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AN ANALYSIS OF THE RELATIONSHIP BETWEEN OUTPUT AND COSTS OF INPUTS IN MALAYSIAN TIN MINING OPERATIONS

By

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ABSTRACT

AN ANALYSIS OF THE RELATIONSHIP
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Tin mining activity, despite recent setbacks in output and tin prices, is still going strong in many major producing countries. In Malaysia (the largest tin producer) the tin mining industry is presently facing a host of problems, both external and internal. Among the most serious problems are the rise in production costs and the decline in tin prices which occured almost simultaneously. These have caused a substantial reduction in the production of tin-in-concentrates by Malaysian producers. The decrease of the output of the mines, in turn, has created many other problems for the producers, the government and the economy as a whole.

Major options by Malaysia or by any other single producing country to revive the industry are limited. Efforts are encouraged to sustain the viability of the tin industry through intensifying the government's interference, especially in helping the local producers to reduce the burden of increased production costs in mining operations.

The phenomenon of the decrease in output of the mines and the increase in the cost of production was the central focus of this study. Among other objectives, this study aimed to identify input factors that

are associated with the variations in the output of the mines. The cost of input factors has been defined as the expenses paid by the producers to extract one ton of tin-in-concentrate. These costs are divided into seven categories: land, labor, capital, energy, material, taxes, and other miscellaneous operating expenses.

The study examined the relationships between these variables and the output levels of the sample of tin mines for a period of ten years, i.e. from 1973 to 1982. Study data were collected from the survey conducted by the Department of Mines, Malaysia. The analyses of the study were done at two levels: the industry and the groups of mines according to various methods of operation. The major hypothesis tested by the study was that the output level and the cost of inputs are inversely related and that the relationships between those variables differ significantly among methods of operation. Correlation and multiple regression analyses were employed, especially for the purpose of creating predictive models in the study.

The result of the analyses showed that at the industry level, the costs of land and capital were not related to the level of output. The costs of other input factors, however, demonstrated significant relationships to the output of the industry. Among them taxes proved to be correlated the most strongly.

The analysis of the groups of mines according to various methods of operation (dredge, gravelpump, opencast, and underground mining) revealed that there was a difference in terms of the relationships between the cost of each input factor with the output of the mines that used a particular type of operation. Certain methods are biased toward certain kinds of input factors. Predictive models for estimating the output of these mines were developed based on those observations. The reliability of those models were tested by comparing the results of the forecast with the actual data.

The study also found that many of the existing mining-related policies influenced the costs of some input factors, and thus affected the level of output of the mines. Among the most influential policies are the taxation system, subsidy and incentive programs and the equity participation policy. Not only do these policies affect the level of output of the tin mines, but also the choice of technology to be used in tin mining operations. The study suggested that some of those policies be reviewed or modified so that the efforts in revitalizing the industry would be consonant with the overall development objective of the country.

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Tons i.e. metric tons (Tonnages are in metric tons unless otherwise indicated.)

1 Ton	=	0.984206 long ton
	=	16.534665 picul
	=	1000 kilograms
1 Picul	=	100 katis
	=	133 1/3 lbs
	=	60.48 kilograms
1 Cubic Yard	=	0.76455 Cubic Meters
$1 Ringgit Malaysian	=	US$ 0.4310 (Official Conversion for 1982)

CHAPTER I

INTRODUCTION

The Importance of the Tin Mining Industry

Mining activity was one of the earliest human industries carried out in various parts of the world as early as the Bronze Age of the world's civilization. Tin mining, begun then is still a viable industry today. Because of special characteristics, which have prevented its substitution by other materials, tin has become one of the important materials for modern human use, particularly in the developed countries. Unfortunately, the bulk of tin ore is mined in those developing countries lying in the equatorial regions of Southeast Asia, Africa and South America, and none of those producing countries has been a consumer of any importance in modern times.

Most of the tin metal is consumed in three highly developed regions, namely, North America, Europe and Japan. Therefore, the bulk of tin is widely traded between tin producing countries and tin consuming countries. As such, tin trading has become an instrument for the formation of various international organizations, such as the International Tin Council (ITC). In fact, tin is the only commodity which has an organization in which both producers and consumers sit together to regulate trade and to safeguard the interests of both parties. This arrangement reflects the uniqueness of this industry in the world.

In many consuming countries, tin has been regarded as one of the vital materials in sustaining industrial growth. The uses of tin are generally associated with a high standard of living or a relatively high degree of industrialization (Robertson, 1965); therefore,the industrial leverage of tin is ranked higher than that of its competitors (Arad and Arad, 1979). On a global scale, tin has been ranked the tenth most important raw material on the basis of world production, international trade, and importance in engineering (Wu, 1973). Even though there are substitutes for tin in various uses, the degree of substitution prevailing since the early part of this century can be regarded as slight (Knorr, 1945). No doubt, these are some of the reasons why tin metal has been selected as one of the strategic and critical materials in the stockpile, especially in the United States of America and Italy.

However, the importance of tin or rather the tin mining industry to producing countries stems from different reasons. In many producing countries, the tin mining industry has been one of the major economic activities generating national income, foreign exchange earnings, capital expansion, employment and other related aspects of development. The dependency of many developing countries, especially Bolivia, Thailand and Malaysia, on the tin mining industry as a source of economic growth is very great. The tin mining industry also plays important role in enhancing their standing in the world.

In Malaysia, the tin mining industry has contributed considerably to overall socio-economic development. It has been said that the early development of the country was a result of the initial development of the tin mining industry (Yip, 1969). Although the non-fuel mining sector contributed only about 5 percent to the Gross Domestic Product

(GDP) of Malaysia in 1981, mineral exports of tin alone amounted to 9.6 percent of Malaysia's overall earnings that year. Despite the fact that the export of tin has decreased in the 1980s to less than 10 percent of total exports compared to about 20 percent in the 1960s, the tin industry in Malaysia still remains the fourth largest primary commodity export following rubber, petroleum and processed palm oil. In terms of employment, this industry has created vast job opportunities, especially in semi-skilled labor. At the end of September, 1980, a total of 39,720 persons were employed by this sector. Although the production of tin-in-concentrates in Malaysia has decreased substantially lately, the Malaysian Government is determined to maintain its position as the largest tin producer in the world; a position which it has maintained since 1880.

It is expected that the tin mining industry will continue to play an important role in socio-economic development in the world, particularly in developing producing countries, despite the fact that this industry has lately suffered a major setback. The future of this industry, particularly in Malaysia, will depend on the effectiveness of the measures taken to overcome the problems faced by the industry, and on how soon the industry can get out of the 'lock-up' position which it is now in.

The Problem Statement

The tin mining industry has been branded as one of the most volatile industries in the world (Mikdashi, 1976), and it has not always been regarded as a very profitable enterprise (Varon, 1979). This is due to the nature of the industry itself. Some of the most common problems faced by the industry are: the high risk of operation, the degradation and depletability of the mineral deposits, dependency on various uncontrollable factors, fluctuations in output, rate of consumption and prices, the heavy capital investment, reliance on foreign capital and technology, and the decentralized nature of the industry, (VanRensburg, 1978). These inherent problems, coupled with structural and institutional problems in many producing countries have made this industry more difficult to manage.

The tin mining industry in Malaysia, to a certain extent, faces most of the problems mentioned above. Lately, the health of this industry has been labeled as 'critical' (COM, 1981). There are several indications of this situation: First, the number of active mining units is decreasing from year to year. There were about 608 active mining units at the end of 1982 compared to over 900 ten years ago. Second, the amount of output produced by Malaysian tin mines has declined considerably from year to year. Figures for 1982 show only about 52,000 tons of tin were produced by the industry compared to over 60,000 tons annual production in the 1970s (DOM, 1982). Third, more and more workers in the industry have been retrenched from year to year. In 1982 alone, 13.2 percent or 4,448 persons were displaced from their jobs in the mines. Fourth, a growing number of mining firms are suffering a decline in profits and many of them have been closed down, either temporarily or permenantly. In 1982, about 42 percent of the total mining firms did not make a profit, and 15 percent of these were shut down (DOM, 1982). All these facts indicate the shaky and unstable nature of the tin mining industry in Malaysia at present.

In addition to those inherent problems, the tin mining industry in Malaysia is also faced with various external problems: Competition among the producer countries to supply tin to the world market, a decrease in consumption of tin metal in the world due to a lag in industrial growth and to tin substitutes, and depressed tin prices are among the external problems causing a downtrend in the tin mining industry in Malaysia. Internal problems in the industry such as insufficient investments, declining efficiency, competition in land use, administrative decay, ineffective taxation and fiscal policy, inadequate research and development efforts, lack of coordinated action on mineral development, smuggling activities, and an increase in the production costs are also reasons for the present unfortunate situation of the tin mining industry (Mohd Salleh, 1977; Jaafar, et. al., 1977; Scott, 1983).

All of these reasons, however, boil down to one most important syndrome, which is the rise in production costs on one hand, and the decline in tin prices on the other, which have occurred almost simultaneously (ITC, 1982). Although there may be other valid causes for decline, these forces alone have created a tremendous effect on the industry, not only in Malaysia, but in other producing countries as well.

The major increase in the costs of production in the tin mining industry in Malaysia began in 1973, parallel to the increase in price for oil and other mining materials, which contributed to the world recession. Even though the prices of tin followed this trend, they were not sustained. In fact, the prices of tin were beginning to fall in 1975, while the costs of production kept rising rapidly. Although there was a slight recovery in tin prices in the later part of the 1970s, it was not commensurate to the increasing production costs. Perhaps, the worst effects of this syndrome suffered by the tin mining industry in Malaysia occured in 1981. The average costs of production increased more than four-fold compared to those in 1972, whereas, the price change was less than a two-fold increase between those years. One of the consequences of this syndrome was a considerable drop in the production of tin from the mines in Malaysia from about 76,000 tons in 1972 to about 52,000 tons in 1982. This decline in production, in turn, caused other problems. The mine workers suffered retrenchment and the government lost revenue collections from the industry. The setback of the tin mining industry slowed down growth of the economy as a whole.

There may be other answers to the question of why the levels of production in Malaysian tin mines have decreased significantly lately, but the issue of rising costs of production could be the one that is largely responsible. This notion is, in fact, the basic tenet of the investigation to be carried out in this research. Perhaps, at this juncture, the most important questions concern the relevance of production costs in determining the levels of output of the tin mining industry, and the relationship of these two variables. Also a relevant issue to be considered is the susceptibility of those cost factors to change, which in turn causes variability in levels of production in the tin mining operation.

