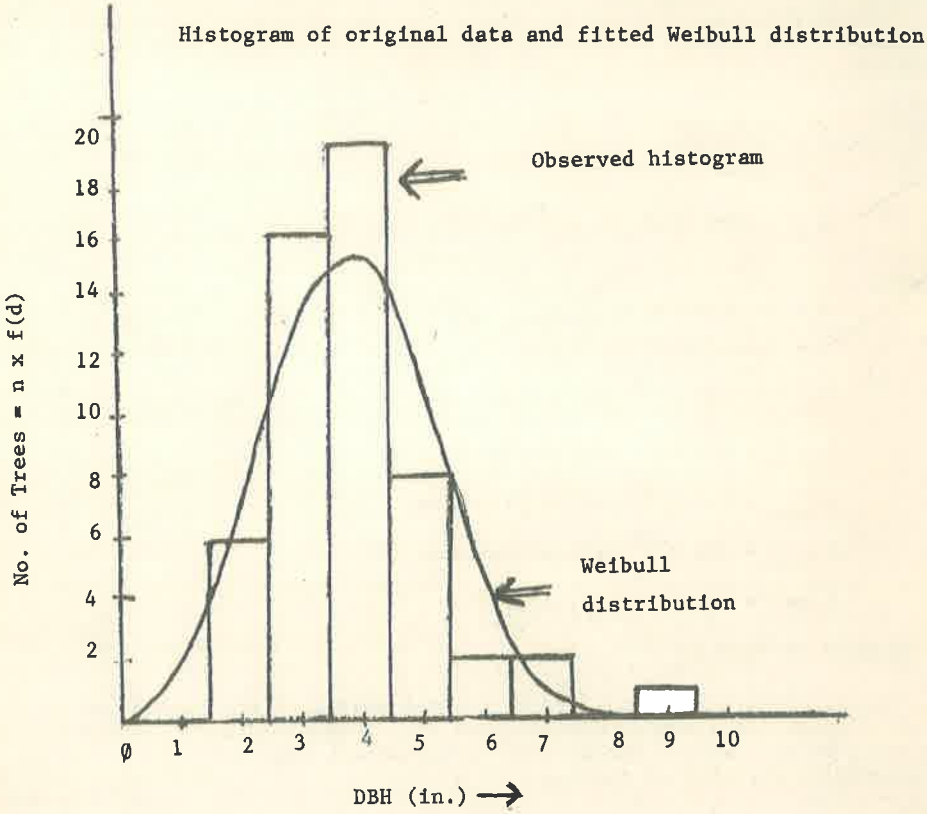

Figure No. 2

ii) Parameter estimation

$d_{.17n}$ = 2.7 inch.; $d_{.40n}$ = 3.5 inch.; $d_{.82n}$ = 5.0 inch.; $d_{.97n}$ = 6.9 inch.

$$\hat{\alpha} = \frac{-2.93487}{\log e\ (2.7/6.9)} = 3.12796011.$$

$$\hat{\beta} = e^{.5547 \log e\ (5.0)\ +\ .4453 \log e\ (3.5)} = 4.2657182.$$

Equation No. 2 can be modified to obtain the number of trees in each dbh class by:

$$n \{ F(d+w) - F(d-w) \}$$

$$\text{or, } n \{ e^{-\left(\frac{d-w}{\beta}\right)^{\alpha}} - e^{-\left(\frac{d+w}{\beta}\right)^{\alpha}} \} \qquad - (5)$$

Where,

dbh = diameter at breast height (4.5 ft. above the ground level)

n = total no. of trees
d = mid point of dbh class
w = 1/2 of class width

In this example 1" dbh classes are taken, with w = 1/2 inch when α and β are substituted by $\hat{\alpha}$ and $\hat{\beta}$, respectively, equation number 4 can be used to predict the number of trees by dbh class as follows:

Dbh class	Predicted number of trees
1	2
2	7
3	13
4	15
5	11
6	5
7	1
8	0
9	0

If computing facilities are not available, the predicted number of trees can directly be read from the graph as shown in Figure 2.

iii) Results

Whether the given data follows a particular distribution is a matter of the experience and the knowledge about the system that the data comes from. If these are not sufficient, or it is preferred to test whether such suppositions are true or not, different statistical tests can be used to perform these tests. In this example, the chi-squared (x^2) test can be used to test whether the data follow a specific, Weibull, distribution or not.

x^2 is defined as: $\sum_{i=1}^{n} \frac{(0-E)^2}{E}$

Where: 0 = Observed cell frequency.
E = Expected cell frequency.
n = No. of cells.

Dbh class	Observed frequency	Expected frequency
1	0	2
2	6	7
3	16	13
4	19	15
5	8	11
6	2	5
7	2	1
8	2	0
9	0	0

$$x^2 = \frac{(0-2)^2}{2} + \frac{(6-7)^2}{7} + \ldots\ldots + 0$$

$$= 8.2364.$$

Because the computed value of x^2 is less than the critical value $x^2_{.05,6} = 12.5916$ (out of the total 9 cells, 3 df. are lost: 2 on estimating α and β and one as $\Sigma n_i = n$) at the 5 percent level it is concluded that there is not enough evidence to reject the null hypothesis that dbh doesn't follow a Weibull distribution.

CONCLUSION

The above example shows how easily parameters of a two-parameter Weibull distribution can be estimated and used to model the system of interest. When a forest stand is evaluated economically, size classes (dbh) of crop should be considered. Trees falling in larger size classes (dbh) fetch more money per unit wood volumes than trees in smaller size classes. Once a diameter distribution is fit to estimate the number of trees by dbh class, wood volume by dbh class can easily be computed using a volume equation. As wood price per unit volume varies with tree size (dbh), dbh classes that fall under similar price categories can be pooled together while computing total wood value per hectare.

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