SOME EMPIRICAL INVESTIGATIONS ON THE DETERMINANTS OF COST BEHAVIOUR IN COAL MINING INDUSTRY

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SYNOPSIS

The paper describes the results of a few empirical investigations on the determinants of cost behaviour in coal mining industry through two field surveys undertaken at two different points in time. It attempts to analyse the structural composition of total average costs as also tries to delineate the inherent changes that took place over time on the basis of both cross-section analysis and time series data. It is observed that the overheads constitute a major share in the TAC, and their share gradually become increasingly larger over time in the lifespan of a coalfield. Subsequent to this, it is also noted that there is a discernible overheads cycle resulting from an extraction-cycle. The paper also observes that the Wage-bill contributes more towards the rising extraction costs in the coal mining industry. In this context, it is found that there is a negative correlation between the per tonne pithead costs and the proportion of materials-bill. Inter-mine variations in extraction costs have also been explained through regression analysis by identifying some of the major causal factors such as: the underground hauling distances in the mines; output per a unit of hauling distance; seam thickness; vertical depth of the workings, OMS, etc. The findings of this empirical study will be useful in devising cost control systems, pricing and extraction strategies.

The whole subject of the cost of production in coal mining industry is attaining a new level of importance and

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This is the first part of my studies on cost behaviour in Coal mining industry. The other forth-coming part will have data from 1974 onwards till 1991-92. Some more new determinants of costs will be explored, the data on which have already been collected. In the present paper, a coal mine is considered more as a "transport undertaking" than a producing or depleting asset.

usefulness, because of the renewed emphasis laid on the development of new coal fields on a large scale in several countries and especially in the vital factors of prices and their stabilization. It is, therefore, necessary that the various aspects of cost structure should be considered critically and thoroughly with the purpose of providing practical guidance to policy makers in regard to the matters of the pattern of investment, prices and wages, the closing and opening of mines or coal fields. It is in this direction that the present paper aims to bring out new empirical dimensions in cost behaviour.

On the basis of cross-section analysis, the paper examines the structural composition of costs of extraction in varied ways over two points in time as also attempts to delineate some of the diverse factors that affect costs. It also deals with the changes in cost composition over time, or in other words, the longrun cost analysis. The paper is divided broadly into Three sections. Section I presents the scope and data base for the study. It also analyses the structural composition of total unit costs at two points in time along with longrun cost analysis. Section II examines mine-by-mine structure of 'Wages' and 'materials' cost components, and also analyses the relation between costs and wage-materials components. Section III identifies some of the major determinants of cost behaviour in coal mining.

SECTION I

1.1 DATA BASE, SCOPE AND COVERAGE:

The study is based on the primary data collected through two field visits of different durations made to the same set of coal fields - one in 1968 and the other after a decade in 1980. The industry under study is a nationalised one and thus represents fairly well the character of all-India coal industry which came under public ownership in 1974. The industry does not generally agree to give data for the recent years. The period of the study therefore refers to the years 1964-65 and 1974-75. Both the years are normal. The study does not cover the opencast mines.

For the year 1964-65, the study covers 22 coal mines, spread out in five coal fields. These mines produced a total annual output of 3.65 million tonnes which formed about 5% of all-India coal output. The OMS was 0.51 tonnes in the same year. The surveyed industry under study made a substantial progress by 1974-75. As a result, the coverage of our study increased to 26 coal mines which together produced an annual total output of 6.18 million tonnes. This forms about 7% of the all-India coal output of that year. The OMS for the year 1974-75 worked out to 0.64 tonnes. Thus, the industry under survey achieved a significant progress in terms of output and OMS - 69% and 25% respectively during the reference period. In view of the fairly large size of the sample and in view of the stability and economic normalcy prevailed in the reference period, it can be stated that structures found out and the observations made in this study will have wider application.

All the mines that have been surveyed for the study are under one management. They are homogenous with respect to technology, mining methods, managerial effectiveness, wage rates, input prices and so on. This homogenity gives credence to observations made in this study.

1.2 CLASSIFICATION OF COSTS[1/]:

Detailed cost data on various aspects covering in all about 60 cost items have been collected. The study adopted a two-way classification of costs into variable and fixed costs or Direct and Overhead costs. The making of a two-fold division of costs as above is a difficult task because of the fact that no cost item is totally fixed or totally variable.

1/ For a detailed discussion on classificatory systems of costs, see Joel Dean "Managerial Economics", Prentice-Hall of India Private Ltd., New Delhi, 1968, Ch 5.

Each cost item has a mixed character.[2/] The classification adopted in the present study has thus some limitations.

1.3 STRUCTURAL COMPOSITION OF TOTAL AVERAGE COSTS (1964-65):

Unlike the case of manufacturing sector industries, the structural composition of costs differ substantially in extractive industries. This is, perhaps, in the very arrangement of production facilities and conditions.[3/]

Consequently, the extractive industries are guided by and adhere to a different set of economic/production laws. The structural composition of total average costs of coal mining industry reflects its distinctive features.

STRUCTURE OF TAC (1964-65) - ALL-INDUSTRY*: The structure of total average costs (TAC) in the coal mining industry is given in Table 1, the coverage of which is 22 coal mines lying in five coal fields with a total annual output of 3.651 million tonnes. The five coal fields presented in this Table are arranged in ascending order of their age levels so that a few broad trends over time (or age) can be observed across the coal fields. The study observes that the overhead costs form a sizable portion in the TAC of the coal industry, as it has to maintain a wide network of social and administrative infrastructures. This is necessitated by the fact that the mineral extractive industries are in general located in forest/barren areas wherein the social and civic infrastructures are conspicuously absent. The study reveals (see Table 1) that the total average overhead costs at the all-industry level form as high as 40.7% of the TAC. The composition of overhead costs indicates that it comprises a major proportion on welfare costs like housing, roads, medical care and so on. These welfare costs together account for about 6% of the TAC, or about 14% of the total average overhead costs. On the other hand, the general administrative overheads account for 5% of the TAC while the trading and technical overheads account for 4.9% and 2.7%

2/ J Maurice Clark, '<u>Studies in the Economics of Overhead Costs</u>', University of Chicago Press, 1923, P. 51.

3/ For more details, particularly regarding the logical aspects and impact analysis, See N.Naganna "Economic Analysis of Coal Mining Industry: With Some Empirical Explorations in the Behaviour of Costs and Input-Out Relations" (Unpublished Thesis): University of Poona, Poona-7. Hereafter, this will be referred to as <u>Unpublished Thesis</u>.

* "All-industry" refers to the aggregation of mines covered in the present day.

respectively at the all-industry level. Interest and depreciation charges alone constitute 16.2% of the TAC. If this item which is independent of both production and economic laws, is eliminated then the structure differs substantially in which the total average overhead costs form about 30% of the TAC instead of 40%. Similarly, other items also change their relative positions.

STRUCTURE OF TAC ACROSS COAL FIELDS: As can be observed from Table 1 that the structure of TAC varies widely across different coal fields. For instance, the proportion of technical overheads in the TAC varies from a low of 1.5% in coalfield No.5 to a high of 3.8% in coalfield No.1. The general administrative overheads vary from a low of 3.5% in coalfield No.5 to a high of about 6% in coalfield No.1, while the social overheads vary between 4% and 7%. Similar is the case with other overhead cost components. Another notable observation is that the proportion of production (or pit head) costs in the TAC also varies, though not substantially from field-to-field. There is, however, an indication that the proportion of production costs in the TAC has a tendency to decline over the age of a coalfield. In other words, the overheads gain an increasingly larger shares in the TAC overtime. For instance, the proportion of total per tonne overhead costs form 38.3% in coal field No.5, the newest one; while they stage a rise to 42.2S in the coal field No.1, the oldest one (see Table 1). Further, it can be observed from the cross-section evidence given in TAble 1 that the per tonne production costs tend to increase over time. Time/age enters in a very different way in this industry. It reflects the total impact of cumulated outputs extracted till a reference year. From this, it follows that:

- both per tonne production costs and overheads have a tendency to raise over time.

- Overheads have a tendency to increase faster than the production costs, resulting in an increasing percentage of overheads in TAC over time (Later, this proposition will be modified slightly).

- Besides, the following generalisations, though tentative, can be made:

  i) The technical overheads, both per tonne and as a % of TAC have a tendency to increase over time.

  ii) Similar is the case with the administrative and social overheads.

It may be noted that these observations are independent of price-effects and as such, they refer to real costs. The overhead costs increase faster than production costs overtime. The empirical evidence in support of the above generalisations seems to be blurred to a little extent due to deviations in normal annual rates of extraction which again is due to fertility differences in the coal deposits. The more fertile deposits are developed faster than others which would result in blurs in cross-section analysis.

TOTAL AVERAGE COSTS (1964-65) - FIELD-WISE: Besides various other factors, the TAC reflects the impact of age of the coal fields or, in other words, the impact of cumulated outputs of the past. The TAC varies widely across the five coal fields between a maximum of Rs.30.39 per tonne in coalfield No.1 and to a minimum of Rs.23.32 per tonne in coalfield No.5 (see Table 1). The maximum TAC is found to be higher by about 30% than the minimum. The all-industry TAC is worked out to be Rs. 27.41 per tonne. There are two coalfields (Nos. 1 and 2) whose TAC is considerably higher than the all-industry TAC. They are respectively higher by about 11% and 5%. In addition, these two coal fields are operating a cost which is higher than the ruling ex-colliery price of about Rs.28.50 during the reference year. However they are meeting fully their operating/variable costs. The operation of some mines/fields with costs higher than the market price is not an uncommon phenomenon to this industry. This happens because of operating some uneconomic workings with geological handicaps as in the above two coal fields[4/] (viz., Nos. 1 and 2) to meet the high pressure of coal demands on the one hand and to achieve conservation, on the other. As all these five coalfields are operated under a single management which is a public sector enterprise, the industry is following a policy of cross-subsidisation. This policy enables the industry to operate some of the mines/fields under financial losses.[5/]

THE LONGRUN COSTS: It can be observed from Table 1 that the TAC the per tonne production costs and the per tonne overhead costs increase consistently from coalfield No.5, the newest one, to coalfield No.1, the oldest one, with an only exception in coal field No.3. This exception occurred because of the inclusion of a very new field to it, resulting in reducing particularly the production costs in coalfield No.3. If adjusted, this coalfield also falls in line with the trend. The TAC increases almost continuously from

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4/ See Chapter II of the <u>Unpublished Thesis</u>, for various types of geological handicaps.