Based on the notion that the productivity of the tin mining industry is affected, to a certain extent, by the costs of input factors (Anders, et. al., 1980), it is therefore, hypothesized that the amounts of tin produced by the industry are closely associated with the variability of the costs of extracting the ores from the mines. While, this assertion might hold true at the industry level, any generalization of this to the firm or mine level could be misleading due to the fact that the magnitude of each factor of production has a differential effect on the amount of ores to be produced by each mine. Many researchers suggest that the variability in the production levels and the costs of production in tin mines depend, to a great extent, on the methods of extraction used in mining (Thoburn, 1977; Scott, 1980; ITC, 1983). Based on these assertions, it is therefore, further hypothesized that the association between the amounts of ore extracted and the types of input factors and the costs of those input factors varies significantly from one mining method to another. These are the major areas of investigation of this study.

The Research Procedure

The major hypotheses advanced above will serve as the central focus of this research. However, a number of sub-hypotheses will also be developed later to strengthen the case in the investigation. The main thrust of the research is to prove these hypotheses by using certain statistical analyses. This research is also intended to seek answers to the questions posed in the study. As pointed out earlier, the phenomenon to be investigated in this research is the relationship between the production levels and the costs of input factors in tin mining operations. In this case, the level of production is treated as the dependent variable, while the cost factors are the independent variables.

The relationships between these variables will be established in two phases. First, the relationship between the output of the industry and the average costs of input factors in the industry will be determined. Second, the relationship between the amount of ore produced by a group of mines using similar methods of extraction and the average costs of input factors incurred in each of those methods will be analyzed. In this case the Malaysian mines will be grouped according to four major methods of operation, namely, dredging, gravelpumping, opencasting, and underground mining. These relationships can easily be established by using regression analysis which is felt to be appropriate and suitable for the purpose of this study.

The results of the regression analysis will enable the study to construct various predictive models to reflect the behavior of the mines in terms of the decision to produce the minerals. The reliability of the proposed models will be discussed and evaluated by comparing the results of forecasts made by the models with the actual data.

As indicated earlier, 1973 was the beginning of the decline of the tin mining industry in Malaysia; therefore, this year will be used in this study as the base year for the analysis. The ten-year period, between 1973 and 1982 provides a sufficient scope to trace the behavior which led the industry to its present situation.

This research will require a great deal of data and information in order to substantiate the hypotheses projected in the investigation. The best way to obtain this data and information is to conduct a primary data collection. However, certain constraints, especially the problem of access to the mining firms, have made this study rely mainly on readily available data from various sources. One important source of data is the Department of Mines, which has conducted numerous surveys on the tin mining industry in Malaysia since 1972. A survey on the costs of production in Malaysian tin mines is done twice a year, in accordance with the survey format provided by the Economic and Price Review Panel of the ITC. This particular source of data will be used extensively in this research.

Study Objectives

It is believed that in order for the tin mining industry to revive and to sustain its viability in the future, the industry should be in a healthy situation. Solving some of the most critical problems faced by the industry currently is a step in that direction, which is urgently needed. Therefore, this study is designed to examine one of those critical problems, namely, the increase of the costs of production in mining activity. Although this one dimensional view cannot solve all of the problems in the tin mining industry, it may provide valuable information which could lead to a better understanding of the real issues in the industry.

The more specific objectives of the study include the following:

1. to identify all elements which could be considered as costs in the mining operations;
2. to establish and analyze the relationships between output levels and cost factors in the operation of tin mining;
3. to create predictive models for estimating the output of the tin mines;

4. to assess and evaluate the proposed models for the purpose of forecasting future output of the tin mines in the country;
5. to analyze the impact of existing government policies on tin mining activities;
6. to analyze the choice of different methods of mining in the industry.

This research is significant in two areas. One area is the magnitude of the relationship between the levels of production and the costs of production. An understanding of this will serve as a framework for decision making on both macro and micro levels of the industry. A second area is the sensitivity of each of the cost factors affected by unfavorable policy measures taken by the operators as well as the government. The significance of these two areas has been insufficiently appreciated in the past and increased understanding will provide a basis for more effective action in eliminating problems in the tin mining industry in Malaysia.

It is hoped that this research will result in an appropriate model reflecting tin mining activity carried out in Malaysia. Some of the findings of this study could also be useful in application to other types of mineral industries. However, due to the limited scope of this study, which focuses only on the nature of production costs and their relationship to production levels, the findings would be useful only within those limits. Nonetheless, it is envisaged that this study will complement not only other studies in this area, but also studies done on technical and marketing aspects of this industry.

Organization of the Study

This study is divided into various chapters. Chapter I, the Introduction, provides the framework of the research within which the problem statement and the study objectives are laid out. Chapter II gives a historical perspective of the tin mining industry. It also discusses the trends in the world tin economy, which led the industry into the present situation.

Chapter III deals with the development of the tin mining industry in the context of Malaysia and discusses the problems affecting this industry currently. Chapter IV gives an up-to-date review of the literature on the subject of mining, with particular reference to tin mining. This chapter also provides details of the research methods and statistical procedures of the investigation.

Chapter V presents the results or findings of the study in various phases. Chapter VI offers discussion and analysis of the findings, particularly in relation to the reliability of the models created for forecasting purposes. This chapter will also discuss the implications of existing government policies and the issue of technological choice in the industry. The last chapter, Chapter VII presents a summary, a conclusion and recommendations.

CHAPTER II

TRENDS IN THE WORLD TIN ECONOMY

In this chapter, a brief account of the global situation in the tin industry will be presented for the purpose of understanding current trends in the world tin economy. This section includes an historical perspective of the tin industry, and discussion of production and consumption patterns, the pricing system of tin, and the world reserves of this resource.

The Emergence of the Tin Mining Industry

The emergence and development of the tin industry can be traced to as early as the Bronze Age of the world's civilization. Archaeological findings supported by literary evidence confirm that tin was among the earliest metals known to man. Objects made of bronze (tin and copper) dating as far back as 3500 B.C. have been found in the Middle-East. By the early days of the Roman Empire, the use of tin was fairly widespread, especially to make bronze and for the tinning of copper vessels (Cohglan and Case, 1957; Marechal, 1963).

Tin was used in many parts of the ancient world but mined only in a few places. In the early history of tin production in the world, England played a prominent role. It was to Cornwall in the Southern tip of England that the Phoenicians sailed from their eastern Mediterranean homeland to trade for the tin found there. That was in 1500 B.C. Historians believe that Cornwall was probably already an important source of tin around 500 B.C. (Flower,1880). By the 13th Century, England had become the largest supplier of tin in the world. By the 14th Century, the Belgian city of Bruges had become one of the leading centers for tin production in Europe. With the creation of the East India Company in the 17th Century, tin was shipped as far afield as India and Japan. By this time, tin was exported to practically all the more advanced countries in the world (Hedges,1964).

In the East, China and Malacca had long used and produced tin in the early Century, but the importance of tin was noted by the Portuguese only in the 16th Century and later on, in the 17th Century, when the Dutch ousted the Portuguese from Malacca (a state in Malaysia now).

The fortune of the tin industry reached new heights during the 19th Century as a result of the Industrial Revolution, which represented a milestone in man's economic development. The need for pumping water out of the Cornish tin mines was a potent force in the development of the steam engine (Hedges,1964). Technological development during the Industrial Revolution was matched by great advances in medicine at the beginning of the 19th Century. Those factors caused a dramatic increase in the use of minerals, such as tin, and an unprecedented growth in the world population.

The 19th Century saw the opening of new lands to mining exploration and human settlement. Rich tin deposits were discovered in South-East Asia, Australia and Bolivia. In the 1870s Australia emerged as an important tin producer, but rapid development of the Federated Malay States (Malaysia now) alluvial deposits marked the decline of both the British and Australian tin mining industries.

Towards the turn of the century, Bolivia emerged as an important tin producer as a result of the exploitation of rich underground deposits. By the end of the 19th Century, Malaysia was by far the largest tin producer in the world, followed in order, by the Dutch East Indies (Indonesia now), the United Kingdom, Australia, Bolivia and Thailand.

The Production of Tin

The term production here refers to the output of tin mines, which is called tin-in-concentrates or primary tin metals, in the 20th century. The 20th century has witnessed profound and dramatic changes in the prevailing world economic system, the First and Second World Wars, the economic depression of the 30s, the boom years of the 60s and the recession which started in the middle of the 70s. These phenomena have affected considerably the development and production of tin in the world.

From the beginning of this century, the tin mining industry went through a period of steady growth through the end of the First World War. This was followed by a period of excess production and the tin mining industry had to adjust to the new conditions by cutting back mine output, but the years from 1924 to 1929 represented a period of rapid expansion. The summary of tin-mined production from 1900 to 1970 is shown in Table 1. The figures are the annual average for the total of 10 years of production.

Table 1

World Tin-Mined Production, 1900-1970

(in thousand tons)

Year	Production
1900	99.4
1910	116.7
1920	137.5
1930	139.5
1940	139.3
1950	156.2
1960	136.6
1970	152.0

Sources: Knorr,1945; Robertson,1965; LaSpada,1968,1971.

During the economic recession in the early 30s the demand for tin slumped to very low levels. This had serious repercussions for tin production, which fell considerably. World mine output reached a minimum of 81,000 tons in 1933, the lowest production level in this century. The subsequent recovery in demand brought about a quick revival in tin mining and by 1937 world tin production had more than doubled to 198,000 tons.

During the early years of the Second World War output was stimulated by a growing demand which stemmed from the increasing needs of the war industry and the accumulation of stocks, especially in the USA. The events of the Second World War caused a shift in the sources of tin suppliers from the traditional tin producing areas of South-East Asia to the African and South American producers. Wartime production of tin-in-concentrates reached a peak of 243,000 tons in 1941, but the Japanese occupation of South-East Asia, the largest producing area in the world was completely cut-off and supply came mainly from Bolivia, Nigeria and the Belgian Congo (now Zaire) whose deposits were exploited very intensively.

