CHAPTER FOUR

PRODUCTION TRENDS AND PRODUCTIVITY PERFORMANCE

4.1 Introduction

Open-cast mining requires a huge amount of investment and involves high risks and uncertainties. For instance, the exploration and prospecting for minerals are costly and irrecoverable. For this reason, it would be unwise economically to make a large capital investment when there is a possibility of the ore being depleted in one or two years. However, the sunk cost for some of the capital equipment can be used elsewhere or sold without loss other than depreciation. Sunk cost refers to expenditures or investments that cannot be recovered or salvaged in the event of failure (Greer, 1992). This investment may influence the level of productivity in the mining industry because a large part of the workforce in this industry is engaged in activity that has no effect on current production, such as exploration and development of new ore reserves. Typically, it is difficult to change factor inputs or increase capacity in the short run or even over the long term because substitution of factors input, for instance between capital and labour, is not possible. The mining industry involving open-cast mining is highly capital intensive. It does not require intensive labour in its production line and the number of production workers is much lower than that of other industries. In MCM, the production process is highly automated and mechanized, thus requiring large capital outlays. In view of this, substitution of labour and capital is almost insignificant. With the increasingly better mining technology available, intensifying labour may be ineffective in enhancing total productivity. Although the production line requires relatively less amount of labour, its support groups particularly in administration, maintenance, power, electrical, and workshop departments require a large number of workforce. If their growth of labour productivity is low, higher capital substitution is necessary to enhance total productivity. If however, the low productivity is due to the inefficiency of the workforce, there is a need to review, perhaps by restructuring the company's structure of organisation to create a better system of incentives, coordination and motivation. If the declining productivity rate is due to capital substitution, this means that there is a vital need for more efficient usage of the factors of production. Like other mining industries, productivity in MCM is determined by a combination of factors input particularly; labour, capital, technology and managerial or organisational efficiency.

4.2 Trends Of Output Production

The first production of copper concentrates at MCM started in 1975, with 21,190 metric tonnes, at RM18,576,849. The first shipment of 7,000 metric tonnes of copper concentrates was made in January 1976. The growth of copper production then increased steadily throughout the 1980s and early

1990s as indicated in Table 4.1. However, in 1988 the production dropped to its lowest level since 1977, owing to the inaccessibility of ore as a result of landslide. Production trends for ore concentrates over the last decade is shown in Table 4.1.

Table 4.1

Production Of Copper Concentrates From 1975 to 1994

Year	Quantity (metric ton)	Index Of Production (1983=100)
1975	21,190	17.2
1976	77,617	62.9
1977	99,992	81.0
1978	112,510	91.2
1979	104,697	84.8
1980	114,222	92.5
1981	120,327	97.5
1982	128,755	104.3
1983	**123,444**	**100.0**
1984	122,774	99.5
1985	127,871	103.6
1986	115,304	93.4
1987	122,206	99.0
1988	91,504	74.1
1989	101,471	82.2
1990	101,931	82.6
1991	102,511	83.0
1992	104,736	85.0
1993	106,549	86.0
1994	105,272	85.3

Source: MCM, Annual Reports, 1975-1994

The ore-waste ratio of 1:4 and the pit operation that concentrated on the removal of waste are the main factors that contributed to the low production in 1975 and 1976. However, the quantity of copper production continued to rise steadily from 1980 until 1985 with very slight falls recorded. In fact, the highest production achieved was between 1982 and 1985. The improvement is significant because it was achieved in a year during which short life heavy loading and haulage machinery replacements were minimal. The overall ore to waste ratio was 1 to 1.3. In 1985, the total volume of ore-waste mined increased from 13,653,739 to 14,437,327 tonnes or by 5.7 per cent over the previous year. Total ore milled also increased to 6,251,991 tonnes as compared to 6,075,242 tonnes in 1984. As a result of the increase in volume of ore-waste mined and ore milled, the production of copper concentrates increased from 122,774 metric tonnes in 1984 to 127,871 metric tonnes in 1985. In 1986, the total tonnage of ore and waste mined decreased from 14,437,327 tonnes to 14,414,201 tonnes. The ore milled also decreased by 2 per cent from 6,251,991 tonnes in 1985 to 6,128,062 tonnes in 1986. Consequently, the production of copper concentrates further declined between 1988 and 1990 but increased slightly in 1991. The lowest production of copper concentrates recorded was in 1988. This was due largely to the landslide that occurred in June 1988 which utilized more than half of the machinery and manpower available at the pit to clear and remove the waste. The slide also prevented easy access to ore zones and as a result production of concentrates was adversely affected from June to October before returning to normal in November 1988. Ore to waste ratio then 1: 1.8

as compared to 1: 1.6 in 1987. These factors contributed to the low production of copper concentrates in 1988. In June 1989, the overhanging material from the landslide a year earlier slid further down into the pit. Despite this, the ore to waste ratio of 1: 1.5 compared to 1 1.8 over the previous year, contributed to an increase in the production of concentrates. The production of copper concentrates in 1990 and 1991 also increased due to the increase in tonnage of ore and waste mined from 14.1 in 1989 to 20.6 million tonnes, increase in tonnage of ore milled from 5.4 in 1989 to 6.1 and increase in copper recovery from 83.7 in 1989 to 85.3 per cent. In 1992 and 1993 the production of copper concentrates continued to increase due to the higher tonnage of ore and waste mined, that is 45 7 million tonnes in 1992 and 32.6 in 1993. The production decreased from 106.5 million tonnes in 1993 to 105 3 million tonnes in 1994.