5/ The policy of cross-subsidization as is followed now by the industry tends to refute the well accepted theory of depletable resources (or the Ricardian rent Theory) which predicts that low cost resources will be exploited first. As a matter of fact, the coal industry exploits both high cost and low cost coal resources simultaneously through the above policy. This is a special feature associated with public ownership which may not hold good under private ownership.

Rs.23.32 in coalfield No.5 to Rs.30.39 in coalfield No.1, with Rs.26.07 in coalfield No.4, RS.24.52 in coalfields No.3, and Rs.28.69 in coalfield No.2. On the other hand, the overhead costs increase continuously without a fall from the newest to the oldest coalfield. They increase from Rs.8.94 per tonne in coalfield No.5 to Rs. 12.81 in coalfield No.1, with Rs.10.04 in coalfield No.4; Rs.10.48 in coalfield No.3 and Rs.11.60 in coalfield No.2. Similarly the per tonne production costs also increase almost continuously from the newest to the oldest coal field with only one exception in coalfield No.3 for the reason given already.

On the basis of the fact that the five coalfields are arranged in ascending order of their age-levels with a set of homogenous conditions such as uniform factor input prices, mining methods, technology, managerial effectiveness etc., it can be inferred that the longrun costs in the coal mining industry have tendency to rise. In other words, the longrun marginal costs increase in the extractive industries. This is the typical feature of the coal industry. This type of long run cost analysis should not be mistaken with that of the Ricardian type which is clearly explicit in his rent theory. The principal reasons in our context for rising longrun costs are: i) On the production costs front, the coal industry is subject to increasing costs with output scale (see foot note of Section 1.3). In addition, it is subject to age-size relation and the life cycle trends of various types [6/] including the depletion effect.

ii) On the overheads front, the coal fields are generally opened for extraction in forest belts with almost a zero level of overhead infrastructures. The industry creates them gradually over a period of time.

Besides the above longrun trends in costs, the components of overheads like technical, social, administrative etc., also exhibit increasing tendencies with the age of the coalfields. Not only their absolute levels, but also their proportions in the TAC[7/] show increasing tendencies over time (see Table 1). All these trends together cause both reductions and increments respectively in the proportions of production and overhead costs in the TAC overtime. There could, however, be

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6/ See Ch. IV & VI of Unpublished Thesis, for the size-cost relations and the life cycle trends including the cost behaviour as output cumulates over time.

7/ Gold. B, "New perspectives on cost theory and empirical findings", Journal of Industrial Economics, April 1966, pp 164-197. See also, N.Naganna, "Structural Composition of Costs in Coal Industry: New Perspectives" The Indian Economic Journal, Oct-Dec 1984.

assymptotic limits to these trends. In addition, these trends take place in a finite time-span because of the depleting nature of the coal deposits. All these dynamic processes take place in a very broad cyclical pattern of "opening, growth, decay and closures" of mines/coalfields which impose the upper and lower bounds for the overall extraction costs. Accordingly, the cost trends behave with asymptotic limits. The structure of costs at a particular point of time depends upon the stage in which a mine/coal field is in its life cycle pattern. In view of the structural behavioural trends in costs, the price policy and the problem of cost stability become very complex. They should enter explicitly in these issues. In the ultimate analysis, output planning across mines and coalfields of different age-levels becomes one of the effective policy instruments with which cost stability can be achieved and a rational price policy be evolved.

1.4 STRUCTURAL COMPOSITION OF TOTAL AVERAGE COSTS (1974-75):

The objective of this Section is to delineate the major structural changes that took place in the composition of TAC in 1974-75 over the year 1964-65. Further it also tries to verify the behavioural trends in costs as observed earlier. Thereby, it attempts to modify to give a final touch to the broad statements made earlier. It may be noted that the same coalfields of 1964-65 have been covered for 1974-75. However, they made a substantial progress during this period in terms of output and mine-size.

Field-wise and All-industry progress is given below:

Coal-fields	Output ('000 tons)		Average Mine Size ('000 tons)	
	1964-65	1974-75	1964-65	1974-75
Coalfield No.5	458.6	767.5 (67.4)	458.6	191.9 (-58.0)
Coalfield No.4	524.6	1749.4 (233.5)	131.1	250.0 (90.7)
Coalfield No.3	733.7	1548.8 (111.1)	91.7	221.3 (141.3)
Coalfield No.2	832.2	1126.3 (35.3)	208.1	225.3 (8.2)
Coalfield No.1	1102.2	987.0 (-10.5)	220.4	329.0 (49.2)
All-industry	3651.3	6179.0 (69.3)	165.9	237.7 (43.2)

(Figures in brackets show the % change over 1964-65).

The output of the industry under study registered a rise of about 70% in 1974-75 over 1964-65. Similarly, the mine-size witnessed a rise of about 43% during this period. The total number of working mines increased to 26 in 1974-75, from 22 in 1964-65. All the coalfields under investigation achieved different levels of progress in these terms. More importantly, the industry launched several mechanisation programme on a significant scale, though there was no shift in mining methods.8/ For instance, there was only one mine which was partially mechanised on an experimental basis during the year 1964-65. Thus, the percentage of total output drawn from mechanised sections was insignificant in 1964-65. On the other hand, the industry reported that they could mechanise five mines on a significant scale by 1974-75. Accordingly, the percentage of total all-industry output drawn from mechanised sections recorded a level of 6.1% in 1974-75. However, most of the mechanisation programmes were concentrated in coalfield No.4, due to its favourable geological conditions. It was reported that the percentage of total output of this coalfield drawn from mechanised sections was as high as 17% in 1974-75.

The notable among the structural changes as given above is the mine-size. The coal industry is subject to decreasing returns to scale or increasing costs with scale.9/ One major implication of the increased mine-size is that the industry must be raising its outputs from longer underground hauling distances than before (See Section III of this paper for the impact of hauling distance on per tonne production costs).

All the structural changes in terms of expansion that took place in the industry during the period will have a significant impact on the structural composition of total average costs. This is presented in Table 2. It reveals that the TAC for the year 1974-75 works out to be Rs.58.63 out of which the per tonne production costs are found to be

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8/ N.Naganna, "Technical Change in India's Coal Mining Industry: Structure, Trend, Impact and Extent" in V.Vyasulu (Ed) Technological Choice in Indian Environment" Sterling Publishers Pvt. Ltd., New Delhi, 1980: pp. 175-280.

9/ Briefly, the prevalence of diseconomies of scale or the increasing costs with scale in the coal mining industry can be stated in the following simple regression equation fitted between the TAVC as the dependent variable (Y) and the output size of mines in '00 tonnes as the independent variable (X) for the reference year 1964-65:

$$Y = 10.8633 + 0.0026X \qquad R^2 = 0.84$$
$$(21.67) \qquad (8.37) \qquad (n = 15)$$

Rs.43.41 and the overheads Rs.15.22, accounting respectively for 74% and 26% in the TAC. Regarding the components of overheads, it can be seen that the technical overheads per tonne are found to be Rs.2.12 forming 3.6% of the TAC: administrative overheads: Rs.2.91 (5.0%): trading overheads: Rs.2.07 (3.5%); social overheads: Rs.2.37 (4.0%); Miscellaneous: Rs.1.52 (2.6%); and interest and depreciation: Rs.4.23 (7.2%).

MAJOR DIFFERENCES IN THE STRUCTURE OF TAC IN 1974-75 OVER 1964-65: One major difference lies in the proportions of production and overhead costs in the TAC. The per tonne production costs which accounted for about 59% of the TAC during 1964-75, now takes a larger share of 74% in the TAC during 1974-75; while the per tonne overheads which constituted about 41% of the TAC during 64-65, now forms only 26% during 1974-75. This is the major change in the structure of TAC that took place during this period.

Several forces operated to produce it. Unlike in 1964-65, the production costs per tonne became more important in 1974-75. This fairly reflects the impact of output expansion along with increased mine-size in the industry on the one hand, and the impact of mechanisation programmes launched, on the other. The former was facilitated by the later. These two might have given rise to two types of distinct impacts:

i) Output expansion and the increased mine-size might have pushed the per tonne production costs upwards due to diseconomies of scale.

ii) Mechanisation programmes might have created the opposite effect of lowering down the per tonne production costs.

However, it appears that the effect of diseconomies of scale has outweighed the effect of mechanisation programmes. Further, the overhead infrastructure seems to have not grown in proportion to the expansion of output and the number of new mines (See Tables 1 and 2). This could have lowered down its proportion in TAC during 1974-75. In the same vein, the

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Figures in brackets give t-values. The coefficients are statistically significant at 1% level, confirming the prevalence of diseconomies of scale. For more details regarding the sources of diseconomies of scale, the sequence in which they set in, the reasons, the state of art, etc., see Ch. III and IV of Unpublished Thesis. Under these conditions, the problem of optimum colliery size has also been resolved.
See also, Donald Carlisle "The Economics of a Fund Resource: Mining", American Economic Review, Sept. 1954, Vol. 44, pp. 595-616.

output expansion should have generated scale-effects on per tonne over-heads which has a similar effect.