Five years of war had practically destroyed the industrial infrastructure in many of the producing countries, but the economic recovery which began in 1951 after the war represented the most remarkable period of economic growth in modern history. The Korean War in fact had further stimulated the demand for tin, and this, in turn, caused an increase in production; but the withdrawal from the market of the US Government (reduction in stockpiling goals) in the mid-1950s and the successive periods of export control declared by the International Tin Council (ITC) caused the world production of tin-in-concentrate to drop by about one-third to around 120,000 tons in 1958 from about 175,000 tons in 1953 which was the highest level for the decade.

It took, however, more than a year for mine production to regain the ground lost while the demand for tin was running ahead of production. The expansion of tin production became more apparent in the second-half of the 1960s. The exceptionally high price which prevailed during 1964 and 1965 encouraged investment in tin mining, thus the expansion in production overran the demand for tin. The tin economy moved from a period of deficit to one of surplus. Export controls exercised by members of the ITC caused, once again, world production of tin to drop slightly in 1969, but there was a recovery to marginally higher levels in 1970 and 1971. In 1972 world output of tin reached a peak of 196,400 tons. The high level of production had a depressive effect on the tin price and the ITC once again had to reintroduce export controls on tin in 1973. This resulted in a drop in mine production to the same level as two years earlier.

The production of tin-in-concentrate from 1973 to 1983 (excluding communist countries) is shown in Table 2.

Table 2

World Tin-Mined Production, 1973-1983

(in thousand tons)

Year	7 Major Producing Countries	Others	World
1973	140.9	46.9	187.8
1974	139.2	39.3	181.5
1975	135.7	42.8	178.5
1976	141.2	41.3	182.5
1977	136.0	43.9	179.9
1978	151.9	41.6	193.5
1979	158.5	42.7	201.2
1980	163.2	38.0	201.2
1981	144.3	57.6	201.9
1982	128.4	55.4	183.8
1983 (f)	107.2	54.0	161.6

Sources: ITC, 1983; LaSpada, 1981.

(f) estimated figures worked out by the ITC (1983)

The producing regions now include Asia: China, Indonesia, Japan, Malaysia and Thailand; South America: Bolivia and Brazil; North America: the USA, Canada and Mexico; Europe: Belgium, the Republic of Germany, Portugal, Spain, The United Kingdom and Russia; Africa: Nigeria, Rhodesia, Rwanda, South Africa and Zaire; and Australia. However, the major producing countries, in order of importance, are: Malaysia, Thailand, Indonesia, Bolivia, Australia, Zaire and Nigeria. These seven countries contributed more than 85 percent of the total tin-mined production in the world (excluding communist countries).

The production of tin in the 1970s took an unprecedented trend in the history of the industry. The year 1973, to be specific, marked a shift in trends. The last quarter of that year was a very eventful period which had far-reaching effects on the world economy. The Arab - Israeli War in October, 1973 originated the oil crisis. The price of oil was raised to very high levels in a very short time. This triggered a rapid upward movement in the price of all materials, including tin, leading to the commodity boom, inflation and economic recession. The period from 1973 to the beginning part of this decade was probably the most unstable in the post-war history of the tin mining industry.

World mine production of tin-in-concentrate which had reached a high of 196,400 tons in 1972, declined steadily to a low of 178,500 tons in 1975. Although export control had been enforced from January to September, 1973, increased production costs, caused by the oil crisis and the economic recession which followed in 1975, were mainly responsible for the decline. The recession affected tin prices and export controls were enforced again from April, 1975 through the end of June, 1976. World tin production increased significantly thereafter, reaching 201,200 tons in 1979, a record for the decade.

In the beginning of the 1980s, the production of tin-in concentrate was quite stable, around 200,000 tons; however, this trend was altered in 1982 when production was reduced to 183,800 tons. The effects of export control, increased production costs, the low prices of the commodity and the continuing worldwide economic recession were largely responsible for this continuous decline in the world production of tin.

In 1983, production was expected to continue to decline to around 160,000 tons (ITC, 1983). However, a slow recovery is expected by the beginning of 1984, thus, production of tin in the near future is expected to increase slowly, following the trends of the recovery of the world economy.

The Consumption of Tin

The consumption of tin includes the use of tin-in-concentrates, the use of manufactured tin metals which are called secondary tin metals and the use of recycled tin materials. For the purposes of this study, the consumption of tin refers only to the use of tin-in-concentrate or as it is known in consumption terminology, primary tin metal.

Primary tin metal is rarely used in its pure form in industrial processes. It is consumed mainly by industry in the manufacture of numerous products containing tin metal in varying amounts. It differs, therefore, from other metals which may depend to a substantial extent on a product which enters the market in large tonnages as a pure or semi-pure metal.

The wave of inventions in modern technology and the population explosion which occured during the last two centuries, have brought about an increase in the use of tin. The uses of tin have developed from traditional usages in coating and alloying to many new uses, such as in cast iron, electroplated coatings, plastics, paints, industrial fungicides, disinfectants, and in agriculture in the form of fertilizer and other chemical compounds (ITC, 1982).

It is also a characteristic of tin that its uses are generally associated with a high standard of living or a relatively high degree of industrialization (Robertson, 1965). Therefore, it is obvious that the major source of tin users are the developed countries. The so-called 'old-established' consumers of tin in the world include the USA, Japan, Canada, the United Kingdom, Belgium, France, the Republic of Germany, Italy, the Netherlands and Australia. Other new users are Argentina, Brazil, Chile, Columbia, Mexico, Venezuela, India, the Philippines, Turkey, Greece, Portugal, Spain and Yugoslavia. The consumption in the rest of the world is not of any significance (LaSpada, 1968, 1971; Yahya and Hollands, 1981).

In developed countries, the major consumption of primary tin metal is in tinplate, tinning, solder, and with alloy. While, in less developed countries, the major uses are in tinplate and solder. On a global scale, primary tin metal is used extensively in tinplate, representing approximately 40 percent of the world consumption (excluding communist countries). Ninety percent of this tinplate is consumed by the packaging industry; the remainder is used in a wide range of applications, mainly in light engineering. Solder is second in importance, about 24 percent. Tin chemicals account for approximately 10 percent. The remaining 26% is used in a wide variety of tin and tin alloy coatings and alloys such as the bronzes and brasses (Govett and Robinson, 1980).

The development of world consumption of primary tin metal may be seen most clearly, not from the absolute figures of the metal consumed, but from the consumption per capita. During the second half of the 19th century, the consumption of tin per capita in the world rose sharply from .14 lbs. in the 1930s to .17 lbs. in the 1940s; however, per capita consumption decreased to .14 lbs in the early 1950s (ITC, 1954). The 1960s per capita consumption of primary tin metal in the leading tin consuming countries was as follows: the USA, .66 lbs; the United Kingdom, .90 lbs; France, .53 lbs.; Japan, .33 lbs. (Robertson, 1965). The largest tin consumer in the world is the USA, followed by Japan and European countries.

Current world consumption of primary tin metal is about 164,000 tons a year or an average of 55 grm. per inhabitant, which is a decrease from 180,000 tons or 60 grm. per inhabitant during 1978-1980. Table 3 shows the consumption of primary tin metal from 1900 to 1970 (excluding communist countries). The figures are the annual average for a total of ten years of consumption.

Table 3

World Primary Tin Consumption, 1900-1970

(in thousand tons)

Year	Consumption
1900	81.1
1910	95.2
1920	105.0
1930	138.0
1940	118.0
1950	151.5
1960	167.4
1970	168.2

Sources: Knorr, 1945; ITC, 1964, 1971.

From the beginning of the Century until the 1920's there was a steady increase of around one percent per annum in the consumption of tin. A considerable increase in demand was noticeable in the early part of the 1930s, but this trend was not sustained. In the 1940s the consumption was down to slightly higher than the levels in the 1920s. A major increase began in the 1950s, that is after the Korean War, which abruptly pushed the demand for tin to around 150,000 tons, compared to only 118,000 tons during the 1940s. During the 1960s, the rate of consumption further increased by 1.3 percent annually. The major increase was recorded in the developing countries which accounted for 42 percent of the total increase compared with 13 percent in developed countries (LaSpada, 1968).

The 1970s witnessed a drastic change in the demand side of the industry. 1973 started the unprecedented surge in the demand for tin. Table 4 presents the consumption pattern in the 1970s. Under the driving force of the commodity boom, and the fear of higher prices, world consumption of primary tin metal (excluding Communist countries) reached an all-time record of 214,000 tons. This is 22,000 tons or 11.9 percent higher than consumption in 1972. The excess demand was met by heavy sales from the ITC Buffer Stock and the USA stockpiles. The strong demand for tin continued well into 1974, pushing prices to record levels. However, with further sales from the ITC Buffer Stock and the USA stockpile, the price of tin stopped increasing. The world consumption of primary tin metal started to decline by the end of 1974, from 200,000 tons to 183,000 tons by the end of the decade. This was the result of among other things, the economic recession and other structural changes in the world economy in the 1970s. World consumption at the beginning of the 1980s stood at around 162,000 tons annually. The US consumption of tin dropped by one-tenth and that of the United Kingdom by one-quarter in the 1980s compared to that in the 1970s. In the 1980s the major consuming countries of primary tin metal in the world, in order, are the USA, Japan, the Federal Republic of Germany, France, the United Kingdom, and Italy.

Table 4

World Primary Tin Consumption, 1973-1983

(in thousand tons)

Year	Major Consumers*	Others	World
1973	188.8	25.4	214.2
1974	172.9	27.2	200.1
1975	146.5	27.4	173.9
1976	165.4	28.6	194.0
1977	155.7	29.1	184.8
1978	153.9	30.1	184.0
1979	153.4	29.9	183.3
1980	148.0	29.4	177.4
1981	131.5	31.2	162.7
1982	127.3	33.7	161.0
1983(f)	132.1	33.8	166.1

Source: ITC, 80,82,83.

*Major Consumers include the USA, Japan, the United Kingdom, Germany, France, Italy and the Netherlands.

World consumption excluding the communist countries.
(f)Estimation made by the ITC.

If we examine the production and consumption of primary tin simultaneously the picture of the world tin economy is characterized by deficits of supplies against demands in 1973-1974 and in 1976-1977, by a rough balance in 1978, and by surpluses in 1975 and 1979-1982.

The supply and demand of tin in the world is in fact influenced to a certain extent, by the activities of the USA stockpile program and the ITC Buffer Stock Control Schemes.