The above analysis indicates that the quantity of concentrates produced is largely determined by factors such as the volume of ore mined, ore-waste ratio and pit stability [1]. Other factors such as quantity of ore milled, ore grades and metal recovery are also significant in determining the production of copper concentrates.

There are thirty-four copper concentrates producers in the world today. Amongst these countries, Chile and U.S.A. are the two major producers.

1 The ore-waste ratio indicates the quantity of ore and waste or unwanted materials in the pit. What this means is how many tons of waste or material are handled for every ton of ore. Higher ratio of waste is undesirable for it would reduce the quantity of ore obtained and supplied to the mill.

Chile, the world's largest producer of copper, is one of the leading mining countries. With its wide variety of minerals, the country is experiencing an increasing level of mining investment. In 1992 Chile and United States produced 1.9 million and 1.7 tons of copper respectively. Indonesia is the third largest producer of copper with an output of 0.9 million tons in 1992. Other major producers are Portugal, China, Belgium. India. Iran and Zambia. Tables 4.2 and 4.3 show the percentage share of MCM of the world output and its copper concentrates output in Asean, respectively

Table 4.2:

Malaysia's Role In World Production Of Copper (Mine Production Of Copper Concentrates)

Year	World Production ('000 tonnes)	Malaysia's World Output Share (%)
1975	5,737	0.3
1976	6,637	1.2
1977	6,289	1.6
1978	6,096	1.8
1979	6,133	1.7
1980	6,042	1.9
1981	6,507	1.8
1982	6,240	2.1
1983	6,236	2.0
1984	6,373	1.9
1985	6,440	2.0
1986	6,503	1.8
1987	6,634	1.8
1988	6,893	1.3
1989	7,100	1.4
1990	8,463	1.2
1991	9,174	1.1
1992	8,894	1.2

Source: Mining Annual Review, 1975-1992, Mining Journal, London

The Table in 4.2 shows that in 1975 the output of MCM, which is a sole monopoly producer for Malaysia, was about 0.3 per cent of the world output share.[2] This share increased to 1.9 per cent in 1980 and 2.0 per cent in 1985. In 1990 and 1992, however, the percentage share declined to 1.2 and 1.1 per cent respectively. The decline was inevitable because MCM's production remained unchanged while the production of other major world producers increased.

Amongst Asean countries and Myanmar, Malaysia is the third largest producer of copper concentrates as indicated in Table 4.3. Although Malaysia has only one copper mine, its production is higher than some of the Asean copper producers. The Philippines, for instance, has eight copper mines yet it produced only 29 per cent more copper concentrates than Malaysia in 1991 and 8 per cent in 1992. Although Myanmar is not yet an Asean country it is included in the table here since it is a close neighbour of Asean. Japan is also included for it imports all of Malaysia's copper concentrates.

[2] Refer to Mining Annual Review, 1975, Mining Journal, London

Table 4.3

Asean Copper Producers

Country	**Production (Tonnes)**			
	1989	**1990**	**1991**	**1992**
Indonesia	331,571	437,307	656,520	906,657
Philippines	192,990	182,139	144,944	114,375
Malaysia	101,471	101,931	102,511	104,736
Myanmar	16,932	30,033	14,226	18,318
Japan	14,650	12,927	12,413	12,047

Source: Mining Annual Review, 1989-1992, Mining Journal, London

4.3 Productivity

Productivity, which is derived from the Latin word 'producere', consists of 'pro' which means forward: and 'ducere' which means to lead or draw out the quality or the state of bringing forth and of generating results (Koss and Lewis 1993). The U.S.A. Bureau Of Labour Statistics simply defines productivity as " output per man hour." However labour, or man-hours, is only one of the resource inputs a firm requires in order to produce a product or provide a service. Siegel (1980) goes a step further in defining productivity as a family ratio of input price to output price instead of ratios of output and input quantities.[3] In its general sense, productivity may be

[3] Productivity ratios based on output value (quantity of output multiplied by the price of output).

defined as a ratio between output and the total input of factors required to achieve it. This concept is normally linked to the theory of production, which describes how scarce resources are used to produce goods and services.

4.4 Importance Of Productivity: Why Companies Measure Productivity

Productivity improvement is a key goal for business and MCM is no exception. Productivity is a performance measurement concept. Specifically, at the firm level, productivity measures the relationship between the output (amount of goods and services) produced in a period of time and the inputs (amounts of labour, capital, materials and energy) needed to produce that output at the desired quality level. The measurement of productivity growth in the longer run, an important element in the determination of the growth of potential output, may also have implications for company policy. For example, difficulties in measuring the gap between actual and potential output could lead to policy error. Misperceptions about productivity growth by companies may also affect their performance. For instance, if workers continue to expect increases in real wages during periods of zero productivity growth, their demands could result in unemployment and higher inflation. A firm may also need to measure its productivity for it could serve as an indicator for input efficiency. Input efficiency can be best measured by the amount of output obtained per unit of input.