There are also substantial differences in the structure of overhead components. The 'technical' overheads which accounted for 2.7% of the TAC during 1964-65 have witnessed a rise to 3.6% during 1974-75. This reflects the need and the nature of growth of technical infrastructure to support the expanded outputs. The 'administrative' overheads retained their relative position at 5% during this period. The 'trading' overheads lost their relative position from 4.9% of the TAC during 1964-65 to 3.5% in 1974-75. The proportion of 'social' overheads in the TAC declined substantially from 5.8% during 1964-65 to 4.0% in 1974-75. Similarly, the 'miscellaneous' component declined to 2.6% in 1974-75 from 6.1% in 1964-65. Surprisingly, the 'interest and depreciation' which constitutes as high as 16.2% of the TAC during 1964-65 registered a remarkable fall of 7.2% during 1974-75. It may be noted that there are a few classificatory changes in the costing system and financial management practices adopted by the industry during this period. They took place mainly in the "miscellaneous" component and 'trading' overheads. This aside, the overall evidence on the structure of TAC at two points in time indicate that the overhead infrastructure did not grow proportionately with the growth of the industry. The social overheads is a case in point. Consequently, it has lost its relative importance in the TAC while the production cost has gained increasing importance during the period under study. As these changes take place in a cyclical pattern in a bounded-way, the overheads are likely to gain increasing importance (in the TAC) in the coming years.

PERCENTAGE CHANGES IN PER TONNE COSTS IN 1974-75:

Different cost components have increased at different rates during the period. This analysis would show which of the cost components contributed more towards the total rise in the TAC during this period. It also reflects the impact of general inflationary tendencies prevailed in the economy during this period. It is assumed that the general inflation during this period will have uniform impacts on all cost items. At the outset, it may be noted that the TAC recorded a sizable rise of 113.9% during 1974-75 over the year 1964-65 (see Table 2). As against this, the per tonne production costs registered a faster rate of increase by 167.1% in 1974-75 over the earlier year. In contrast with this, the per tonne overhead costs mustered a rise of only 36.4% during this period. The overhead components have witnessed different rates of change (see Table 2). The 'technical' overheads mustered a high increase of 182.7% in 1974-75 over the year 1964-65; while the 'administrative' overheads also made a similar rise of 112.4%. These two components recorded faster rates of increase than others between 1974-75 and

1964-65. The 'trading' overheads increased by 55.6% in 1974-75 over 1964-65; and the 'social' overheads by 49.1% during this period. In contrast with these positive changes, the 'interest and depreciation' and the 'miscellaneous' components showed declining trends respectively by 4.5% and 9.5% in 1974-75 over 1964-65. These two declines show the classificatory changes made in the costing system on the one hand and the changes in financial management on the other. One can workout the cost proportions by excluding the 'interest and deprecition' from TAC.

The above relative changes in the per tonne costs of various components between 1974-75 and 1964-65 indicate that the production costs have contributed more towards the rising total costs in the industry during this period by way of their faster rates of increase. On the other hand, the overhead infrastructure lagged much behind the production costs. However, they are likely to take a rising trend in the coming years to cope with the expanded levels of output. As the coal industry is subject to increasing costs, the phenomenal growth of the industry in terms of output, the number of mines, and the mine-size has resulted in raising the per tonne production costs faster than the overheads and thus enhancing their proportion in the TAC.

THE LONGRUN TRENDS IN THE COSTS (1974-75): As in Table 1, the same five coalfields are arranged in increasing order of their age levels in Table 2 to verify the observations made earlier. Due to the effect of the expansion in the industry during the period, the observations made earlier on the long run cost behaviour are slightly blurred. On the whole, the evidence as presented in Table 2 confirms the trends established earlier. The TAC rises persistently across the coalfields (except the coalfield No.5) and so also, the per tonne production costs. The per tonne overheads increase continuously from the newest to the oldest coalfield (See Table 2). As these coalfields are arranged in increasing order of their age levels, it confirms the fact that the long run costs in the coal industry have a tendency to rise. In other words, the longrun marginal costs rise in this industry.[10/] Not only their absolute levels, but also their proportions in the TAC undergo changes over time. Some overheads grow faster; some do not; and some decline in their relative importance in the TAC. On the basis of overall evidence, it can be stated that the proportion of 'administrative' overheads, technical overheads, and that of the 'social' overheads have a tendency to increase overtime.

10/ Oriss C. Herfindahl, "Three Studies in Mineral Economics" RFF Inc., Washington D.C. 1961; Particularly the one on "Longrun costs in Mining". See also, - "Some Fundamentals of Mineral Economics" Land Economics, 1955, Vol. 31, PP. 131-38.

They become increasingly important in the TAC. This shows the nature of the growth of overhead infrastructure in this industry over a period of time.[11/] Other types of, overheads viz., Trading and "Interest and depreciation" are mostly matters of Policy and financial management practices. Although these generalisations are not totally tentative in nature, they need validation with larger samples.

The phenomenon of cross-subsidization still persists in the industry in 1974-75 because it is operating some of the coalfields at costs above the over-all TAC of the industry and above the market price of coal as well (see Table 2). This policy is, perhaps, inherent in extractive industries to achieve stability over time in terms of outputs, costs, etc., and to achieve conservation in extraction. In its absence, and under the private ownership with competitive market conditions, the geologically handicapped mines will tend to be closed, resulting in waste/loss of mineral resources.

AN OVERVIEW: The TAC in the coal industry is a complex whole reflecting many and varied kinds of influences which are often off-setting, mutually conflicting and opposing too. For instance, the overheads and the extraction costs are guided by and adhere to different set of laws. The extent and composition of overheads are guided by the attitudes, policies and the culture of management, the profitability levels, the strength of institutional factors like trade unions and other associations, and so on. On the other hand, the production costs are guided by the conventional production laws, the geological and other natural factors, the locational factors and so on. In point of these differences, it is better to treat them separately because they are not additive for analytical purposes. However, aggregation into the TAC may be made to arrive at an appropriate pricing policy.

The study reveals that the extent of overhead infrastructure is subject to two major influences:

- the scale effects.

- the age of a coalfield reflecting a progressive and gradual additions to overheads stock.

These two exert opposing influences on the per tonne overheads through time. The first factor has a lowering effect while the second has a pushing-effect on the per tonne

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11/ There is a substantial rise during 74-75 in the per tonne overheads of coal field No.1. This could be partly due to the fall in its output level. However, even considering the output level of 1964-65 for this coalfield, the pattern of trends do not change much.

overheads. Experience shows that the second one overweighs the former influence (due to limited scope for scale economies), resulting in increased levels of per tonne overheads through time. Consequently, the overheads become increasingly important over time.

The production costs in the coal industry on the other hand, are subject to diseconomies of scale/increasing costs which in ultimate analysis results logically in "smallness of mine-size". This comes into direct conflict with the large scale expansion schemes envisaged by the coal industry in the recent years. The output expansion (possibly with partial mechanisation schemes) resulting in increased mine-size leads to rising per tonne extraction costs in the industry. Because, the positive gains of expansion like fuller rate of utilisation of factor-inputs etc., will significantly be offset by the increased mine-size with concomitant longer haulage ways (see Section III). But, expansion will have scale-economies on the overheads. Thus, the TAC in coal industry is a complex phenomenon reflecting the impact of mutually opposing forces. Merely because the overheads are subject to scale economies, one should not recommend output expansion/large sized mines to reap the scale benefits because its counterpart i.e., the production costs is subject to diseconomies of scale. Therefore, the industry has to make a rational balance between the expansion schemes and the extent of overhead infrastructure. The expansion schemes should be carefully examined in relation to its impact on operating costs, mine size, coalfield size, the number of mines and the extent of overheads needed to support such schemes through the cost point of view. Thus, an overall planning for the coal sector is needed to achieve its targets at the least cost point.

1.5 THE CHANGING STRUCTURE OF COSTS: TIME SERIES ANALYSIS:

The observations made so far on the cost structure and its trends were based on the cross-section analysis of five coalfields. In this section, a time series analysis is adopted to bring out the structural trends in the TAC through time. It is assumed that the price changes in factor inputs have uniform effect on all cost components. Detailed cost data have been collected for a sufficiently long time period from 1955 to 1974-75. It covers only two coalfields because of non-availability of time series data for others. These two fields are homogenous with respect to their history, growth and the geological conditions. They were respectively opened in the years 1918 and 1927. The area under lease reflecting the coal bearing strata is respectively 500 and 100 sq. miles with proved coal resources of 600 and 350 million tonnes. Due to lack of space and other constraints, the data has been broadly aggregated into only two major components viz., overheads and production costs. Further, this would facilitate to test a working hypothesis as proposed by the National Bureau of Economic Research, USA (NBER) Study[12/] The NBER study observes:

"It is a pertinent question whether these elements of overhead costs have increased as a proportion of total costs in recent years ... There is general evidence, however, that the kinds of costs that are 'fixed' with respect to output (or atleast undergo only small changes) in a single accounting period have become somewhat more important". Further they state: ".... on general grounds there are reasons to suspect that the proportion (of overheads in TC) tends to increase" (emphasis added). This study also gives some reasons for such a trend.

The evidence given below confirms the NBER hypothesis that the proportion of overhead costs in the TAC tends to increase over time; subject, however, to asymptotic limits.

THE STRUCTURE OF T.A.C. OVER TIME (OR THE LONGRUN BEHAVIOUR OF COSTS)

Year	Average Overhead Costs (A.O.H.) @		Average Variable Costs (A.V.C.)		Total Average Costs (T.A.C.)	
	Index	%	Index	%	Index	%
1955	=100	25.5	=100	74.5	=100	100.0
1956	106.4	24.8	110.6	75.2	119.6	100.0
1958	123.2	25.7	122.5	74.2	122.6	100.0
1960	140.7	27.9	124.6	72.1	128.7	100.0
1961	131.4	27.1	121.2	72.9	123.8	100.0
1962-63	146.5	29.5	120.1	70.5	126.9	100.0
1964-65	192.2	32.8	135.4	67.2	149.9	100.0
1965-66	210.6	33.2	145.6	66.8	162.2	100.0
1974-75*	320.5	22.6	375.8	77.4	361.7	100.0

Source: Field Investigations.