The deficit years during 1972 to 1974 may have been worse had it not been for the interference of the USA stockpile program and the ITC Buffer Stock operations. The same picture might have occured in 1976-1977 when an expected deficit turned out to be a surplus when the USA Stockpile and the ITC Buffer Stock supplies entered the world market. In fact, the world tin economy has been perpetuated not only by the normal processes of supply and demand, but to a greater extent, by the forces of international control such as the USA stockpile program and the ITC Buffer Stock schemes. These factors are vital to the world tin economy and require special attention. They will be discussed in the next section.

The International Control of Tin

Tin is perhaps the only metal that is subject to international price controls. In the history of tin trading, tin prices have been affected by severe fluctuations, especially prior to the international control efforts. To follow the development of international control, it is necessary to go back more than 60 years to the difficult times immediately following the First World War. On the one hand, business conditions constricted demand and on the other hand, a shortage of shipping had led to large accumulations of tin and tin ore in the chief producing countries (Hedges,1964). These and other factors coming together sharply depressed the price of tin in the immediate post-war years, causing great hardship to many producers. The price of tin became subject to violent fluctuation; for example, in 1928 alone, the fluctuation between the highest and the lowest price of tin recorded was around 26 percent of the mean (Knorr,1945).

In the distress caused by the greatly depressed tin prices immediately following WWI, various important mining interests in tin producing countries sought government aid. The Government of the Federated Malay States (Malaysia) for instance, bought tin on the market as a price-support measure, but the fact that national action alone could not stem the downward course of prices led the major producing countries to seek international cooperation in tin tradings.

The first attempt at this kind of cooperation was known as the 'Bandoeng Pool,' established on February 28, 1921, whereby representatives of the Federated Malay States and the Netherland Indies agreed to create a 'stock pool' for the purpose of taking excess supplies of tin off the market and selling them after prices had recovered (Lawrence,1953). The second attempt was initiated on July 11, 1929 in London to establish the Tin Producers Association (TPA), of which The Federated Malay States, The Netherland Indies, Bolivia and Nigeria were members. This organization later formed the International Tin Control Scheme (ITCS) effective March 1, 1931. The objective of the Scheme was to secure a fair and reasonable equilibrium between production and consumption of tin with the view of preventing rapid and severe oscillation of prices (Myers,1937). The ITCS was to be administered by the International Tin Committee representing the four signatory Governments. Later, in January, 1934 Thailand was admitted as a member to the ITCS.

In the middle of 1934 a new and official International Tin Pool was created as an adjunct to the ITCS whereby a 'Buffer Stock' was established to protect the interests of producers and consumers. The Buffer Stock, accordingly, would serve as another implement in the hand of the Committee to assist in the prevention of undue price oscillations and in the maintenance of a reasonable balance of supply and demand (ILO,1943).

However, in the 1940s, the ITCS was somewhat ineffective due to the Second World War. Therefore, the old agreement expired without renewal and legal restriction came to an end. In July, 1942, the remaining funds of the tin buffer pool, long inactive, were distributed among the participants and the pool was formally liquidated (Knorr,1945).

The next major move towards international control began in the middle of 1955. The ITCS was revived through a new concept of international tin cooperation, which was known as the International Tin Agreement (ITA). A council was formed to administer the ITA, which is known as the International Tin Council (ITC). The ITA's have been renewed for 5 year periods from 1956 through the present. The objectives of the tin agreements are manifold. The fourth, fifth and sixth agreements especially, center on the problems of maintaining a balance between world production and consumption of tin, preventing excessive price fluctuation, promoting export earnings, and ensuring an adequate supply at prices that are fair to consumers and renumerative to producers. The preamble and objectives of the Sixth International Tin Agreement are in Appendix A.

Membership in ITA is open to all exporter and importer countries. The membership of the Fifth ITA which covered a period from July 1, 1976 to June 30, 1982 is as follows:

Producing Countries: Australia, Bolivia, Indonesia, Malaysia, Nigeria, Thailand and Zaire.

Consuming Countries: Austria, Belgium, Bulgaria, Canada, Czechoslavakia, Denmark, France, Germany, Hungary, India, Ireland, Italy, Japan, Netherlands, Norway, Poland, Romania, Spain, Turkey, the United Kingdom, the United States of America, the USSR and Yugoslavia.

Interesting to note here is that, the United States of America, the biggest consumer of tin, joined the ITA only in the Fifth Agreement. This was the first time the USA had joined a metal commodity agreement (Harris,1978). The USA, as a condition of its membership in the Agreement, insisted that disposals of tin from their Strategic Stockpiles would not be affected by membership in ITA. This precaution was stipulated because the objective of the General Service Administration (GSA) which administers the stockpiles in surplus disposal operations is different from the objective of ITA operations. The GSA's objective is to assure that its operations are carried out in a way that will minimize impact upon the domestic commercial market (US Congress,1976), while the ITA's objective is to reduce fluctuation of tin prices on the international market.

As instruments to achieve its objective, the ITC has three main tools: a) the Buffer Stock Operation; b) the Export Control Scheme; and c) the Price Setting Arrangement.

(a) The Buffer Stock Operation

The operation of Buffer Stock is a method of maintaining tin prices. In order to do that the Buffer Stock Manager has to be the net seller or the net buyer of tin on the market, depending on the market situation. During a surplus period, Buffer Stock absorbs the excess tin on the market, and during a deficit period, it is sold, thus, stabilizing the price. Buffer Stock is financed jointly and equally by both producers and consumers. It is comprised of two balancing components from member countires: first, a cash or tin metal contribution equivalent to 30,000 tons and second, borrowing for the purchase of tin, to a maximum of 20,000 tons (The Sixth ITA, 1981).

In the 1970s the operation of ITC Buffer Stock was very active. Table 5 shows the amount of tin traded in the Buffer Stock operation from 1971 to 1982. During 1971 and 1972, the Buffer Stock operation was on the average the net buyer, while, in 1973 and 1974 it was the net seller. This coincides with the situation of surplus during 1971 and 1972 and the deficits during 1973 and 1974. However, the operations of Buffer Stock were more or less balanced during 1978, 1979 and 1980, therefore, it was neither the net seller nor buyer. A big jump in the operation of Buffer Stock was noticeable in 1982 when it bought about 51,600 tons of tin on the market. At the end of the Fifth Agreement, the amount of tin in Buffer Stock was 21,619 tons. In addition to that, it has collected about 31,061 tons of tin during the Sixth Agreement up to this year.

Table 5

Operation of the Buffer Stock, ITC, 1971-1982

(in thousand tons)

	1971	1972	1973	1974	1975	1976	1977	1978	1980	1981	1982
Bought	5.4	5.8	-	-	19.9	-	-	-	-	1.1	51.6
Sold	-	-	11.9	0.9	-	19.3	0.8	-	-	-	-

Sources: LaSpada, 1981; ITC, 1983.

(b) The Export Control Scheme

Parallel to the operation of Buffer Stock, the ITC also used export control measures to achieve its objectives. Export controls were implemented in the producing countries in order to reduce the excess supply of tin on the market. This scheme has been in forced since the early period of the ITC. However, the limit of export imposed varies from period to period depending on the market situation. During the 1950s the permissible tonnage for export among the member countries was in the range of 20,000 to 30,000 tons annually. During the 1960s, the permissible tonnage for export was between 36,000 and 41,000 tons yearly.

In the early 1970s this scheme was eliminated due to a bullish market in tin, which followed the commodity boom. The export control scheme, however, was reinforced again in 1973 as the world tin market depressed. Table 6 shows the enforcement of export controls from 1973 to 1983. Initially, this scheme applied for one quarter of the year only; however, subsequent extensions are permissible if the situation warrants.

Table 6

Export Controls of the ITC, 1973-1983

(in tons)

Control Period			Total Permissible Export	Total Actual Export
19/1/73	-	31/3/73	35,040	n.a.
1/4/73	-	30/6/73	42,644	n.a.
1/7/73	-	30/9/73	42,644	n.a.
18/4/75	-	30/6/75	26,560	27,379
1/7/75	-	30/9/75	33,000	33,158
1/10/75	-	31/12/75	35,000	34,205
1/1/76	-	31/3/76	32,835	32,979
1/4/76	-	30/6/76	40,000	n.a.
27/4/82	-	30/6/82	25,000	25,099
1/7/82	-	30/9/82	23,200	22,604
1/1/83	-	31/3/83	23,200	n.a.
1/4/83	-	30/6/83	23,200	n.a.

n.a.: Not available
Sources: Govett and Robinson, 1980; ITC, 1983.

Export controls were abandoned in September, 1973 and in 1974 as ITC virtually lost its influence as the USA released its stockpiles. It was resumed again in 1975 and continued through 1976 at the average of 33,000 tons of permissible export. However, from 1977 to 1981 this scheme was not in force. From 1982 to the middle part of 1983 the total permissible export of tin among the producer countries stood at around 23,000 tons annually. Export control has always been considered the only potent tool to avoid long term surpluses of tin on the market.

The appropriation of permissible export of tin among the producing member countries is negotiated in the ITC, taking into consideration certain prevailing situations in each country, such as the costs of production, the loss of production, and the amount of tin contributed to the international market. The last export control applied to the member producing countries is shown in Table 7.

Table 7

Permissible Export of Tin Among the

Member Producing Countries Under ITA

From April to June, 1983

(in tons)

Country	Production	Percentage of Total Production	Permissible Export	Percentage of Permissible Export
Australia	13,998	9.66	2,241	9.66
Indonesia	36,409	25.11	5,825	25.17
Malaysia	60,132	41.47	9,621	41.47
Nigeria	2,412	1.66	385	1.66
Thailand	29,842	20.58	4,775	20.58
Zaire	2,208	1.52	353	1.52
Total	145,001	100.00	23,200	100.00

Source: ITC, 1983.

Permissible export is the amount of tin that can be exported by producing countries.

(c) The Price Setting Arrangement

The other instrument used by the ITC in maintaining the price of tin on the international market is the price setting arrangement. The ranges of price as agreed upon in the ITAs consist of the Floor price, Lower sector, Middle sector, Upper sector and Ceiling price. The prices are in Malaysian Ringgits per picul of tin. The price ranges are determined by majority vote or consensus of the ITC. An example of the price ranges is shown below:

For 13 March, 1980 to 13 January, 1981	Floor Price	(M$) 1,650 (27,280)*
	Lower Sector	1,650-1,815 (27,280-30,000)
	Middle Sector	1,815-1,980 (30,010-32,740)
	Upper Sector	1,980-2,145 (32,740-35,400)
	Ceiling Price	2,145 (35,400)

*Parenthesis are the equivalent prices per ton of tin.