Siegel (1980) argues that a company should measure productivity for it assists the company in controlling the ratio of input; instance, by making or keeping the proportion of "indirect" labour as small as possible or as large as necessary to support a level of company output. Koss and Lewis (1993) stress the importance of productivity measurement because it tends to evaluate the efficiency of an individual, group or organisation. At the industry level, the measuring of productivity enables the firm to know the ratios between output and each of the inputs which may be an important factor for decision making. A firm's productivity measurement will help planning, forecasting of the firm's growth and ensuring competitiveness. Productivity can also heighten awareness at all staff levels concerning the importance of getting output from a given output.

Harl and Bresses (1984) explored the relationship between profitability and productivity changes have positive effects on profitability although there exists a significant amount of variance. Rastogi & Mohanty (1988) in addition, in their studies of five selected industrial sectors of the Indian economy, found that productivity in three sectors namely; cement, tyre and pharmaceutical is positively related to profitability. They conclude that increasing profitability is due to the increase in value-added and better productivity.

In 1979, the American Productivity Centre (APC) developed a system that examines beyond the traditional financial statements to analyse company performance. The "Total Performance Measurement System" (TPMS) develops the premise that the profit performance of a company's operations can be traced directly to productivity and price recovery factors.[4] Since productivity depicts the relationship of outputs over inputs, price recovery is defined by the APC as the relationship between resource input prices and output sales prices. Price recover measures the ability of the firm to pass on the changing inputs costs of labour hours, materials, energy units, and capital to the customer in the selling price. The APC measurement system is a multi-factor model since it isolates specific productivity changes in each of the firm's input factors The system shows how each input's productivity performance translates to the bottom line profitability of the company or organisation. Some organisations have some control systems that monitor profitability, but they are unable to conveniently analyse whether their profitability changes are the result of productivity changes or price cost movement. The APC model relates a company's profitability change to two factors: period-to-period changes in productivity and price recovery.

4 Price recovery relates to the changes in output prices in response to changes in input costs. In other words price recovery is the degree to which input cost increases are passed on to the consumer.

Figure 4.1

APC Model Of Total Performance Measurement System

PRODUCTIVITY-------- >PROFITABILITY<---------PRICE RECOVERY
CHANGE CHANGE CHANGE

Using the above definition the APC model then becomes:

Change in output units produced
↓
Productivity -------------> Profitability change <--------- Price Recovery change
↑
Change in input units consumed

Change in selling prices charged
↓
Price Recovery change
↑
Change in input prices paid

Since profitability is viewed as total revenue less total costs. the APC model for measuring total performance changes can be completed as follows:

Changes in output units produced ------------------------> Changes in period-to-period revenue <-------------Changes in selling prices charged

Changes in output units produced ↓ Productivity change
Changes in period-to-period revenue ↓ Profitability change
Changes in selling prices charged ↓ Price Recovery change

Productivity change --------------------> Profitability change <--------------- Price Recovery change

Changes in input ↑ Productivity change
Changes in period-to-period total costs ↑ Profitability change

Changes in input ----------------------------> Changes in period-to-period total costs <------------ Changes in input price paid

***Source:* Landel, 1986: *Managing Productivity Through People: An Operations Perspective,* A Reston Book, Prentice-Hall, Inc**

The Total Performance Measurement System (TPMS) model formulates relative productivity changes as a ratio model of period-to-period change in output and each input quantity. The input ratio measures the change in the quantity of input used in a given period relative to the quantity of input used in a base period. Similarly, the output ratio measures the change in the quantities of outputs produced relative to the production in the base period. The productivity ratio, which is the ratio of output to input, measures the change in output quantities produced as a result of changes in a particular input quantity. Thus, a productivity ratio of less than 1.0 would indicate that the system was consuming more of a particular input factor to produce a given level of output than it had consumed in the base period. A ratio of more than 1.0, on the other hand, would indicate good performance. The TPMS model also identifies price recovery and profitability ratios in a similar manner. According to Landel (1986), the TPMS model links the three change ratios of profitability, productivity and price recovery by the following relationship:

Relative Profitability = Productivity x Price Recovery

The price recovery ratio measures the change (relative to the base period) in the ability of the firm to pass on to its consumers changes in the prices of its resource inputs. Similarly, the profitability ratio measures the overall change in value relative to the base period where value is defined as the product of quantity and price. The TPMS model shows how a company can generate profit growth from productivity improvement or from price recovery. It works as follows: any change in unit output produced and input used would lead to a change in productivity, total revenue and total costs. A change in input price paid by the company and selling prices charged to consumers would change price recovery, total revenue and total costs. Profitability is achieved through changes in productivity and price recovery and also changes in total revenue and total costs as indicated in the model. The simple model of the TPMS helps us to analyse overall organisational productivity by examining changes in profitability and changes in price recovery.

In some cases, an increase in profit may not always be due to an increase in productivity. A monopoly firm, for instance, may discriminate against its consumers by charging a higher price for its product to obtain a higher profit without minimising its cost of input.[5] Gross profit may not reflect a true picture because an increase in output may not be the result of increased productivity but may be achieved by merely increasing input. Thus a monopoly company's profit may increase year after year, but productivity may actually be on the decrease, just as an increase in production and sales may not necessarily lead to increases in profit, when costs or inputs employed to attain the increase in output have increased out of proportion. Under a competitive market, this may not be possible for the company must operate on a low-cost basis to improve its productivity and hence competitiveness.