@ Here, the A.O.H. does not include "Interest and depreciation.

* Data for this intervening period could not be obtained. For a detailed item-by-item break-up of costs, see the unpublished thesis.

12/ "Cost Behaviour and Price Policy", a study prepared by the Committee on Price Determination for the Conference on Price Research, National Bureau of Economic Research, New York, 1943, pp. 58 and 78.

The above evidence clearly indicates that the percentage of overhead costs in TAC has increased in the coal industry during the period 1955 to 1965-66. The increase is substantial from 25.5% in 1955 to 33.2% in 1965-66. There is almost a continuous and persistent rise in the proportion of overheads in TAC during this period. Correspondingly, the percentage of AVC in TAC has declined during this period.

The proportions of overhads and variable costs in total costs depend upon the relative pull and push of various factors. As there was no significant technological or other changes in the coal industry under study during the reference period, the changes in the proportions in TAC over time are attributed mainly to overheads.

Logically, the proportion of AOH in TAC cannot go on increasing overtime because it is a simple absurdity to visualize a situation wherein the overheads occupy a near 100% level in the TAC. This just cannot exist. Therefore, at some point or the other, the asymptotic limits will set-in beyond which there cannot be any rise in the proportion of overheads in TAC. In the present study, it appears that they were set in some time after 1965-66. Consequently, the proportion of AOH in TAC staged a decline to 22.6% in 1974-75 from 33.2% in 1965-66. This decline is mainly due to the depleting nature of the coal deposits embedded in the coalfields and partly due to increasing production costs. The former imposes a limit on the additional expansion of overheads or even withdrawal of some of the existing overhead items. As a result, its proportion tends to decline after the asymptotic limits are set in. On the other hand, the extraction costs per tonne tends to rise in the old mines/coalfields[13], which pushes upwards the proportion of extraction costs in the TAC. As a result of these pushes and pulls, the percentage of overheads in TAC has declined during 1974-75.

There is yet one more noticeable feature. The pattern of rates of change in AOH, AVC and TAC is different between the two periods, viz., 1955 to 1965-66 and 1965-66 to 1974-75. The index of AOH has increased faster than the index of AVC and that of the TAC during the first period between 1955 to 1965-66. Thereafter, it lagged behind the indices of AVC and TAC. Instead, the index of AVC increased faster than the indices of AOH and TAC during the second period between 1965-66 to 1974-75. These trends clearly indicate that it is the overheads that contribute more towards rising costs during the first period, while the variable costs contribute more

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13/ See Chapter VI of unpublished thesis for life cycle theory of the mine. It also explains the reasons why the per tonne production costs tends to rise in the old mines or as outputs cumulate over time.

during the second period. This is one of the distinctive features of longrun cost behaviour in coal industry. It is the consequence of exhaustibility of coal resources. On the basis of the relative growth rates of AOH, AVC and TAC, and on the basis of the life cycle trends in extraction costs, it can be generalized that the overheads contribute increasingly more towards rising costs during the first phase in the life span of a coalfield; while the extraction costs contribute more during the second phase.[14/] This is same as saying that the industry can get 'easy coal' during the first phase in the life span of a coalfield; while it becomes increasingly difficult to get coal during the second phase. This happened because of two reasons. Firstly, there will be the depletion of more fertile deposits and secondly, the mines decline in their productivity/fertility.

Graphically, it can be hypothesized that the shape of AOH curve with respect to time would be generally an inverted U-shape one with a flat top[15/]. This graphic relation explains the nature and composition of the rising long run costs in the coal mining industry (as observed in the earlier section).

The trends in long run cost behavior are more discernible in the compound annual growth rates computed on the basis of end years for the data presented earlier.

Period		Compound annual growth rates (%)		
		A.O.H.	A.V.C.	T.A.C.
i)	1955 to 1965-66	7.7	3.8	5.0
ii)	1965-66 to 1974-75	5.3	11.1	9.3
iii)	1955 to 1974-75 (overall period)	6.3	7.3	7.0

14/ It may be noted that a coalfield has a finite life span which is divided here into two broad phases for the sake of convenience. This has been made on the basis of the turning point in the proportions of AVC and AOH in TAC over the broad life span of a coal field. The turning point need not necessarily take a sharp turn, but takes place over a range. The length of the life span of a coal field depends upon several factors such as the amount of reserves and their qualitative features, the annual rate of recovery etc. However, it may be in the range of 50 to 75 years.

15/ The empirical evidence as brought out recently by one of our research students show that the % of AOH in TAC is only about 8 to 10% for a very new and comparable coal

It is evident that the AOH registered faster rates of growth during the first period, while the AVC did so during the second period. There is thus a clear shift in their relative contributions to total rising costs in the industry over time. This confirms the graphic relation established before. However, considering the overall period (1955 to 1974-75), it is clear from the growth rates that the AVC or the extraction costs have contributed comparatively more towards the total rise in the TAC. They also contribute more towards the rising costs in the longrun. It can thus be inferred that the extraction cost dominate the total life cycle cost of a coalfield. In other words, extraction costs obviously form a larger share in the total life cycle costs of a coalfield.

1.6 COAL EXTRACTION CYCLE AND OVERHEADS: On the basis of surface data regarding the earth's crust, the presence of coal below the ground is inferred. This will be followed by intensible drilling operations which confirm the extent of economically and technically workable coal reserves over a specified region. This region is denoted as a coal field in which a number of mines (depending upon the extent of coal bearing area) will be opened for winning coal. To facilitate and conduce the extracting operations, the overhead infrastructure facilities will start growing gradually over time. As the coal resources are exhaustible, the embedded coals under the mines will start depleting over a period of time. Consequently, when the coals are depleted, the closure of mines start taking place in a coal field. Then takes place the retardation in the growth of overheads and slowly they will be virtually withdrawn. For instance, when mines are closed, the office buildings, roads, transmission lines, township and so on will be abandoned. In the meantime, the search for new coal deposits/mines continues and the cycle repeats. The fall in the output level of coalfield No.1 (the oldest one) and the slower rate of growth of output in coalfield No.2 (the next oldest one) confirms the coal

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fields of less than 10 years age from the Western Coalfields. This would support the hypothesis in question.

extraction cycle a reality[16/] (see Section 1.4). This would explain briefly the nature of cyclical behaviour of overheads in the coal mining industry over time. As a matter of fact, the extraction cycle gives rise to the overheads cycle in the life span of a coalfield.

16/ Further, an inverted U-shaped age-size relation established empirically on the basis of 21 collieries reiterates the prevalence of a coal cycle. The relation is as below:

$$Y = \underset{(2.96)}{39.325} + \underset{(4.28)}{345.710X} - \underset{(-3.13)}{9.516X^2} \qquad R^2 = 0.63$$

Where Y = Mine output (in '00 tonnes)
X = Age (in years)

Figures in brackets show t-values. The coefficients are statistically significant at 1% level. This regression model would also indicate the nature of coal supply function particularly with respect to time/age.

SECTION II

So far the cost analysis was carried out at the aggregate level. In this Section, it will be made at the mine level. All the surveyed mines have 'incline' type of entry and they adopt the popular 'Bord and pillar' method of extraction with mostly 'caving'. Each one operates under different sets of widely varying natural and working conditions. All the mines covered in the present study vary substantially in size, age, history and natural conditions. The resource base its quality and quantity, exhibits wide inter-mine variations. The structure of mining operations differs. All these factors together produce inter-mine variations in unit operating costs and their composition by 'wages' and 'materials'. The typical feature of the coal mining industry is that the composition of extraction costs by wages and materials varies from mine-to-mine under given technology and mining methods and also with a given factor-input prices. In this section, the pattern of behaviour of the wage-materials cost components in extraction costs across the mines is analysed.

2.1 INTER-MINE VARIATIONS IN THE COMPOSITION OF EXTRACTION COSTS BY "WAGES" AND "MATERIALS":

Mine-by-mine composition of extraction (or pithead) costs by "wages" and "materials" is given in Tables 3 and 4 respectively for the years 1974-75 and 1964-65. The evidence in these tables indicate broadly that the industry did not undergo any major technological change during the period; it also reflects that the industry maintained the same type of mine-mix. This is inferred on the basis of the fact that the proportions of "Wages" and "Materials" at the all-industry level did not change significantly during the period between 1964-65 and 1974-75.

There are large inter-mine variations in the total per tonne pithead costs and its composition because they extract coal under widely varying natural and working conditions. During the year 1974-75 (see Table 3), the range of per tonne pithead costs lies in between a high of Rs.54.23 in mine-v and a low of Rs.31.09 in mine-m with a difference of Rs.23.14 per tonne or 74.4% over the minimum. This is, indeed substantial. The highest cost is found to be more by Rs.10.82 (or 25%) over the all-industry average of Rs.43.41. Similarly, the lowest cost is observed to be lower by Rs.12.32 (or 28.4%) over the all-industry average. So also, the per tonne 'wages cost' varies widely in the range of Rs.41.56 in mine-x and Rs.22.67 in mine-m with a difference of Rs.18.89 or 83% over the minimum. The per tonne "materials cost" also varies substantially in the range of Rs.16.22 in mine-v and Rs.8.19 in mine-y with a difference of Rs.8.03 or 98% over the minimum.