The Floor price is the basis of the effective working of the tin agreement. The Council takes into account production costs of tin, so that the Council's floor price makes sense in relation to the costs of the tin mining industry (Allen,1975).

The actual trading prices of tin are determined at three main so-called free markets for tin: one in Penang, Malaysia (price ex-work), one in London, London Metal Exchange (LME Standard), and the other in New York (price ex-dock). Of these three, the Penang market is the most important because it is used as the foundation of the world's tin prices. The Penang market is purely a physical market which is operated by the two Malaysian tin smelters; the only sellers are the smelters and the only buyers are direct consumers and traders. Overnight bids from dealers in Malaysia and throughout the world are made for the physical tin smelted by the Straits Trading Company and Datuk Keramat Smelting Sendirian Berhad, both in Penang. These bids are considered on the basis of the daily quantity of metal available--all of which is invariably sold--and a single price is announced at 10:30 a.m. local time; this becomes the official quotation for the day. The price quoted is ex-smelter or ex-work and the tin is usually available in one to three weeks; the price is in Malaysian Ringgit per picul (133.33 lbs) for high grade tin (99.85% minimum). Since July, 1972, the ITC has used the Penang price as the basis for its official pricing system. From 1981 the prices of tin are quoted in kilograms. Other principal quotations for tin are those of the London Metal Exchange and the New York Market. Both offer cash and forward metal prices.

It is observed that the price ranges of the ITC have more or less followed the actual trading prices of tin on the markets. The determination of ceiling and floor prices depends on fluctuations in the actual prices of tin. However, during boom periods, normally the actual prices of tin go far beyond the ceiling prices of the ITC.

During the early period of the implementation of this instrument, the ITC prices seemed to parallel the actual trading prices, but the situation changed considerably during the 1960s when the actual trading prices were far higher than the ceiling prices of the ITC. The same phenomena occurred in the middle part of the 1970s. In the 1980s the situation has been reversed and actual trading prices have been within the price ranges of the ITC. It has been claimed that the price setting of the ITC works well only during a 'good price period' (COM,1983), but during poor market situations the ITC price ranges seem to be insufficient to maintain the price levels. In fact, the price range has been the subject of a great deal of disagreement and negotiation among the producing countries. Bolivia for instance, consistently argues that the price is too low since it reflects the production costs of the low-cost Southeast Asia producers rather than Bolivia's high costs of production (Govett and Robinson,1980).

Another aspect of international control of tin is the role of US stockpile activity, which to a greater extent, has influenced the supply and demand situation of tin in the world. For instance, in 1973 and 1974 the heavy selling of US stockpiles, 19,600 tons and 23,500 tons, respectively, affected the prices of tin adversely, pushing the prices of tin to record low. The release of GSA stockpile has been the issue which has lately prompted producing countries to find other means to safeguard their interests. This has led to the formation of the Association of Tin Producing Countries (ATPC) whereby Malaysia, Thailand, and Indonesia, which produce about 65 percent of the world's total production, have entered into agreement. Other countries including Australia, and Burma have yet to sign the agreement.

The emergence of this Association will certainly affect the tin situation in the world. The promises made by the leading members of the Association not to create another cartel operation in commodity markets will perhaps safeguard the interests of both producers and consumers in the future. Although the future of the tin industry does not depend solely on this movement, the Association will certainly influence the direction of this industry in the future.

The Future Prospects of the Tin Industry

The prospects of the tin industry in the future depend on various factors, such as the reserves of tin in the world, production levels, consumption patterns, the prices of the commodity, technology in the industry, and so on. Perhaps, most important of all, is the availability of this resource. That eventually will determine its production and consumption in the future. The future of the tin industry can be looked at from two perspectives: the short term and the long term.

The long term prospect of the industry depends very much on the availability of tin reserves in the world. An early estimate of tin reserves was done by the ITC in 1962 by asking each producing country (excluding communist countries) to estimate its reserves on the basis of a tin price of 800 Pound Sterling per ton in 1960 and at prices of 1100 Pound Sterling per ton in 1965 and 1970. The conclusion was that tin reserves in 1960 were 3.9 million tons; at a higher price they were estimated at 4.1 million tons in 1965 and 3.5 million tons in 1970 (Robertson,1964). These figures were subsequently modified and added to by Sainsbury in 1969 who estimated on the basis of a tin price of US$3000 per ton, that world reserves (including the USSR and China) were 5.6 million tons. Sainsbury also estimated that there was an additional 11.4 million tons that could be considered as economically mineable of which 4.3 million tons were in the USSR and China (Sainsbury,1969).

Recent estimates differ significantly from earlier estimates, primarily because of different methods of estimation. McKelvey's works, which have been used by the United State Bureau of Mines and the US Geological Survey lay a sound foundation for estimating reserves of mineral resources. In this method, reserves are classified into three categories; measured, indicated and inferred reserves (McKelvey,1973). The United Nations uses different terminology in classifying reserves. Reserves which have been explored on at least two sides or by a sufficient number of borings to leave no doubt as to their existence may be called certain or proved reserves. Probable reserves are those whose existence is deduceed on the basis of purely geological data

(Legandre,1951). However, the most common method used to estimate reserves in many developing countries is the one used by the ITC, which, in fact combines both McKelvey's and Legandre's methods, and uses them synonymously. That is:

(1) measured reserves (analogous to proved reserves)

(2) indicated reserves (analogous to probable reserves)

(3) inferred reserves (analogous to possible reserves)

The term 'reserves' is used to indicate the fraction of the total resource that has been measured and is producible under present economic conditions of prices, costs, technology, etc. (Robertson,1964).

Based on that definition, Sainsbury and Reed in 1973 estimated that world reserves of tin amounted to 10.1 million tons. However, they also included another category of reserves, that is the total resources which could be found in the world. Therefore, world reserves and resources of tin were estimated at 37.6 million tons (Sainsbury and Reed,1973). In fact, the latest estimate of tin reserves made by the US Bureau of Mines has not changed very much from these figures. According to the Bureau of Mines the total reserves of tin are 10 million tons and the total resources are 27 million tons, yielding a total of 37 million tons (US Bureau of Mines,1978).

The absolute figures of tin endowment do not convey very much in and of themselves. They must be related to figures of current and expected consumption, since, absolute figures of availability are meaningless unless measured against both present and future demand for them. A relevant metaphor for that relationship is that of 'life-span', the amount of time before exhaustion of a resource. This life-span figure can be obtained by calculating the number of years of consumption inherent in a given stock of tin.

On the basis of an average annual world tin consumption (including communist countries) of approximately 240,000 tons, the measured and indicated reserves estimated by the US Bureau of Mines or Sainsbury and Reed, would be adequate for about 15 years; if inferred reserves are added, the total reserves estimated would be adequate for 42 years' consumption (Govett and Robinson,1980). Other estimates of this nature were made by many people using different methods and assumptions with varying results. For instance, the Council on International Economic Policy of the USA estimated the life-span of tin is less than 25 years (USA, 1974), while Indra Rajaraman (1976) predicted tin reserves would be exhausted in about 14 to 18 years from 1976. Another estimate made by F.E. Banks (1977) suggested that the life-span of tin would be around 19.3 years and McGragor (1975), taking total reserves and resources as a basis, estimated the life-span of tin would be between 101 to 200 years.

There are other pessimistic views on the availability of this resource in the world. Meadows, et. al., (1972), for instance, claimed that the present resources of all but a few metals will be exhausted within 50 years if consumption rates continue to grow as they presently are; if current trends are allowed to persist, a breakdown of society and irreversible disruption of life support systems on this planet are inevitable. Lecomber (1979) seemed to support this view in his assertion that if usage of non-renewable resources is essential to sustain life, then eventual 'doom' is unavoidable; the most that can be done is to minimize usage to prolong life.

On the other side, there are some optimistic predictions that non-renewable resources (including tin) may be sufficient to meet human needs. For example, Barnett and Morse (1963) conclude from the evidence that economic growth yields increasing, not decreasing returns and reject the hypothesis that economic scarcity of natural resources, as measured by the trend of real cost of extractive output, will increase overtime in a growing economy. Norhaus and Tobin (1975) in rebutting Meadows' claim, seem to support Barnett and Morse's claim that growth will accelerate rather than slow down the world economy, even as natural resources become more scarce in the future.

In essence, in the long term perspective, the world tin economy is dependent on tin reserves; thus more accurate estimates of the reserves are necessary for projecting the future of this industry. The task of making accurate estimates admittedly difficult to accomplish but it is useful for predicting the life-span of tin. This subject will be discussed further in a more specific context in the next Chapter.

As for the short term prospects of this industry, consumption trends of tin become an important determinant. If the present surplus remains as it is now, then the future of this industry is not optimistic. The difficulty in forecasting the short term prospect of this industry is due to the rapid changes in world consumption of tin. New end-uses of tin are developing rapidly, but at the same time, there is an increase in tin substitutes in manufacturing processes. Taking all these factors into consideration, based on assumed world tin reserves of 10 million tons, if the present trend of decreasing tin consumption continues (240,000 tons in the 1970s to 160,000 in the 1980s), and the annual production level of 160,000 tons is sustained, then the short term prospect of this industry is more favorable. Even at an anticipated increase in consumption of 0.4 percent in the USA and 1.3 percent per year in the rest of the world, the future demand for tin, at least up to the year 2000, could be sufficiently met (Harris, 1978).

CHAPTER III

THE DEVELOPMENT OF THE TIN MINING INDUSTRY IN MALAYSIA

Malaysia in Brief

Malaysia is situated in the humid tropics of Southeast Asia, between 1 degree and 7 degrees of latitude north of the equator. It comprises two main segments. One of these is West Malaysia, which occupies the southern portion of the Malay Peninsula. The other segment of the country, separated by some hundreds of miles of south China Sea, is made up of two contiguous States of Sabah (formally British North Borneo) and Sarawak. Malaysia covers an area of about 340,000 square Kilometers, 60 percent of which are in the two Borneo States. the total land surface of Malaysia is approximately 32.6 million hectares. So far Malaysia has brought into use only 30 percent of her total cultivated land. At present, it is estimated about 65 percent of the land area was covered with dense tropic forests.