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[5] Price discrimination can entail inefficiency of a monopoly in utilising its input

4.5 Definition of Variables And Measurement

In the expression of labour productivity, it is represented by:

$$P_L = \frac{Q}{L}$$

Productivity of capital or the average product of capital is represented by:

$$P_k = \frac{Q}{K}$$

Total Factor Productivity (TFP) is defined as output per unit of labour and capital, material and fuel combined.

$$TFP = \frac{Q}{L + K + M + F}$$

Q = Output

L = Wages, salaries, overtime pay and bonuses of employees during the year

K = Capital input, defined as net fixed asset

Net fixed asset = building and structures + plant and machinery + vehicles transportation + equipment + mine development during the year.

M = Raw Materials which include spare parts, drilling and blasting accessories, chemicals, grinding media, and miscellaneous items such as welding rods and wires

F = of fuel oil, diesel. gasoline and lubricants.

4.5.1 Productivity

Productivity measures the efficiency with which inputs are transformed into useful outputs within the production processes.[6] Higher productivity means achieving higher output with the same amount of factor inputs. Very often, analyses seeking to measure productivity have confined themselves to partial, sometimes known as specific productivity, expressed as the ratio between a given measure of output and a given measure of one or more production factors. Thus it is possible to talk of the productivity of labour, capital, raw materials, energy and fuel. Usually, however, the cost of raw materials and fuel are not considered. According to Kendrick and Vaccara (1980), productivity can be measured into three different methods as follows:

a. **Partial Productivity:** Ratio of gross or net output to only one type of resource input, for example, labour productivity, capital productivity, material productivity, energy productivity.

b. **Total Factor Productivity**: Ratio of gross or net output to total labour and capital inputs expressed in monetary equivalents.

c. **Total Productivity:** Ratio of gross or net output to total inputs including labour, capital, material, energy, fuel and others - all being expressed in monetary equivalent.

This analysis measures total factor productivity with all inputs: labour, capital, material and fuel combined. There have been conflicting arguments as to

[6] In some cases, technical efficiency is assumed to be directly linked to the assessment of productivity performance of the firms since productivity reflects the extent to which resources are used to obtain output.

how to define the various inputs and output. For example. Craig and Harris (1973) recommend the taking of net production in monetary terms as the real output of the organisation while Taylor and David (1977) advocate the value-added concept as the real output of the organisation. Rugayah (1993) on the other hand, uses value-added in the calculation of Total Factor Productivity. This analysis, however. calculates productivity ratios on output-based.

Productivity can be calculated in two ways: as average productivity and marginal productivity, that is, the change in output per additional unit of the production factor in question. In this analysis. the productivity of labour and capital will be measured based on average productivity. For the calculation of average productivity for a group of factor inputs, there is a choice between averaging the productivities of the different components and calculating an average reflecting the relative importance of each component in the group.

The measurement of labour productivity is important because it indicates how efficiently labour is utilised in accomplishing a set of objectives in the production process. In a highly labour-intensive firm, higher labour productivity is important. In view of this, the measurement of labour productivity is useful for manpower planning and requirement such as in the designing of training programmes for the workforce. Labour productivity is widely used as a tool for measuring productivity in view of the simplicity in deriving it as well as its being a popular indicator of an increase in the standard of living. The use of the labour productivity concept for measuring labour productivity may not however, be related to the causes or changes of productivity levels. An increase in labour productivity, for example, may be due to a change in the skills and effort of workers. An increase in labour productivity may also result from the use of more or better capital equipment, better quality raw materials or improved organisation or management. The labour force is not homogeneous, that is, there are skilled workers, unskilled workers and professionals, who may also be inter-related with capital input. Hence, sometimes, instead of depicting a true rise in labour productivity, its increase could also be caused by the substitution of capital for labour or by the scale effects and technological changes. It follows therefore, that labour productivity may also decrease as a result of a decrease in capital intensity. Sims and Stanton (1980) suggest that about one-quarter of the labour productivity slow down in Canada was attributed to a decline in the growth rate of capital intensity. To conclude, labour productivity may not fully reflect an accurate productivity performance in capital intensive industries like mining because the increase in productivity may thus be generated by additional fixed capital instead of labour.

Labour has been defined as "mental or physical effort applied during a certain time". For measuring the labour input in production, the definition is confined to effort applied to an economic purpose, though the dividing line is not always clearly drawn. For example, the effort expended by the great majority of workers in travelling to and from their workplace is not taken into account in calculating labour productivity unless this travelling time is actually reckoned as working time and paid accordingly. In view of the marked differences in the intensity of effort, some choose output per man-hour as their labour productivity indicator. (ILO, 1969) postulates that for short-term projections, hours actually worked is undoubtedly the most suitable instrument for estimating productivity, whereas normal working hours or the number of persons employed would probably be preferable for long-term projections. For the purpose of this analysis, labour inputs for productivity purposes are estimated on the basis of output per employee-wages and salaries.