Regarding the proportion of 'Wage' cost component in total pithead costs per tonne, it can be found (see Table 3) that the highest is at 79.9% in mine-y and the lowest at 63.7% in mind-d as against the all-industry proportion of 73%. In contrast with this, the proportion of 'materials' cost component is found to be highest at 36.3% in mine-d and lowest at mine-y, as against the all-industry proportion of 27%. In between these extreme cases, the 'wage-materials' proportions vary in the other mines.

More or less, a similar pattern of inter-mine disparities in pithead costs per tonne and their composition can also be found for the year 1964-65 (see Table 4). It needs no explanation. It is clearly evident that the wage-materials composition in production costs is not stable across the mines although the technology, mining methods and factor-input prices are same over all the mines.

The coefficient of variation as a measure of inter-mine variability computed over the surveyed mines for each cost element is given below:

Cost element	*Coefficient of variation (%) 1964-65	1974-75
1. Wage cost per tonne	31.9 (31.9)	13.6 (15.8)
2. Wages cost - %	7.6 (7.1)	13.1 (4.9)
3. Materials cost per tonne	17.2 (17.3)	16.1 (14.4)
4. Materials cost - %	17.9 (21.4)	15.1 (17.2)
5. Total pithead costs per tonne	25.8 (26.0)	13.5 (12.8)

* Figures in brackets show the variation after excluding the cost of Power consumption.

The notable point in the above pattern of inter-mine variations is that the coefficients of variation have declined significantly during 1974-75 over the earlier year 1964-65. It reveals that the industry could achieve stability in terms of unit production costs. In one sense, it shows an improvement in performance/efficiency of the industry because it is operating more uniform undertakings under more stable cost conditions than before reflecting a better output planning.

2.2 PROPORTIONS OF 'WAGE-MATERIALS' COST COMPONENTS IN HIGH AND LOW COST MINES:

There is yet an important observation in Tables 3 and 4. It can be noticed that all the high-cost bearing mines have relatively low proportions of materials cost in their respective pithead costs. On the other hand, these mines rightly have higher proportions of "wages" cost. An opposite situation can be observed in the case of low-cost bearing mines. This is broadly the type of divergence in the structure of pithead costs between the 'high' and 'low' cost bearing mines. In explanation of this, a simple correlation coefficient has been computed between the total per tonne pithead costs and the % of materials cost for the years 1974-75 and 1964-65. They are as below:

Year	Correlation Coefficient	Correlation Coefficient*
1974-75	-0.61 (n=26)	-0.70 (n=20)
1964-65	-0.67 (n=22)	-0.77 (n=18)

(n= number of mines)

Another correlation coefficient has been computed between the total per tonne pithead costs excluding the cost of power consumption and the % of materials cost. The cost of power has been removed because it is felt that it is not a material in the normal sense. The correlation coefficients are found to be higher as below:

Year	Correlation Coefficient	Correlation Coefficient*
1974-75	-0.74 (n=26)	-0.77 (n=20)
1964-65	-0.68 (n=22)	-0.76 (n=18)

(n = number of mines)

The correlations as given above are quite high. From this pattern, it can be inferred that it is the wages-bill

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* Some of the deviant mines have been deleted from computation because either they are partially mechanized or suffer from some acute geological handicaps.

and not the materials-bill that contributes more towards increasing costs in the coal mining industry. In support of this inference, it has also been observed through regression analysis that most of the material-input coefficients do not bear a statistically significant linear relationship with the unit pithead costs, while the labour-coefficients do bear.[17] In addition, the labour productivity (O.M.S.) is found to be low in the high-cost bearing mines and vice versa (see Section III of this paper). In view of all this, it can be reiterated that it is the labour-inputs that cause the inter-mine variations in pithead costs, or rather increasing costs either with increasing output scale or through time, in the coal mining industry. Although the observation is confined only to a limited number of mines - 22 and 26, the generalization based on it, will be of wider application both in man power planning and the materials requirement planning. As stated earlier that the coal mining industry is subject to diseconomies of scale in extraction.[18] It is now clear that the diseconomies are set in more by wages cost than by the materials cost. Same could be true in the case of longrun costs. In conclusion, it can be stated that the wage-bill is a key determinant of cost behaviour either over time or over different output scales.

17/ N.Naganna, "Input Structure of the Coal Mining Industry - A Case study on the Stability of Input Coefficients" - Anvesak, Vol. IV, No.2, Dec. 1974, pp. 145-170.

18/ A Cobb-Douglas form of production function fitted to the all-India coal industry for the time series period 1954-1972 gives the following:

$$Y = 1.221\ L^{0.1020}\ K^{0.5090} \qquad (R^2 = .98)$$

where: Y - underground coal output; L= Labour employed. K = aggregate installed Horse Power. The coefficients are significant at 1% level. + = 0.6110 . This re-confirms empirically the prevalence of diseconomies of scale in coal mining industry. For this production function, the data have been drawn from N.Naganna, Opcit. See Section 1.4 of this paper. See also Lomax K.S., "Coal Production Functions for Great Britain" Journal of Royal Statistical Society, Series A, 1950. Lesser C.E.V., "Production Functions and British Coal Mining", Econometrica, Vol.23, p. 442, 1955.

SECTION III

The major objective of this section is to identify some of the important factors that exert a sizable influence on the unit operating cost levels. There are many and varied factors that affect the unit cost levels in many different ways. Some exert a position influence and some negative. The knowledge about these factors will be helpful in colliery planning, cost-controlling policies, pricing and in achieving cost stability. The major factors that have been considered here will exert more influence on operating costs than on fixed costs and hence, only operating costs have been considered. A simple regression analysis is carried out in this exercise.

The dependent variables on which the selected factors are supposed to have influence are:

a) Total average variable costs or unit operating costs (Y)

b) Cost A or the underground unit costs (Y')

3.1 FACTORS CONSIDERED OR THE DETERMINANTS OF COST BEHAVIOUR:

Some of the main factors (or explanatory variables) that are supposed to exert a significant influence on unit operating cost levels are:

1) Output per 100 feet of underground hauling distance (in tonnes) - X_1

2) Total underground hauling distance per tonne of coal raised (in feet) - X_2

3) Total underground hauling distance per working face ('00 feet) - X_3

4) Maximum depth of the working faces (in feet) - X_4

5) Total underground hauling distance of workings ('00 feet) - X_5

6) Average thickness of the seams under working (feet) - X_6

7) Output per manshift (OMS) in tonnes - X_7

THE ROLE OF HAULING DISTANCE: Depletion leads to longer hauling distances. A tonne extracted is a tonne depleted. And a tonne depleted makes the next tonne to get extracted from a longer distance from the surface. This is how, the scale of output is related to the hauling distance. As extraction goes on, the length of underground hauling distances also goes on increasing/decreasing depending upon the stage of mining operations.

Longer hauling distances lead to the consumption of larger amounts of labour, materials and capital inputs per tonne. If the workings are pushed into far off places, larger amounts of capital inputs like hauler engines, track line, wire ropes, tubs, cables, pumpsets, pipes etc., are required. The material inputs of larger magnitude are required to maintain the enhanced capital inputs. More importantly, larger amounts of labour inputs are required because, apart from other things, more labour time will be consumed in reaching the works. On the whole, the net effect of longer hauling distance is the increased unit production costs and vice versa.[19/] It has a built-in mechanism with respect to inputs and unit costs. It is thus a major determinant of cost behaviour in coal mining industry.

The longer hauling distances increase the production costs because:

(a) It requires longer time for workers to reach the workings and thereby shorterning their effective time for work. Besides, it also causes physical exertion and fatigue which make workers less effective and thereby reduces labour productivity;

(b) Supervision becomes difficult and less effective;

(c) Increase haulage costs;

(d) Ventilation becomes a problem;

(e) Increase capital and maintenance costs;

(f) Increase the number of accidents, breakdowns, etc.

19/ This implies that the additional amount of labour and other factor inputs cannot be applied with same 'advantage' as before. In Ricardian sense it reflects the 'increasing difficulty of obtaining the mineral'. See John C.Murdock, "Diminishing Returns in the Depletion of Mines" Land Economics, Nov 1956, No.4, Vol. 3, pp. 313-317. See also, Roberts Warren "Diminishing Returns in the Mining Industry" Journal of Land and Public Utility Economics, 1939,1 No.1, Vol. 15, pp. 21-28.

3.2 **THE FACTORS EXPLAINED:**

In what follows is a brief description of the explanatory variables.

1) OUTPUT PER 100 FEET HAULING DISTANCE (X_1): As output enters into this ratio, it refers to the 'intensity' of mining operations in a mine, particularly in relation to the hauling distance. This is a kind of 'concentration ratio' reflecting the mine performance in terms of productivity. It shows indirectly the extent of rate of utilisation of various factor inputs. By increasing outputs per unit length of hauling distance, a mine can achieve better utilisation of its inputs. Consequently, this can also serve as a measure of mine-productivity or a performance index. As this factor will reflect a better or fuller utilisation of various factor inputs, there will be a negative relationship between the unit costs and the 'output per 100 feet hauling distance'.

2) TOTAL UNDERGROUND HAULING DISTANCE PER TONNE OF COAL RAISED (X_2): This is the reciprocal of the earlier one. The opposite of explanation as was given in the earlier factor will hold good. The total hauling distance refers to the distance to be travelled by both the coal raisings and all the factor-inputs. Distance implies a number of things that involve cost such as the maintenance of trackline, proper roof supports, proper sides, communication network and so on. In addition, distance has an effect on the turn-round time of tubs and hence, on the requirement of the number of tubs and the haulers etc. Therefore, this factor will exert a positive influence on operating costs. The sign of this coefficients is expected to be positive.