The history of Malaysia could be traced as far back as 35,000 years. Its strategic location between the West and the East has made Malaysia vulnerable to many foreign influences. In the beginning of recorded history, the Indians from India, the Arabs from the Middle East, and the Chinese from China came to Malaysia and many of them settled there. Malaysia was under the colonialization of Portuguese from 1511 to 1640, the Dutch from 1640 to 1740, the British from 1778 to 1941, the Japanese from 1941 to 1944, then the British again from 1944 to 1957. Malaysia gained independence in 1957. Malaya, as it was known after 1957, annexed Sabah and Sarawak in 1963 and became Malaysia. Singapore was separated from Malaysia in 1965.

The population of Malaysia was an estimated 14,003,000 in 1980. The average annual rate of population growth is about 2.6 percent. Of the total 1980 population, about 85 percent resided in West Malaysia (the peninsula), 6 percent in Sabah and 9 percent in Sarawak. The ethnic composition of the population was estimated 54 percent Malays and other indiginous groups (called Bumiptra), 35 percent Chinese, 10 percent Indians and 1 percent others. About 35 percent of the population lived in urban areas (10,000 or more population) and the rest were in rural areas (TMP, 1979). The official language of Malaysia is Bahasa Malaysia (Malay Language) and the official religion is Islam, representing about 55 percent of the population.

Economically, Malaysia practices a laisser-faire economic system, with wide latitude for free enterprise. The major goal of Government since independence has been industrialization of the economy. Policy has stressed cooperation with the private sector and a minimum of direct government participation; an increasingly dynamic and direct planning role has been played by the government. The major tool for planning has been the Five Year Plan. The current five year plan is the Fourth Malaysia Plan and covers the period of 1981 to 1985, which is based on the Twenty Year Long Range Plan, 1970-1990. The spirit of the planned development is based on the New Economic Policy, which was introduced in 1970 as a result of the racial turmoil of 1969. The two-pronged strategy of the New Economic Policy (NEP), eradicating poverty and restructuring society, is aimed at creating more equitable economic opportunity among the races in the country. The emphasis was on increasing Bumiputra participation in economic activity to at least a 30 percent share, in order to reflect the social structure of the country.

Malaysia is basically an agricultural country, producing about 40 percent of the World rubber output, 30 percent of the world supply of oil palm, cocoa as the second largest producer in the world, rice, sugar, pineapple, tobacco and pepper. During the last two decades, an export-oriented economy based on primary production has evolved in Malaysia. Currently, the major sources of national revenue, in order of importance, are petroleum, rubber, oil palm, tin and manufactured goods.

The Gross National Product (GNP) of Malaysia in 1980 stood at $23.1 million (at factor cost). The average annual growth in GNP was around 8.7 percent in the 1970s, but it has declined to 4.6 percent per annum in the 1980s (Year Book, 1982).

Politically, Malaysia is a democratic country, run by a Coalition Government, and the Barisan National (the National Front) political party (comprised of various communal-based political parties) holds power in the government. Parliament, the legislative body of the government, is made up of two components: the House of Representatives and the Senate. The Prime Minister is the Chief Executive and the Yang Dipertuan Agong (the King) is the supreme ruler of the country. As a federation, Malaysia is comprised of fourteen states, namely, Perlis, Kedah, Penang, Kelantan, Terangganu, Perak, Pahang, Selangor, Melacca, Negeri Sembilan, Johore, Sabah, Sarawak and the Federal Territory. Each state has its own Ruler and Chief Executive. The Constitution of Malaysia provides specific schedules of the separation of powers between the Federal and the State governments. Although most powers relating to revenue collection and expenditures are vested with the Federal government, the States still maintain absolute power over land, water and other natural resources, power which has been safeguarded jealously over the years.

Tin and the Process of Extraction

Tin was one of the earliest metals known to man. Pure tin was used in Egypt and elsewhere in the civilized world as early as 600 B.C. (MacNaughton,1935). Tin may not be as well known as some commodities, but certainly tin has indirectly touched many facets of our daily lives. Tin has a wide range of applications: tin-plate, solder, Babbitt metal and anti-friction metal, bronze, brass, pewter, and others. Its most popular use is in the manufacture of containers for the preservation of foodstuffs. The 'can' or 'tin-container' is a common feature of every-day life in modern society.

According to Webster's Dictionary, tin is a soft, silver-white, metallic chemical element, malleable at ordinary temperatures, capable of a high polish, and used as an alloy in tin foils, solders, utensils, type metals, etc., and in making tin plate. The Symbol for tin is S_n. Its atomic weight is 118.70 and the number is 50 (Webster,1980). This definition fits the description of tin as a metal; however, tin is not found as a metal in the ground, but as an ore.

Tin in its original form, ore, is a nonfuel mineral resource, useful and valuable in the condition in which it is found. A tin mine is a fund of wealth. The minerals it yields are both useful and scarce, and those minerals can be taken from it only once, and cannot be renewed (Carlisle,1959). Tin is sometimes referred to as an exhaustible resource, since withdrawals from its stock lead eventually to its exhaustion (Randall,1981).

Tin ore is relatively scarce in the earth's crust (2 parts per million) when compared with other non-ferrous metals such as aluminum (81,3000), chromium (100), zinc (70), copper (55), and lead (13) (LaSpada,1981). Its average annual output is consequently relatively small compared to other metals.

Tin has special characteristics which make it appropriate for human use, particularly for end-use in commercial activity. The properties on which the commercial use of tin rest are the following: (a) extraordinary malleability, (b) a low melting point and easy fusibility, (c) softness, (d) lightness, (e) corrosion resistance, (f) nontoxicity, (g) anti-friction qualities, and (h) appearance. Because of these special characteristics, tin metal is very useful for metallurgical, chemical and other uses. Sometimes, it is non-substitutable (Knorr,1945).

The origin of tin ore can be traced to a time when the Earth's crust was forming. It was then the tin ore was forced into the still-molten granite rocks beneath the crust of the Earth. The pressure which forced the granite rocks up through the crust of the Earth combined with the movement of the rock itself as it cooled and settled, squeezing the tin ore inside it into <u>lodes</u>. These lodes are called primary deposits because they are found where they were originally placed. From the lodes of tin comes another type of deposit, which is known as a secondary deposit because it is not found where it was originally formed. Secondary deposits are more commonly called <u>alluvial</u> deposits because they are formed by water, that is, the primary tin ore in the rock is gradually worn away, and the particles are carried down by rain and rivers to the valleys. These deposits do not reach the center of the crust. They are found between the surface of the Earth and the solid layer of rock beneath it, may be 20 feet to 120 feet or deeper in the ground (Deller, 1963).

Tin ores are found as minerals. The most common tin bearing mineral is cassiterite, a compound of tin and other minerals. The chemical formula is S_nO_2. Other minerals which are commonly mixed with tin ore are ilmenite and rutile which produce titanium, columbite or niobium, zircon or zirconium, and monazite. These minerals, sometimes called the by-products of tin mining, are also useful and are as valuable as the tin itself.

Tin ores are mined from the ground. There is a series of processes involved in mining the tin ore. Broadly, these processes can be grouped into four stages: prospecting, extracting, dressing, and smelting. There are various methods used in each of these processes, and mining methods vary in different countries, depending on factors, such as the nature of the known deposits, the topographic condition of the land to be mined, the structure and scale of the firm involved in the mining operation, the level of technology in a particular country, and the national laws governing the mining operation. Generally, a rule of thumb in the tin mining operation is that if tin deposits are known to exist in the form of lodes, the normal method of extraction is underground mining. If tin deposits are spotted on the ground or not so deep beneath the surface in the form of alluvial deposits, the common method used is opencast mining. Opencast mining has many variations: hydraulic pump, gravelpump, dry mining, panning, and so on.

In this section, a brief description of each of the processes involved in drawing out the tin ore from the ground is provided for the purpose of understanding the nature of the tin mining industry. Even though these descriptions are specific to Malaysia, essentially they can be generalized.

Prospecting for Tin Ore

To prospect means to search or examine the earth for minerals. In mining terms, "a prospect" means (a) a place where a mineral deposit is sought or found; (b) a sample of gravel, earth or ore tested for a particular mineral, or (c) the resulting yield of mineral (Webster, 1980). In prospecting for tin ores, the purpose is to strike a rich mineral deposit in the ground. This first stage of mining operations requires a great deal of knowledge, skill, and patience, and involves hard work and discomfort. Prospecting is done by using special equipment called a boring tool. This drilling equipment can be operated manually or mechanically depending on the type of tool. Exhibit 1 shows the work for prospecting the tin ore. The most common drilling tool used in Malaysia is called the Banka Drill which is operated manually.

The first task involved in Banka Drill Method is to put down a number of bores on the land which has been selected to see whether it contains alluvial tin. These are called 'scout' bores and they enable the prospector to decide whether to continue or to terminate the work due to unsuccessful results. The next step, test-boring, consists of putting down a greater number of bores over the area, one every 600 feet or so on a larger piece of land, to find exactly where the tin deposit

Exhibit 1 - Prospecting the tin ore by using a boring tool. The results of this test-boring will determine the exact location of the ores to be mined.

Exhibit 2 - Breaking the earth by using both Excavator and Water-pump. This process is applicable in the gravelpump and other opencast mining methods.

is. The results of test boring provide an indication of the richness of the deposit.

The final stage of this process is to close-bore the area so that samples from bore-holes (about 100 feet apart over the whole area) can be taken and analyzed. This yields information on the extent of the deposit, and the varying depths at which it lies, and enables the prospector to calculate the quality of tin ore waiting to be mined.

Prospecting for primary or lode tin requires expert knowledge of rocks and prospectors are usually trained geologists. The boring tools are similar to those used in alluvial tin prospecting, but the cutting edge of the tool is tipped with diamonds so that it will cut through granite and other hard rocks (Deller, 1963).

Extracting Tin Ore

If the prospecting indicates worthwhile deposits of tin, the next process is to extract those tin ores from the ground. There are many methods used to draw out tin ores from their deposits. Since the majority of tin deposits in Malaysia are alluvial, most of the mining methods used are opencast in nature. The vital element used in opencast mining is water. Just as water deposited the ore in the valleys and lowlands, so water is used to wash the tin free from the ground. Exhibit 2 show how a water-pump is used to break the earth. Water is also used to separate the tin ore from materials mined with it. The most common methods of mining in Malaysia are the following:

The Dredge Method

A dredge is essentially a machine used to process the earth, mud, and sand in which tin ores are contained. It is like a huge ship or factory floating on an artificial pond made by itself. The dredge uses mechanical buckets which dig down as deep as 100 feet or more below the surface into tin-containing ground. There is a treatment plant aboard the dredge in which the tin ore is separated from much of the materials dug up with it. The unwanted materials are discharged by chutes at the rear of the dredge as 'tailings' which are used to fill in the pond again. The size of the dredge varies depending on the scale of the mining operation. The common dredge in Malaysia is about 70 feet high, 250 feet long and 75 feet wide. A picture of this kind of dredge is shown in Exhibits 3 and 4. A large size dredge may contain more than 100 buckets which dig at the rate of about 20 buckets a minute. As each bucket holds about 15 cwt of material, this dredge is able to dig 15 tons in one minute.