Due to the shortcoming of the labour productivity measure in assessing firm's performance, the productivity measure should include the measures of capital productivity. In examining this question, it is worth noting that there is still a good deal of controversy over the quantitative role of capital formation in generating productivity growth. In a labour-intensive industry, the role of capital may be small. However, in a capital-intensive industry such as MCM the contribution of capital in enhancing productivity may be significant.

Assessing a firm's performance by merely focusing on capital productivity is inadequate. This is attributed to the problem in defining and measuring the capital itself. The most commonly used element in capital input is fixed assets. The implication then would be, that capital productivity yields higher values since output is only divided by the stock of fixed capital without accounting for the flow of capital services. Like labour productivity, capital productivity alone may not be a wholesome indicator of productivity measurement in capital intensive sectors.

Rather than attempting to measure labour and capital productivity growth, economists are now measuring the total factor productivity. This measurement which is based on a single or partial factor productivity has the advantage of simplicity and feasibility in computation, but nevertheless makes it difficult to identify the casual factors accounting for observed productivity growth. The total factor productivity measurement however, permits and accommodates labour, capital and other inputs as the main component of factors of production employed in the production process. Solow (1967), Caves, Christensen and Swanson (1981), Chan and Mountain (1983) estimate total factor productivity. More recent works on measuring total factor productivity were done by Maisom and Mohd Ariff (1993) and Rugayah (1993) with multiple outputs and inputs of various manufacturing industries in Malaysia. Contrary to their studies, this analysis of productivity is a single output case. All the three types of productivity indices are computed namely; labour, capital, and total factor productivity.

Labour inputs are measured by wage bill and salaries without specifying sex, age, education and occupation. This is relevant for the productivity of a single firm for efforts of all employees are considered and taken into account in order to produce total outputs. As for capital inputs, these are measured by fixed assets which are expressed in Malaysian Ringgit.[7] Material inputs take the form

[7] For calculation of capital productivity, net fixed assets is used. Cost of capital may be more appropriate for a single company but it is not used due to problem of defining and obtaining data

of the material cost of spare parts, drilling and blasting accessories, grinding media, chemicals and miscellaneous items such as welding rods, while fuel inputs comprise fuel oil, diesel, gasoline and lubricants also expressed in Malaysian Ringgit.

The framework of this analysis is also to examine the total factor productivity namely: labour, capital, material and fuel productivity with a view to determining the relative importance of labour, capital, material and fuel scale economies in generating growth. The basic types of productive inputs are land, raw materials, technological know-how, labour, capital, and managerial skills. In most studies of factor productivity such as Griliches and Jorgension (1966), Chan and Mountain (1983), Dollar and Wolff (1993), Maisom and Mohd Ariff (1993), only two factor inputs; labour and capital are estimated in the production function. In several other studies, the cost of raw materials and fuel are also opted out due to data deficiency. The omission of material and fuel as factor inputs is a serious handicap for production function estimation. This is due to the fact that in the production process, material and fuel are significant factor inputs and therefore, should be included. In practice, it has been observed that raw materials bear a constant relation to output at all levels of production (Koutsoyiannis 1979). Briskin (1987) in his study of productivity and competitiveness, also emphasizes the importance of the cost of materials as input to the production process. Thus, instead of using two factor inputs, material and fuel are also included in the calculation of productivity.

With some notable exceptions, much of the empirical literature on productivity measurement disregards the potential importance of scale economies. On the other hand, those studies which do incorporate scale economies in their productivity measures find that scale economies explain at least twice as much productivity growth as does technological change (Aivazian, Callen, Chan and Mountain 1987). Thus, other than analysing productivity, the analysis also attempts to examine the performance of returns to scale of MCM. The concept of returns to scale deals with production relationships over a time span sufficiently long to allow changes in any of the inputs, especially those inputs such as plant, major capital equipment, and managerial capability, which are typically fixed in the short run. Increasing returns to scale exist when the change in output is more than proportional to the change in input and this may exist in a new enterprise, whereas decreasing returns to scale occur when the change in output is less than proportional to the change in input. Decreasing returns to scale may occur in an old enterprise which can no longer expand. Constant returns to scale on the other hand, exist when the change in output is equal to the proportional change in input. This indicates whether the efficiency of resource inputs rises, falls or remains unchanged when the usage of all inputs is increased in the same proportion. This is analysed by examining the relationship between inputs and output produced. In this analysis, copper concentrates is the output and labour, capital, material and fuel are the inputs in the estimation of returns to scale (the translog production function). The coefficient's estimate is obtained by regressing the production function using ordinary least squares.

4.5.2 Model

The estimation of returns to scale can be written in the following equation: The dependent variable of the model is the output while labour, capital, material and fuel are the independent variables.

$$Q = K^{\alpha} L^{\beta} M^{\delta} F^{\mu} e^{\lambda t} \qquad (1)$$

Where Q = output
K = capital
L = labour
M = material
F = fuel
t = time

In relating this framework to mining, we assume that gross output (Q) is a function of capital (K), labour (L), material (M), Fuel (F). The term **t** is added to take into account the trend effect in the case of time-series data.

The estimating equation is:

$$\text{Log } Q = a + \alpha \log K + \beta \log L + \delta \log M + \mu \log I + \lambda t \qquad (2)$$

Where a is the residual and λt is defined as the rate of factor productivity growth.