3) UNDERGROUND HAULING DISTANCE PER WORKING FACE (X_3): A working face is an area in the mine where the actual extraction activity takes place. It is simply a producing section in mine. A mine maintains several of them at a point of time. Each working face is an independent unit of operation and separately identifiable. In view of the fact that the natural resources (coal) are "Fund Resource", their extraction has to take place not in one single place but in several places. This is the nature of resource exploitation. A mine is thus found to be a multiple-unit operating system. The following regression equation fitted between mine output in '000 tonnes (Y) and the number of working faces in a mine (X) confirms it:

$$Y = -32.599 + 20.509X$$

19.63) (15.43)

$R^2 = 0.92$

n = 21.

(Figures in brackets give the t-values)

The coefficient is significant at 1% level. These working faces in a mine have a distribution by distance from surface. On general grounds, it can be stated that wider the scattaration of the working faces, higher will be the unit operating costs because it implies longer hauling distances per tonne of coal raised. The hauling distance per working face in a mine gives the nature of the scatter of workings. The longer this distance, higher will be the costs. Its sign will be positive.

4) MAXIMUM DEPTH (X_4): As against the hauling distance which refers to the horizontal distance from surface, this refers to the vertical depth from the surface reached by the workings in a mine. Only maximum depth is noted. This will increase the gradients of the road-ways in a mine. The larger the depth, the greater will be the problems in mining operations such as roofing, dewatering, ventilation, hauling, etc. Therefore, the larger the depth, higher will be the per tonne operating costs. The sign of this coefficient will be positive.

5) TOTAL UNDERGROUND HAULING DISTANCE (X_5): It needs no explanation. It shows the extent of total distance in a mine by which the movement of coal and other inputs takes place. It also implies time dimension to the movements. Besides, it also indicates the magnitude of maintenance costs on roadways, roofing, etc. Longer the distance, higher will be the operating costs per tonne. Its coefficient will bear a positive sign.

6) AVERAGE THICKNESS OF SEAM (X_6): Unduly thick seams will pose a lot many problems in regard to extraction operations. Similar will be the case with unduly thin seams. Discussions with the mining personnel indicates that an average thickness of 8 to 10 feet for a coal seam will be the most favourable size at the present state of technology and mining methods. There are no unduly thin seams in the industry under survey. Unduly thick seams will pose several problems in regard to roofing, flooring, hauling, etc; and consequently the operating costs will be high.[20/] It will have a positive sign.

7) OUTPUT PER MANSHIFT (OR O.M.S.) (X_7): This is a measure of labour productivity commonly used in the coal mining

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20/ The problem of seam size has been extensively discussed in Martin B., Zimmerman, "Modelling Depletion in a Mineral Industry: The case of coal" The Bell Journal of Economics, 1977: Vol. 8, No. 1, pp. 41-65. It is noticeable in this study that the American coal mining situation is opposite to that of India's. So also, the conclusions.

industry. The industry is a labour-intensive one in which "wage-bill" constitutes about three fourths of the production costs. Therefore, the O.M.S. will exert a major influence on costs. The higher the O.M.S., the lower will be the unit costs and vice versa. Hence, its coefficient will have a negative sign.

THE DATA: It was very difficult to get the mine-wise distribution of workings by distance from surface. The whole data on distances was obtained not from records but from the mine layouts. Each mine has a separate layout for each of its seam under working. In the mine-layout, all the working faces operated during a year are marked in colour along with the distance from the surface and the progress made during the year. The distance between the surface and the centre of the working face has been taken as the "distance of the working face". Thus, each working face has been measured separately with the help of a scale and noted its distance. In this strenuous way, 213 working faces operated in 21 mines have been measured and arranged in various class-intervals. The data thus collected refers to the year 1964-65 and are presented in Table 5. Except the O.M.S. the rest of the data refer to the engineering variables. Extraction operations are undertaken in a given frame of a matrix of technology/mining conditions. Therefore, the engineering data are useful in analyzing the economic phenomena.21/

3.3 EXTENT OF VARIABILITY AMONG THE FACTORS

The factors that have been identified, reflecting specific cost conditions, vary widely from one coal field to the other and also from one mine to the other within a coal field. The extent of variation among the factors is given below:

Factors	Mean	S.D.	C.V.
X_1	515.5	150.5	29.2
X_2	0.2155	0.0790	36.7
X_3	33.21	12.63	38.0
X_4	614.84	157.07	25.6
X_5	376.64	297.86	79.1
X_6	20.13	23.91	118.7
X_7	0.713	0.209	29.3

21/ Chenery, H.B. "Engineering Production Functions", Quarterly Journal of Economics, Vol. 63, 1949.

It is evident that the structure of mining operations to the extent revealed by the factors considered above change substantially from mine to mine. It shows that coal is won under widely varying cost conditions. Consequently, the per tonne extraction costs vary widely across the mines (see Table 5) though they are homogenous with respect to technology, mining methods and factor-input prices.

THE CORRELATIONS AMONG THE FACTORS: There is an inter-connectedness between and among the various factors considered. This is revealed in the correlation matrix as given below.

Correlation-matrix

Factors	X_1	X_2	X_3	X_4	X_5	X_6	X_7
X_1	1.0000						
X_2	-0.9665	1.0000					
X_3	-0.8445	0.7905	1.0000				
X_4	-0.6088	0.5794	0.6181	1.0000			
X_5	-0.6468	0.5598	0.8370	0.4538	1.0000		
X_6	-0.4846	0.4618	0.4104	0.0445	0.1211	1.0000	
X_7	0.7794	-0.7693	-0.8250	-0.7073	-0.5399	-0.4339	1.0000

The correlations are high and their signs realistic. All the factors together reflect to a large extent the structural composition of mining operations in a mine. In point of the fact that mining is a "shifting activity", the nature, composition and the direction of the mining operations get changed in consonance with the rate of mining activity, across the mines as also over different output scales and time. This the correlation matrix provides. It also provides the extent of inter-connectedness among the factors considered.[22/] Factors X_1 and X_7 are in the form of productivity indices; and they are rightly correlated positively. Both of them bear negative correlations with the rest of the factors. Excluding Factor X_6, it indicates that

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22/ As it involves technical knowledge about the mining operations and mine-layouts, detailed discussions on correlations is deliberately avoided. Our discussions with the mining experts show that they are fairly realistic.

higher productivity levels both of labour and capital can be attained by maintaining a skewed distribution of workings towards the pitmouth, or in other words, by extracting more coal from nearby places rather than from far-off places from the pitmouth. Factors X_6 do not bear a high correlation with others.

3.4 **RESULTS OF REGRESSION ANALYSIS**

The data as given in Table 5 are used in the regression analysis. In the first stage, each factor has been considered individually by using the simple linear regression model. These results are presented in Tables 6 and 7. On the whole, the regression results are quite satisfactory because almost all the coefficients are found to be statistically significant at 1% level. The signs of all the coefficients are also realistic and the R^2 high. The results indicate that the factors (X_1, X_2 .... X_7) considered exert significant influences on the unit operating costs. It may be noticed in the above Tables that the R^2 improves when the dependent variable is changed from TAVC to Cost-A or the underground unit costs.[23/] It obviously shows that the Cost-A is more affected by the factors than the TAVC. It may also be noted that the R^2 improves when some of the outlying (or deviant) mines are deleted from the regression equations.

In the second stage, the multiple regression models have been fitted by introducing the factors one by one such that the last equation considers all the factors together. These results are presented in Tables 8 and 9. The results, however, are not much satisfactory perhaps because of the multicollinarity problems. R^2 improves when the dependent variable is shifted to Cost A (See Table 9). On the basis of our a priori knowledge about the mining operations, it can be suggested that a set of factors comprising X_1, X_3, X_4 and X_7 would yield better results in terms of predictive value of the regression model. As X_1 and X_7 are highly correlated, the impact of labour productivity (i.e. X_7) on costs may be separately analysed.

Besides the above factors, a few others such as:

- the state of water conditions
- the nature of roof or overburden
- the geological nature of the seams
- inclination or the gradient of the seams

23/ Cost-A covers only those costs incurred below the ground on various mining processes. It does not cover the surface costs such as the pit office, tub repairing, workshops, coal screening, cost of power, etc.

are also known to cause significant inter-mine variations in Unit operating costs. These factors reflect the qualitative features of the physical resource base of the mines or the extent of "niggardliness of nature". A mine is thus exposed to many and varied kinds of influences most of which are external to it, in the sense that it does not have any direct control over them. Within the given limitations of "natural endowment", a mine has to raise coal in right quantities at right cost. The empirical exercise as carried out in this study on the determinants of cost behaviour will be of some use in devising cost control systems and extraction strategies.

CONCLUSION

Particularly in the context of lack of adequate empirical evidence on the economics of extractive industries, the paper brings out some new dimensions in cost behaviour pertaining to the coal mining industry in regard to the overhead and extraction costs. These matters should enter explicitly into pricing of coals. It also identifies some of the major factors that affect the operating costs on the basis of which a colliery planning and a production strategy can be worked out such that the industry can attain cost stability as also minimize costs for a given level of output targets. Though the study is based upon a limited number of observations, the inferences derived from them have wider and more abstract implications in theory and empiricism.