The tin-bearing material from the buckets passes straight into a preforated, revolving screen in the dredge's treatment plant. Powerful jets of water break up the tin-bearing material inside the screen and wash the heavy tin ore through the revolving screen. Stones and other hard material pass straight through the perforated plates and are discharged. Fine sand and other materials drop through the screen with the tin, so the material called 'take-off' which is collected from under the screen is passed over sets of jigs to wash the tin free of the unwanted material; the technical term for this process is 'concentrating the ore'. The waste material is discarded through the tailing chutes and the concentrated tin ore is pumped into a large storage bin. This

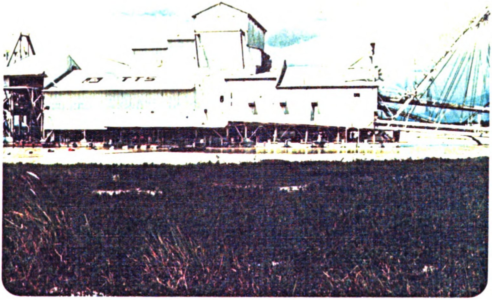


Exhibit 3 - The dredge - a floating factory - is a self-contained mining unit. It floats in the pond as it enlarges the excavation.

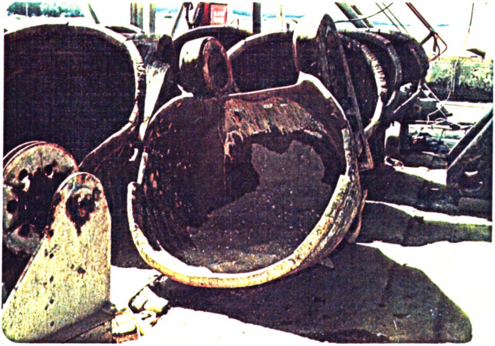


Exhibit 4 - Some of the dredge buckets used to scoop the mud containing the ores from the pond. These buckets will go to the treatment plant for further processes.

concentrated ore will be sent ashore to the dressing sheds for further treatment.

This method of mining is most appropriate for large land areas which have not been mined before.

The Gravelpump Method

The gravelpump method, as the name suggests, involves the mechanical pumping of gravel and other materials; therefore, it is ideally suited for alluvial deposits. The opencast mines that use gravelpumps are called 'gravelpump mines'. At these mines, tin-bearing materials are washed away from the sides or face of the mine with a powerful jet of water from a monitor, a gun-like nozzle that can be swivelled round and be moved up and down. The tin-bearing materials are channeled to a collecting area called 'a sump' over which the gravelpump is placed. The pump then sends the material to the treatment plant, high above the ground.

This treatment plant is called a 'palong' (in the Malay language this means a through or a launder). Pictures of a palong is presented in Exhibits 5 and 6. The tin-bearing material is thrown into it and washed with flowing water to get rid of the sand and earth. The palong can be opened at either end, thus treating larger amounts at one time. Pieces of timber are fixed at intervals across the palong to trap the heavy tin ore as, separating from the material passing down the palong, it sinks.

Every week or 10 days, the tin ore that has been trapped in the palong is removed. Clean water is pumped down the palong and the ore and fine sand trapped behind the timber 'riffles' is raked against the

Exhibit 5 - A 'palong' or a "launder" into which the tin-bearing materials are thrown and washed with water to get rid of the sand and other unwanted materials.

Exhibit 6 - A closer view of a 'palong' which is about 30 feet wide and 130 feet long. The 'palong' is used in gravelpump as well as in other opencast mines.

flow to allow more of the fine sand to float away. Pictures of 'riffles' and how they are washed are shown in Exhibits 7 and 8. What remains is concentrated ore which is then shoveled into buckets and taken to the dressing shed for further treatment.

The size of the palong varies from mine to mine; those working large deposits use a larger palong or even two or more palongs. The approximate size of an average palong is 30 feet wide and 130 feet long. Small deposits of tin are generally mined by the gravelpump method but it is also used on land that has been dredged and where the bed-rock is very uneven and forms pinnacles. This is because a dredge's buckets cannot reach such deposits, but the monitor's powerful water jets are able to force it out.

The Opencast Method

Opencasting is not really a method of mining, but rather a collection of many methods of extracting tin-bearing material. The opencast method includes, use of the gravelpump as discussed above, the hydraulic pump, and dry opencasting. The difference between the gravelpump method as such and this method lies in the way water is used. In terms of the treatment plant, both methods are the same. The opencast method uses water power to send the tin-bearing material up to the palong. Hill water supplies the water power or, properly, hydraulic power. A dam is built in the hills and streams are directed into it. The rains also wash down into the dam. The water is taken to the mine in the valley below through high-pressure pipes. The process of collecting the tin ore concentrate in the treatment plant, the palong, is similar to that of the gravelpump method.

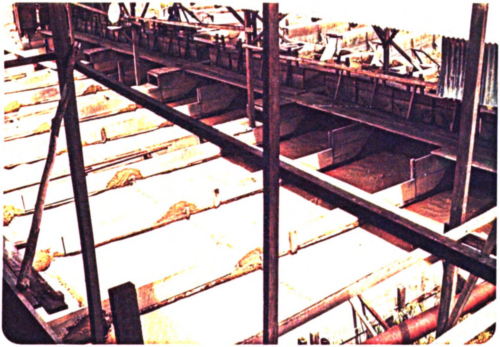


Exhibit 7 - A closer look at the 'riffles' of a palong where the ores and fine sand are trapped. The fine sand will be washed away by the flowing water, leaving only the concentrated ores behind the 'riffles'.

Exhibit 8 - The 'tailing' of a palong when it is washed by the flowing water. The tailing may contain some left-over tin ores; the 'panning' method is used to get them.

This method of mining requires larger area of land and needs many skilled workers, such as mining engineers. Normally, it takes months to develop and prepare the mine for operation.

Another phase of this method called dry-opencasting uses mechanical shovels and excavators instead of powerful jets of water to remove the tin-bearing material from the ground. The sides of the mine are cut into rows of benches, to prevent their falling in. As the tin deposits are dug out, the benches are cut back and new ones are made. The mechanical shovels and excavators will empty the loads of tin-bearing material onto the conveyer belts leading up to the mine's treatment plant where it is mixed with water and then shaken in order to separate the tin ore from the lighter sand and other materials, which wash away. This method also requires a large area in which to work. A dry opencast mine may measure approxiamtely a quarter to a half mile across at its widest part and about 300 to 500 feet deep.

The Underground Mining Method

The underground method of mining in Malaysia is similar to underground mining methods elsewhere. This method is used to extract tin ore from primary deposits, lode tin, which exist deep under the ground. Various tunnels are constructed as deep as 1000 feet or more under the ground. The tunnels lead off from a central shaft in which runs a lift. Everything that is taken down into the mine, or brought up out of it, is loaded on the lift. To mine the tin lodes, 'levels' are driven from the tunnels into the rock, or 'stopes' are driven upwards through the roof of a tunnel.

The lode tin is drilled out, or blasted out with high explosives. The drills are worked by compressed air. The tin-bearing rock is loaded into trucks (normally run by a small electric train) and taken up to the surface, to the treatment plant. At the treatment plant, the process of separating tin ore is the same as in other methods of mining discussed earlier.

This method of mining, not only requires a very large area of land, but also proper planning in order to protect the mine itself and the land around the mine. Usually, plans are made of all the underground mines so that the exact whereabouts of all the underground workings, including the old workings can be traced.

Other Methods of Mining

Besides the four major methods described above, there are various other methods used in Malaysia to extract tin ore from the ground. Some of them are traditional methods which are simple, manual methods, and some are highly mechanized, such as the method used in off-shore mining. Since these methods are few and not very common, they are not of any significance to the overall mining industry in Malaysia. However, one traditional method of mining, which is called 'dulang' washing, is probably worth describing here because it has some relationship to methods described above. A picture of 'dulang' washing is shown in Exhibit 9.

'Dulang' washing or the panning method of mining is probably the oldest method. It has been used in Malaysia for hundreds of years. The 'dulang' or pan is shaped like a saucer and is about 20 inches in diameter. It is made of a light but strong wood from the Jelutong tree, indiginous to Malaysia. The dulang washer scoops up the tin-bearing sands with water into the dulang, then swirls it round and round so that the sand washes over the edge and the tin ore sinks to the bottom. More water is added until all the sand and other waste material is washed away and only the tin ore remains.

Dulang washing is done manually, normally by women, in areas where tin ore is found on the surface of the ground, usually in old opencast mines and in the beds of shallow rivers and streams. It is also used in large opencast mines to catch the tin ore trapped behind the riffles on the palong, as described earlier.

The Tin Dressing Process

The next stage of the process is dressing the tin ore. This dressing process is carried out in the dressing sheds, located at the mines. The purpose of this process is to further separate the tin ore by removing unwanted materials which are too fine to be washed away by the treatment plants on the dredges and at the mines. In the dressing sheds, vibrating tables and hand washing are used to remove all the non-mineral impurities from the ore.

The table in the dressing shed has a slanting top with strips of wood fixed at intervals across it to trap material as it is shaken down the table. A stream of water flows over the table against the direction in which it moves. The heavy tin ore remains at the top end of the table and, as the table moves, is shaken along the riffles and falls off the end of the table. Fine grained ore is washed lower down the table

Exhibit 9 - 'Panning' the ores in the valley or left-over areas in the gravelpump or opencast mines. It is normally done by women and children.

Exhibit 10 - In the dressing shed the ore concentrates are packed in small bags before they are sent to smelters.

and the lighter sand and other materials move still further down. The separated materials remaining are called 'middlings', which contain very finely grained almost black, tin ore which will be passed over the shaking table again to concentrate the ore.