The parameter $a, \alpha, \beta, \delta, \mu$ are estimated by using the ordinary least-squares method (OLS).

Since the equation is in double log form, the coefficients $\alpha, \beta, \delta, \mu$ are elasticities of output with respect to labour, capital, material and fuel. Equation

(2) is homogeneous of degree n, where n is the sum of the regression coefficients $\alpha, \beta, \delta, \mu$. Thus it can be determined whether returns to scale are increasing, decreasing or are constant. A constant returns to scale is implied if they add up to 1 ($n = 1$), increasing returns if greater than one ($n > 1$) and decreasing returns to scale if less than 1 ($n < 1$)

4.6 Results and Analysis

The computation of productivity and regression estimate of returns to scale are shown in Table 4.5 and 4.7.

Table 4.5
Labour, Capital, and Total Factor Productivity Performance of Mamut Copper Mining, 1980 - 1994

Year	Labour Productivity	Capital Productivity	Total Factor Productivity
1980	19.5	0.89	0.71
1981	16.4	0.85	0.64
1982	14.2	0.88	0.63
1983	12.8	1.02	0.68
1984	10.2	0.99	0.64
1985	10.3	1.16	0.70
1986	9.7	1.36	0.76
1987	12.0	2.3	1.05
1988	11.3	2.9	1.2
1989	11.8	4.23	1.5
1990	9.8	3.1	1.2
1991	8.8	2.3	1.01
1992	9.1	2.8	1.12
1993	8.9	2.6	1.0
1994	9.0	2.67	1.1

The figures in Table 4.5 show that the productivity performance of MCM was better between 1980 and 1982 compared to the declining productivity performance between 1983 to 1986. This was presumably due to the recession which occurred during this period. The new technology brought in by the new management and the replacement of ageing and worn-out machinery, however, contributed to the improvement in productivity after 1987.

It appears from Table 4.5 that overall, the labour, capital and total factor productivity of MCM improved between 1987 and 1991 compared to the previous seven years: 1980 up to 1986. In the recession period, as was the case in 1983 - 1985, recruitment of additional labour was negligible. During this period, high costs incurred by the company in hiring new employees led the management to hoard labour, especially skilled workers. Training of employees was intensified and as a result, labour productivity increased and was maintained throughout 1987 to 1989. This increase can also be attributed to the displacement of labour due to the increase in mechanisation and technology brought in by the new management. The decline in labour productivity in 1990 and 1993, however, may have been brought about by the continued increase in wages and salaries while the output remained relatively unchanged. The low capital productivity between 1980 to 1986, on the other hand, was due to the high value of fixed assets. The capital productivity, however, showed an improvement between 1987 to 1989 although it appeared to have slightly decreased in 1990 and 1991. The increase in capital productivity can be attributed to the decrease in fixed assets due to depreciation. On top of that there was no significant additional increase of fixed assets.[8] Between 1990 to 1993, the fixed assets increased due to additional expenses incurred by the mine redevelopment plan which, in turn, led to the decline in capital productivity. As for the total factor productivity which was below 1.0 between 1980 to 1986, it increased to more than 1.0 throughout 1987 right up to 1994. The improvement in total factor productivity seems to indicate a better utilisation of input by MCM.

One explanation of a longer-term fall in factor productivity levels in the mining industry as suggested by Stuber (1986) involves declining ore grades of copper, gold and silver. His finding, however, is inconsistent with this analysis. In 1988 and 1989, following a period of heavy rainfall, the northeast upper section of the pit collapsed resulting in a landslide which brought down approximately one million cubic meters of waste. The slide prevented easy access to ore zones and as a result, the production of ore concentrates declined. MCM encountered difficulties in maintaining normal ore grade supplies to the mill. Yet during this period productivity increased. Table 4.6 indicates the inconsistency.

8 Fixed assets are used in our analysis as capital inputs and subjected to depreciation every year.

Table 4.6

The Metal Grades of the Concentrates Produced

Year	Copper (%)	Gold (grammes/tonne)	Silver (grammes/tonne)
1984/85	23.5	20.8	120.9
1985/86	23.4	19.5	119.4
1986/87	24.3	18.8	126.2
1987/88	24.3	21.7	121.8
1988/89	23.97	18.7	116.9
1990/91	24.9	15.9	126
1991/92	25.9	17.9	134
1992/93	25.9	20.7	142

Source:* MCM, *Annual Reports, 1981 - 1993

The ore grade in 1987/88 was relatively higher than that of 1988/89. But the total factor productivity in 1988 was lower (0.39) than in 1989 (0.53). This was also the case in 1990 where the ore grades were relatively higher than in 1989 but the total factor productivity was lower (0.24) against 0.52 in 1989. The ore grade in 1984/85 was relatively higher than that of 1989/90. yet the total factor productivity was low. Thus ore grades are insignificant factors in explaining the decline in total factor productivity of MCM especially between

1980 to 1986 and 1990 to 1991. This suggest that there are factors other than ore grade that may help to explain this phenomenon.