TABLE 1

STRUCTURAL COMPOSITION OF TOTAL AVERAGE COSTS IN COAL MINING INDUSTRY (1964-65)

Sl. No.	Cost Item	Coal-field NO.5 Rs.Per Tonne	%	Coal-field No.4 Rs.Per Tonne	%	Coal-field No.3 Rs.Per Tonne	%	Coal-field No.2 Rs.Per Tonne	%	Coal-field No.1 Rs.Per Tonne	%	All-Industry Rs.Per Tonne	%
I.	Production Costs	14.38	61.7	16.03	61.5	14.04	57.3	17.09	59.6	17.58	57.8	16.25	59.3
II.	Overheads:												
1.	Technical Overheads	0.35	1.5	0.57	2.2	0.60	2.4	0.72	2.5	1.14	3.8	0.75	2.7
2.	Administration Overheads	0.81	3.5	0.98	3.8	1.14	4.6	1.60	5.6	1.80	5.9	1.37	5.0
3.	Trading Overheads	1.29	5.5	1.65	6.3	1.92	7.9	1.07	3.7	1.05	3.5	1.33	4.9
4.	Social Overheads	0.93	4.0	1.17	4.5	1.09	4.4	1.98	6.9	2.10	6.9	1.59	5.8
5.	Miscellanec Overheads	1.13	4.8	1.24	4.8	1.30	5.3	1.80	6.3	2.28	7.5	1.68	6.1
6.	Interest& Depreciation	4.43	19.0	4.43	17.0	4.43	18.1	4.43	15.4	4.43	14.6	4.43	16.2
	Sub Total	8.94	38.3	10.04	38.5	10.48	42.7	11.60	40.4	12.81	42.2	11.16	40.7
	GrandTotal (I + II)	23.32	100.0	26.07	100.0	24.52	100.0	28.69	100.0	30.39	100.0	27.41	100.0

Source: FieldInvestigations.

Notes : Coalfieldsare arrangedin ascendingorderof theirage levels. The Yearsof openingof the coalfieldsrespectivelyin that orderare: 1918, 1927, 1940, 1950 and 1960.

TABLE 2

STRUCTURAL COMPOSITION OF TOTAL AVERAGE COSTS IN COAL MINING INDUSTRY (1774-75)

Sl. No.	Cost Item	Coal-field NO.5 Rs.Per Tonne	%	Coal-field No.4 Rs.Per Tonne	%	Coal-field No.3 Rs.Per Tonne	%	Coal-field No.2 Rs.Per Tonne	%	Coal-field No.1 Rs.Per Tonne	%	All-Industry Rs.Per Tonne	%	% change in per tonne costs over 1964-65
I.	Production Costs	44.04	77.1	39.65	74.5	40.78	75.4	44.63	74.7	52.32	69.6	43.41	74.0	167.1
II.	Overheads:													
1.	Technical Overheads	2.05	3.6	1.96	3.7	2.43	4.5	2.30	3.9	1.81	2.4	2.12	3.6	182.7
2.	Administration Overheads	2.42	4.2	2.54	4.8	2.40	4.4	3.28	5.5	4.27	5.7	2.91	5.0	112.4
3.	Trading Overheads	1.89	3.3	2.04	3.8	1.98	3.7	2.04	3.4	2.45	3.3	2.07	3.5	55.6
4.	Social Overheads	1.73	3.1	1.21	2.2	1.21	2.2	2.70	4.5	6.43	8.5	2.37	4.0	49.1
5.	Miscellaneous Overheads	1.62	2.8	1.50	2.8	1.35	2.5	1.25	2.2	2.04	2.7	1.52	2.6	-9.5
6.	Interest & Depreciation	3.39	5.9	4.36	8.2	3.95	7.3	3.54	5.9	5.88	7.8	4.23	7.2	-4.5
	Sub Total	13.10	22.9	13.61	25.5	13.32	24.6	15.11	25.3	22.86	30.4	15.22	26.0	36.4
	Grand Total (I + II)	55.14	100.0	53.26	100.0	54.10	100.0	59.74	100.0	75.18	100.0	58.63	100.0	113.9

Source: Field Investigations.

Notes : As in Table 1.

TABLE 3

MINE-BY-MINE COMPOSITION OF EXTRACTION COSTS BY "WAGES" AND "MATERIALS" AND THE EXTENT OF VARIABILITY (1974-75)

Sl. No.	Mines	Wage cost		Materials Cost		Total Production Cost	
		Rs. Per Tonne	%	Rs. Per Tonne	%	Rs. Per Tonne	%
1.	Mine-a	26.07	70.0	11.16	30.0	37.23	100.0
2.	Mine-b	27.02	70.8	11.14	29.2	38.16	100.0
3.	Mine-c	31.93	74.2	11.11	25.8	43.04	100.0
4.	Mine-d	25.48	63.7	14.50	36.3	39.98	100.0
5.	Mine-e	24.94	65.0	13.45	35.0	38.39	100.0
6.	Mine-f	33.66	75.2	11.08	24.8	44.74	100.0
7.	Mine-g	25.42	66.5	12.78	33.5	38.20	100.0
8.	Mine-h	31.27	74.0	10.96	26.0	42.20	100.0
9.	Mine-i	26.03	71.2	10.52	28.8	36.55	100.0
10.	Mine-j	36.90	75.5	11.97	24.5	48.87	100.0
11.	Mine-k	37.94	78.7	10.25	21.3	48.19	100.0
12.	Mine-l	34.90	74.8	11.74	25.2	46.64	100.0
13.	Mine-m	22.67	73.0	8.42	27.0	31.09	100.0
14.	Mine-n	38.12	75.5	12.41	24.5	50.53	100.0
15.	Mine-o	26.20	74.3	9.06	25.7	35.26	100.0
16.	Mine-p	29.43	71.7	11.60	28.3	41.03	100.0
17.	Mine-q	36.48	76.9	10.96	23.1	47.44	100.0
18.	Mine-r	30.92	73.3	11 25	26.7	42.17	100.0
19.	Mine-s	29.08	73.9	10.26	26.1	39.34	100.0
20.	Mine-t	37.37	72.3	14.30	27.7	51.67	100.0
21.	Mine-u	37.37	74.3	12.90	25.7	50.27	100.0
22.	Mine-v	38.01	70.1	16.22	29.9	54.23	100.0
23.	Mine-w	30.26	76.5	9.31	23.5	39.57	100.0
24.	Mine-x	41.56	79.7	10.58	20.3	52.14	100.0
25.	Mine-y	32.71	79.9	8.19	20.1	40.90	100.0
26.	Mine-z	34.61	77.9	9.82	22.1	44.43	100.0
	All-Mines	34.61	73.0	11.73	27.0	43.41	100.0
	Mean	37.783	71.89	11.382	26.581	43.164	-
	SD	5.156	9.409	1.834	4.027	5.822	-
	CV	13.646	13.088	16.113	15.112	13.488	-

Source: Field Investigations.

SD = Standard Deviation; CV = Coefficient of Variation.

TABLE 4

MINE-BY-MINE COMPOSITION OF EXTRACTION COSTS BY "WAGES" AND "MATERIALS AND THE EXTENT OF VARIABILITY (1964-65)

Sl. No.	Mines	Wage cost Rs. Per Tonne	Wage cost %	Materials Cost Rs. Per Tonne	Materials Cost %	Total Extraction Cost Rs. Per Tonne	Total Extraction Cost %
1.	Mine-A	9.30	65.2	4.96	34.8	14.26	100.0
2.	Mine-B	8.96	66.3	4.56	33.7	13.52	100.0
3.	Mine-C	8.39	62.7	4.98	37.3	13.37	100.0
4.	Mine-C	8.99	61.1	5.73	38.9	14.72	100.0
5.	Mine-E	14.21	70.0	6.08	30.0	20.29	100.0
6.	Mine-F	11.57	70.7	4.80	29.3	16.37	100.0
7.	Mine-G	10.30	68.5	4.74	31.3	15.04	100.0
8.	Mine-H	9.82	65.5	5.18	34.5	15.00	100.0
9.	Mine-I	7.05	63.8	4.00	36.2	11.05	100.0
10.	Mine-J	9.71	71.6	3.85	28.4	13.56	100.0
11.	Mine-J_1	23.14	77.7	6.65	22.3	29.79	100.0
12.	Mine-K	6.24	63.2	3.63	36.8	9.87	100.0
13.	Mine-L	13.68	77.1	4.07	22.9	17.75	100.0
14.	Mine-M	13.57	75.2	4.48	24.8	18.05	100.0
15.	Mine-N	11.81	72.4	4.50	27.6	16.31	100.0
16.	Mine-O	7.90	65.8	4.11	34.2	12.01	100.0
17.	Mine-P	13.08	78.6	3.56	21.4	16.64	100.0
18.	Mine-Q	10.49	70.1	4.48	29.9	14.97	100.0
19.	Mine-R	16.41	73.6	5.88	26.4	22.29	100.0
20.	Mine-S	15.69	76.5	4.83	23.5	20.51	100.0
21.	Minė-T	14.23	76.1	4.45	23.9	18.69	100.0
22.	Mine-U	10.75	74.7	3.63	25.3	14.38	100.0
	All-Mines	11.70	72.0	4.54	28.0	16.25	100.0
	Mean	11.590	70.291	4.689	29.700	16.293	-
	SD	3.702	5.335	0.807	5.332	4.205	-
	CV	31.942	7.59	17.212	17.954	25.810	-

Source: Field Investigations.

SD = Standard Deviation; CV = Coefficient of Variation.