The results from the analysis are in accordance with a number of other studies that give importance to rates of capacity utilisation and the energy price shock, as explanation for the low productivity between 1983 to 1986. One can argue, however, that if capacity utilisation remain at a low level for a sustained period, why then would MCM not adjust factor inputs so as to raise labour and capital productivity levels. The high labour and capital productivity during 1987 and 1993 indicate that the company had in fact adjusted its factors input by utilising labour input and increasing the utilisation capacity of capital at a time when capital was expensive to obtain. Whilst it is true that the energy crisis, which occurred between 1983 - 1985, led to an increase in fuel prices and hence the price of materials and equipment, this was not true in the early 1990s. There was certainly no energy crisis in 1990 and 1991 and in view of this, the total factor productivity performance of MCM may have been influenced by technological changes

Before we examine the influence of technology on the productivity of MCM, the returns to scale is also important to look into. The MCM's returns to scale is shown in Table 4.7.

Results of Regression is presented in Table 4.7

Table 4.7:

Regression Analysis

Sample 1982 - 1994
13 observations
LS // Dependent Variable is Output (Ore)

$$\log Q = 218.5748 + 0.6459 \log K + 4.8779 \log L + 1.2425 \log M - 4.2358 \log F \quad 7.2678^{\lambda t}$$
$$(1.7174) \qquad (0.9683) \qquad (1.0936) \qquad (-1.7568) \qquad (1.0887)$$

R-squared	= 0.50834
Adjusted R-squared	= 0.26251
D.W	= 2.20481
F stat	= 2.06785

Figures in bracket are t-ratio

The sum of coefficients of capital, labour, material and fuel when added amount to 2.5305 which is more than 1 ($n > 1$). This may suggests an increasing returns to scale operation. An increasing returns to scale may indicate that the output of copper concentrates rises more with an increase in quantity used of input (labour, capital, material and fuel). Hence there is scope for expanding the size of capital, labour material and fuel used in the production process. As the expansion of the capital, labour, material and fuel takes place, the average cost of production of copper concentrates may decline in the long run. The increasing returns to scale as indicated in the result, provides MCM the scope to expand its production capacity.

As expected, the coefficient signs for labour, capital and material are positive, though the size of the estimated coefficient for labour seems larger than would have been expected on the basis of cost-share considerations. This suggests that MCM may be relatively labour intensive. The use of fixed assets as a proxy for capital flow as capital input could be the reason for the low coefficient of capital. The coefficient signs for the fuel variables is negative, indicating that it is negatively related to output. This is expected because the increase in consumption of fuel does not necessarily lead to an increase in the production of copper concentrates. A large quantity of diesel is not directly used in the production process of copper concentrates. Some is used for exploration within and outside the mining lease, generators supplying electricity to company quarter's residents at the Mine Site and Usukan Port. Taking this into account, the lag variable (fuel) is introduced into the model. An increase in the consumption of lubricants is partly due to the frequent leakages. Thus, not all fuel are directly related to the production of copper concentrates.

The coefficient of determination, R-square, examined the values to get an idea of how well the explanatory variables or independent variables explain variation in the dependent variable. For instance, values of R-square close to 0 indicate that the explanatory variables explain only a small proportion of the variation in the dependent variable. Values of R-square close to 1 indicate that the independent variables explain most of the variation in dependent variable. Our R-square result of 0.508340 shows that 50 per cent of the changes in the dependent variable is explained by the changes in the independent variables. The Durbin-Watson statistic is a formal test for serial correlation. If there is no problem of serial correlation, the Durbin-Watson statistic will be around 2. With positive serial correlation, the Durbin-Watson will fall below 2. Thus, in our result, the auto correlation does not exist as indicated by D. W. statistic of 2.2048.

MCM's increasing returns to scale exist because of the impact of technology brought in by the management. The MCM's ability to expand its level of automation and utilise high level technologies, high-speed, automated equipment in the production and processing plant coupled with the opportunities for greater management specialisation, enabled it to operate efficiently.

Increasing returns to scale cannot continue indefinitely. The factors responsible for obtaining output at rates more than proportional to the volumes of resource inputs will soon be exhausted. However, favourable returns to scale can prevail by more efficient use of its factors of production, the expansion of plant facilities and by acquiring high level technology. However, if the firm becomes larger, the problems of integrating the many phases of its activities multiply. Decision-making will be more complex and the burdens of administration become greater. The top management may lose touch with the daily routine of operation and find it necessary to delegate authority to lower management whose level of competence may be low. This factor may contribute to decreasing returns to scale if left unchecked. MCM may therefore improve the quality of workforce through training and getting additional capital by purchasing standard equipment and utilising current technology to maintain its current scale of operation. This may increase the operation cost in the short run but its long-term benefit in terms of production efficiency is not to be overlooked.

4.7 Policies Towards Enhancing Productivity Performance

There are a number of avenues open to MCM to achieve higher productivity and improve its production efficiency. However, the major components of productivity enhancement are associated with automation, the high quality of equipment, technological progress, research and development, the quality of manpower and incentives. Other factors such as effective management policies and managerial efficiency may also contribute to higher productivity. Thus, an entire productivity programme should be carried out to determine appropriate policies and priority.

4.8 Research And Development, The Innovation Process And Technological Change

Increases in the knowledge base and the application of this knowledge to the production process are generally considered the fundamental contributing factor productivity. In this sense, technological advance may include not only the applications of new scientific developments but also day-to-day improvement in the organisation and the process of production. Research and development in mining through technological innovation are crucial for productivity growth. The technological constitutes the hard core of productivity achievement for innovative improvements serve to improve the parameters of plant performance such as speed, reliability, precision, safety, quality, maintenance, and adaptation to changes in material inputs (Maisom and Mohd Ariff 1993). Improvement is achievable using sophisticated systems and equipment such as computer aided processing and control. Oul, Prince and Clarence (1980) found that the level of technology such as automation has a direct bearing on productivity improvement. Griliches (1986) found that at least some evidence of a consistent positive relationship between research and development investments and productivity. With respect to technology, major changes in ore-handling methods and increased use of open-pit mining through proper planning will contribute to the growth of productivity. In MCM, designing the pit is done with the aid of computer to ensure pit stability and also to enable the carrying out of geological exploration in an attempt to locate high grades of ore. This makes sure that only high grade ore is supplied to the mill to reduce processing costs. The Milling plant, where the processing of ore takes place, has its own laboratory to determine the quality of ore being fed into the mill and will alert Mine Engineering personnel if any ore with a below average grade is supplied to the mill. To increase the mill's processing capability, MCM acquired new and innovative equipment for the production process. In early 1988, the company bought a technologically-advanced equipment called In-Stream Analysis (ISA). It is an on-line highly automated computer-vision-based system that can provide the ore's statistical data analysis and subsequently determine the chemical quantity needed for ore treatment. Prior to the acquisition of the equipment, sampling was done manually once in three hours. With the acquisition of this new technology, however, MCM saved time spent on ore sampling. In 1989, MCM bought another sophisticated equipment; the Jameson Cell, which is used to selectively absorb high grades of ore. Although it costs the company RM 200,000, its function is to eliminate low grade ore thus reducing the cost of transportation and shipment of copper concentrates.

The extraction of ore was made easier and safer with the introduction of the latest equipment in blasting technology. Throughout the period of 1975 to 1990, the company used the detonating cord system. This usage, however, ceased and subsequently was replaced with the non-electric signal tube initiation system Primadet. The new signal tube was safe, efficient, and enabled the increase of blasting tonnage thereby achieving a lower overall unit cost.[9]

The acquisition of new technology has enhanced the productivity growth of MCM over a long-term period. The company is constantly looking for better technology to increase its productivity and improve the quality of ore produced. The existing mining technology is basically a Japanese technology but the present management also engages services from a British consultant (RTZ Consultant) to assist its Mine Engineering Department for mine planning. However, despite the expenses spent on technology in the production process, the mill recovery performance remains stagnant. Obviously, the recovery performance cannot be explained solely by the level of equipment technology. For instance, total ore milled increased to 6.3 million tonnes in 1985 compared to

[9] See Mamut Quarterly Copper Magazine, 1992

6.1 million tonnes in 1984 with the average grade of ore increasing slightly from 0.54 to 0.55 per cent copper. However, due to the higher proportion of serpentinite ore, the recovery rate decreased from 87.78 per cent to 86.15 per cent between 1984 to 1985. Ore recovery performance is important because it determines the total output obtained. As indicated in Table 4.8, the average recovery performance does not show significant changes during the period of 1981 to 1994. This shows that merely acquiring technology is inadequate. Quality, reliability, and the capability of technology in producing higher quality output are important. Other than reliable and sophisticated technology, the quality of chemicals in treating the ore is important to determine ore recovery performance.

Table 4.8

Average Mill Recovery (Copper), 1981 - 1994

Year	Recovery (%)
1981	84.8
1982	87.8
1983	87.5
1984	87.8
1985	86.2
1986	87.4
1987	87.8
1988	88.2
1989	84.0
1990	85.0
1991	88.0
1992	85.5
1993	86.7
1994	85.7

Source: MCM , Annual Reports, 1981-1994

This chapter examined the production trends and productivity performance of MCM from 1980 to 1994. The significant finding of the analysis shows that MCM's performance is improving as indicated by the productivity improvement throughout 1987 right up to 1994. The improvements, as examined earlier, seem to be associated with the effort taken by the new management in upgrading its technical efficiency by acquiring technology, replacing the worn-out and unserviceable equipment and machinery. In the past, the low productivity of MCM may be associated with the average age of the company's equipment and machinery. It is possible that the low productivity from 1983 to 1986 was due to the serious neglect of the previous management. In fact, there were a number of machines and equipment that had not been re-equipped during the period of 1975 to 1986.

It has also been observed that MCM is able to maintain and expand its production process with an increasing returns to scale. However, a word of qualification must be offered. Returns to scale in no way reflect the demand side of the picture. The mere fact that the output of a commodity is characterised by increasing returns to scale does not mean that it is profitable. Returns to scale only indicate the direction of change in the performance of production and unit costs which can be anticipated if the size of the firm's production operation is increased or decreased. Moreover, the nature of the production function for a product can change over a period of time because of scientific and engineering developments and advances in managerial technology.

The increasing returns to scale may arise from the expansion of the production operation of MCM in the late 1980's brought in by the new owner and this performance can be sustained if it can maintain the existing production capability and level of technology.