TABLE 5

DATA ON SOME OF THE MAJOR FACTORS AFFECTING UNIT OPERATING COSTS IN THE COAL MINING INDUSTRY

Sl. No.	Mines	TAVC (Rs./ Tonne)	Cost-A (Rs./ Tonne)	X_1	X_2	X_3	X_4	X_5	X_6	X_7
1.	A	14.26	11.25	656	0.1525	29.4	710	294	9.50	0.9266
2.	B	13.52	10.78	686	0.1458	27.3	590	191	13.50	0.7202
3.	C	13.37	10.27	615	0.1626	26.2	497	131	8.00	0.8123
4.	D	14.72	10.83	620	0.1613	27.2	565	194	13.00	1.0702
5.	E	20.29	16.13	253	0.3957	47.7	810	525	10.00	0.4205
6.	F	16.37	12.57	383	0.2608	37.7	795	565	9.50	0.6026
7.	G	15.04	10.53	614	0.1628	30.6	515	245	8.00	0.7130
8.	H	15.00	11.18	579	0.1728	28.2	735	169	9.50	0.7424
9.	I	11.05	7.64	625	0.1599	14.0	390	56	11.00	1.0105
10.	J	13.56	9.78	854	0.1171	21.8	490	87	8.00	0.8501
11.	K	9.87	8.27	641	0.1599	15.5	450	31	8.00	1.0864
12.	L	17.75	13.65	515	0.1943	34.6	755	554	11.50	0.5268
13.	M	18.05	13.54	497	0.2014	39.0	780	507	19.50	0.5274
14.	N	16.31	12.20	419	0.2383	49.6	678	595	8.00	0.5426
15.	O	12.01	8.90	613	0.1633	18.8	530	75	12.00	0.9451
16.	P	16.64	13.00	426	0.2348	40.8	820	449	9.00	0.5906
17.	Q	14.97	11.52	427	0.2342	48.7	700	1119	22.50	0.7077
18.	R	22.29	17.53	235	0.4254	52.8	820	845	32.00	0.4122
19.	S	20.51	16.18	304	0.3288	46.7	620	419	82.25	0.4381
20.	T	18.69	14.04	350	0.2857	43.7	625	306	100.00	0.5028
21.	U	14.38	10.91	501	0.1998	43.6	400	916	18.00	0.8264

Source: Field Investigations.

TAVC : Total Average Variable Cost; Cost-A = Underground Cost.

$X_1 \ldots X_7$ = as given in the text.

TABLE 6

FACTORS AFFECTING THE UNIT OPERATING COSTS (REGRESSION COEFFICIENTS OF THE FORM: $Y=a+bX_i$)

Sl. No.	Eqn. No.	Regression Coefficients a	b	R^2	Remarks
1.	Eqn. 1	24.0238** (16.874)	-0.01626** (-6.140)	0.65	Y=TAVC; X_1=Output per 100 feet Hauling distance in tonnes; n=21.
2.	Eqn. 2	8.5864** (8.210)	32.5798** (7.210)	0.72	Y=TAVC; X_2= Total Hauling distance of working faces per tonne of coal raised (in feet); n=21.
3.	Eqn. 3	14.9327** (17.950)	0.0147 (1.450)	0.05	Y=TAVC; X_3 = Hauling Distance per working face ('00 feet); n=21.
4.	Eqn. 4	5.65704* (2.451)	0.01581** (4.433)	0.483	Y=TAVC; X_4 = Maximum depth of the working faces in feet; n=21.
5.	Eqn. 5	13.4192** (13.543)	0.00566** (2.810)	0.26	Y=TAVC; X_5=Total Hauling distance of the working faces ('00 feet); n=21.
6.	Eqn. 6	14.3495** (18.022)	0.0646* (2.536)	0.214	Y=TAVC; X_6 = Thickness of the seams in feet, n=21.
7.	Eqn. 7	25.0980** (23.184)	-13.2506** (-9.100)	0.803	Y=TAVC; X_7 = Output per manshift (OMS) in Tonnes; n=21.
8.	Eqn. 8	18.8832** (17.199)	-0.01352** (-6.620)	0.682	Y'=Cost A; X_1 = as defined above; n=21.
9.	Eqn. 9	6.0432** (7.692)	17.1234** (7.990)	0.760	Y'=Cost A; X_2 = as defined above; n=21.
10.	Eqn. 10	11.3943** (16.719)	0.01086 (1.306)	0.035	Y'=Cost A; X_3 = as defined above; n=21.
11.	Eqn. 11	3.5376 (1.96)	0.0133** (4.76)	0.520	Y'=Cost A; X_4 = as defined above; n=21.
12.	Eqn. 12	10.0876** (12.622)	0.00466** (2.870)	0.270	Y'=Cost A; X_5 = as defined above; n=21.
13.	Eqn. 13	10.8874** (16.749)	0.0515* (2.476)	0.204	Y'=Cost A; X_6 = as defined above; n=21.
14.	Eqn. 14	19.5247** (21.448)	-10.6614** (-8.702)	0.79	Y'=Cost A; X_7 = as defined above; n=21.

* Significant at 5% level ** Significant at 1% level

(t-values are given in brackets)

TABLE 7

FACTORS AFFECTING THE UNIT OPERATING COSTS (REGRESSION COEFFICIENTS OF THE FORM: $Y=a+bX_i$ - DELETING SOME OF THE OUTLYING MINES FROM TABLE 6)

Sl. No.	Eqn. No	Regression Coefficients a	b	R^2	Remarks
1.	Eqn. 1	25.2509** (22.360)	-0.01773** (-8.032)	0.82	Y=TAVC; X_1= as defined earlier; n=15.
2.	Eqn. 2	9.7868** (10.191)	29.4995** (7.561)	0.80	Y=TAVC; X_2= as defined earlier; n=21.
3.	Eqn. 3	15.0046** (15.810)	0.01463 (1.330)	0.04	Y=TAVC; X_3= as defined earlier; n=18
4.	Eqn. 4	3.6075 (1.258)	0.01906** (4.19[illegible])	[illegible]	Y=TAVC; X_4 = as defined earlier; n=17.
5.	Eqn. 5	11.4191** (23.477)	0.01145** (9.185)	0.85	Y=TAVC; X_5= as defined earlier; n=16.
6.	Eqn. 6	[illegible]** ([illegible])	0.06923* (2.790)	0.29	Y=TAVC; X_6= as defined earlier; n=18.
7.	Eqn. 7	19.8487** (21.434)	-0.01465** (-8,096)	0.822	Y'=Cost-A; X_1= as above; n=15.
8.	Eqn. 8	7.0048** (9.3777)	24.65582** (8.124)	0.823	Y'=Cost-A; X_2= as above; n=15.
9.	Eqn. 9	2.4181 (1.195)	0.0150** (4.840)	0.57	Y'=Cost-A; X_3= as above; n=18.
10.	Eqn. 10	1.7554 (0.790)	0.01611** (4.580)	0.555	Y'=Cost-A; X_4= as above; n=16.
11.	Eqn. 11	8.5044** (23.874)	0.00913** (10.004)	0.87	Y'=Cost-A; X_5= as above; n=16.
12.	Eqn. 12	10.6189** (16.276)	0.05561* (2.812)	0.29	Y'=Cost-A; X_6= as above; n=18.

* Significant at 5% level

** Significant at 1% level

t-values are given in brackets

Notes: Deletion of some mines in the above equations have been made on the basis of our *a priori* knowledge about them. Since the Equation for X_7 proved to be highly significant in Table 6, it is not considered here in Table 7.

TABLE 8

FACTORS AFFECTING THE UNIT OPERATING COSTS

(RESULTS OF MULTIPLE REGRESSION MODEL: $Y=a+bX_1+cX_2+dX_3+eX_4+fX_5$)

Sl. No.	Eqn. No.	Regression Coefficients a	b	c	d	e	f	R^2	Remarks
1.	Eqn. 1	24.02388** (16.874)	-0.0163** (-6.140)	-	-	-	-	0.65	Y=TAVC; X_1=Output per 100 ft of Hauling distance in tonnes; n=21.
2.	Eqn. 2	23.2496** (15.626)	-0.01564** (-5.95)	0.00841 (1.370)	-	-	-	0.66	Y=TAVC; X_2 = Hauling distance per working face (00 ft); n=21.
3.	Eqn. 3	25.4654** (21.030)	-0.0060# (-1.940)	0.002062 (0.434)	-9.6353** (-4.093)	-	-	0.82	Y=TAVC; X_3 = OMS; n=21.
4.	Eqn. 4	23.0953** (7.295)	-0.00552# (-1.77)	0.00137 (0.281)	-8.7644** (-3.360)	0.00250 (0.812)		0.82	Y=TAVC; X_4 = Maximum depth of the working faces in ft; n=21.
5.	Eqn. 5	19.5318* (4.965)	-0 00391 (-1.214)	0.00118 (0.250)	-7.5423* (-2.832)	0.00475 (1.413)	0.02235 (1.444)	0.83	Y=TAVC; X_5 = Thick-Thickness of seams in feet; n=21.

Significant at 10% level   * Significant at 5% level   ** Significant at 1% level

(t-values are given in brackets)

Notes : By deleting some of the outlying mines from the fitted regression equations, one can improve their R^2 and predictive value.

TABLE 9

FACTORS AFFECTING THE UNIT OPERATING COSTS

(RESULTS OF MULTIPLE REGRESSION MODEL: $Y' = a + bX_1 + cX_2 + dX_3 + eX_4 + fX_5$)

Sl. No.	Eqn. No.	Regression Coefficients a	b	c	d	e	f	R^2	Remarks
1.	Eqn. 1	18.8832** (17.199)	-0.01352** (-6.62)	-	-	-	f	0.682	Y'=Cost-A; X_1 = Output per 100 ft hauling distance in tonnes;; n=21.
2.	Eqn. 2	18.3994** (15.793)	-0.01311** (-6.376)	0.00558 (1.161)	-	-	-	0.687	Y'= Cost-A; X_2 = Hauling distance per working face in '00 feet; n=21.
3.	Eqn. 3	20.0353** (20.475)	-0.0058* (-2.340)	0.00080 (0.208)	-7.2162** (-3.82^)	-	-	0.822	Y'= Cost-A; X_3 = OMS; n=21.
4.	Eqn. 4	17.00841** (6.875)	-0.00528** (-2.154)	-0.000065 (-0.017)	-6.1770** (-3.017)	0.00311 (1.290)		0.828	Y'= Cost-A; X_4 = Maximum depth; n=21.
5.	Eqn. 5	14.1808** (4.617)	-0.0040 (-1.579)	-0.00029 (-0.054)	-5.1811* (-2.493)	0.00495# (1.885)	0.01821 (1.510)	0:841	Y'= Cost-A; X_5 = Seam Thickness in feet; n=21.

\# Significant at 10% level * Significant at 5% level ** Significant at 1% level

(t-values are given in brackets)