As mentioned earlier, tin ore also contains other minerals which must be separated from the tin by a 'separator'. This machine is magnetic and electro-static because tin cannot be magnetized or charged with electricity.

These various processes in the dressing shed reduce or concentrate the tin ore to almost pure cassiterite. At this stage, the tin is called 'tin concentrate'. The concentrates are dried, weighed, put into bags and sent to the smelting works for further processing. Exhibit 10 shows a typical dressing shed where tin concentrates are packed in small bags before they are sent to smelters.

The Smelting Process

Smelting can be highly mechanized or manually worked. The objective of this process is to produce crude tin metal. As mentioned earlier, tin ore is mixed with impurities, which are separated out in the smelting process. However, only certain metallic impurities can be removed, while others will be smelted with the tin. Therefore, the quality of the tin varies according to its purity.

In this process, the tin ore will be heated in a furnace at high temperatures until it melts. In Malaysia, this process is done at the Datuk Keramat Smelters and the Straits Tin Smelters, the only two licensed smelters in the country. They are world renowned in the tin industry. The crude metal from the furnace is further refined and then molded into ingots of tin. Each ingot of tin is marked with the name of the smelter, for the purpose of recognition on the world market. At this point, the tin is known as 'tin-in-concentrate', the end product of the mining process. Trading of tin is done on the basis of tin-in-concentrate.

The Occurrence of Tin Deposits in Malaysia

The world's greatest tin mining area is Southeast Asia. The chief tin-bearing belt of Southeast Asia extends southward from Rangoon through the Ithmus of Kra and the Malay Peninsula to the Islands of Bangka and Billiton in Indonesia. The larger part of this area lies in Malaysia.

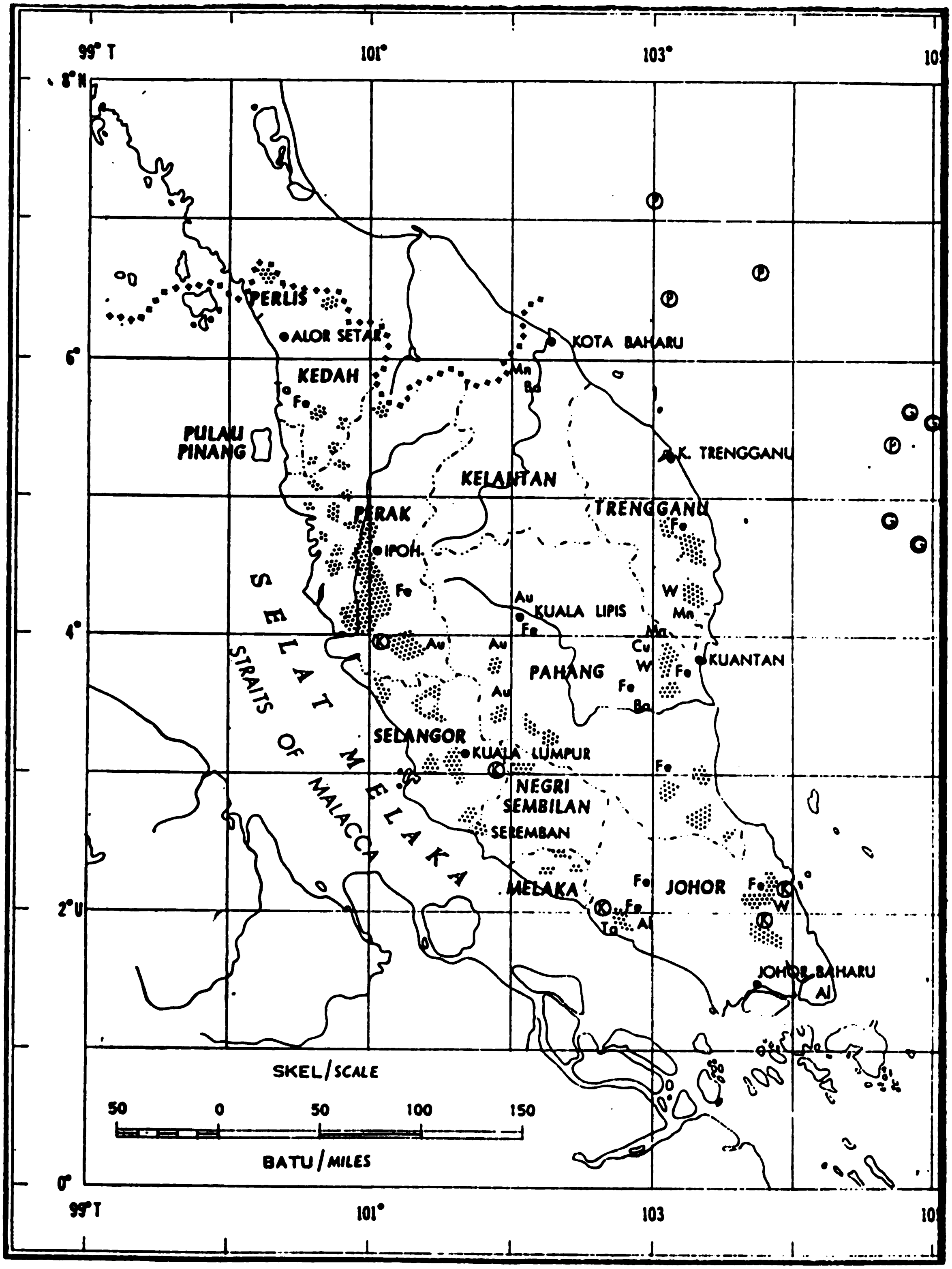
Alluvial flats or eluvial deposits are the dominent source of the rich and extensive Malaysian tin deposits. They are derived from the weathering of primary deposits that are all genetically connected with mesozoic granites. The granite stretches down the mountainous main Range from Kedah in the North to Malacca in the South; it also forms 'limbs' that branch off from the main Range and is found in isolated masses to the east, west and south of Johore (U.N., 1964). Alluvial tin deposits account for 95 percent and primary deposits for 5 percent of the total tin deposits known in Malaysia.

The largest mineralized area in the western belt used to be the Kinta tinfield in Perak which contains the world's greatest known concentration of alluvial cassiterite; but in 1970, another larger alluvial deposit was discovered at Kuala Langat in Selangor. It is believed to be the largest single deposit so far discovered in the world, extending over 40,000 acres with proven reserves estimated at 5 million piculs (30,000 tons). The eastern tin belt includes the eastern parts of Kelantan, Terangganu, Pahang, and Johore. Primary deposits are the main source of tin in this belt. Map 1 shows the distribution of the occurrence of tin deposits in Peninsula Malaysia. A list of the main deposits is supplied in Appendix B.

The richness of tin deposits is measured in terms of the average grade of tin ore treated in the mining process. For the primary deposits, the grade of ore is usually expressed as the percent of tin contained under the ground. The average grade of ore from this kind of deposits in Malaysia measures 72 to 75 percent tin (S_n); for the alluvial deposits, the average grade of ore ranges from 0.15 to 0.30 kati per cubic yard, sometimes measured in terms of kilograms per cubic meter. The type of mining operation used is often a result of the grade of one being mined, i.e. low grade ore is most often mined using dredges.

Another way of measuring the richness of a tin deposit in Malaysia is by estimating tin reserves in the ground. There have been many estimates of the reserves of tin in Malaysia. One of the earliest was done by Lewis Fermor in 1939, which estimated proven tin reserves to be one million long tons of metal, in the land leased for mining and a further 500,000 tons on land not yet then leased making a total of 1.5 million tons, which could be expected to last until 1969 at an annual production rate of 50,000 tons (Fermor, 1939). The second estimate was done by Stoke in 1945, who estimated the reserves of tin in Malaysia at 1 million tons, which would suffice until 1965, at the same rate of

Map of peninsula Malaysia



Map 1: Mining areas in Peninsula Malaysia. Tin mining areas are indicated by ▒ ..
Source: Jabatan Pemetaan Malaysia.

extraction. The third attempt, made by the The President's Materials Policy Commission of the US Government, in what is known as the Paley Report of 1952, put Malaysian proved reserves at 1.5 million long tons of tin-in-concentrates, which would have been exhausted in 1976 if extracted at the rate of 60,000 tons per year (Govett and Govett, 1976).

In 1964, another attempt was made by Robertson for ITC to estimate tin reserves in Malaysia. He estimated total proved reserves at 900,000 tons for 1965 and 600,000 tons for 1970, which, if extracted at 60,000 tons annually, would be completely exhausted by 1980. The latest attempt to estimate the Malaysian tin reserves was done by Sainsbury and Reed in the report prepared for the US Geological Survey in 1973. This report, known as the second Paley Report, estimated measured and indicated reserves of tin in Malaysia at 600,000 long tons, and inferred reserves at 236,000 tons, totaling 836,000 tons of metal. In addition, conditional and undiscovered reserves, that is, those resources containing tin not recoverable at a profit with existing technology and economic climate, were estimated at 1 million tons, producing a reserve total of 1.83 million tons. If this estimate is accurate, at the rate of extraction of 60,000 tons per year, all the tin reserves in Malaysia will be totally exhausted by the year 2003. This has yet to be seen.

Historically, Malaysia has provided 30 to 55 percent of the world annual tin production, yet, there is no official estimate of tin reserves in the country. The absence of a national estimate of tin reserves in Malaysia is due to a variety of reasons. There is a lack of data on prospecting carried out in the country, on actual figures for tin production, on production costs and other relevant information required in making an estimate. The difficulty in forecasting the level of technology, economic conditions including prices, and the rate of return on investment, as well as uncertainty in regard to legal criteria pertaining to mining title makes an estimate hard to determine. The cost of an estimate and the lack of trained manpower to do a proper job are perhaps the main obstacles in obtaining a national estimate of tin reserves. Therefore, the actual extent of Malaysian tin reserves is not fully known. Although, theoretically, all stock resources such as tin, if constantly extracted will eventually be exhausted, the magnitude of the exhaustion, particularly in Malaysia is difficult to estimate. One thing is certain: the richness of ore deposits in Malaysia is declining causing mining activity to expand to areas of inferior quality. If this can be used as an indication of the magnitude of ore depletion, then, the accuracy of the Sainsbury and Reed estimate may be proved by the year 2003, when, according to them, tin reserves in Malaysia will be completely exhausted.

The Early Development of the Tin Mining Industry in Malaysia

There are indications that tin mining activity was carried out in Malaysia more than a thousand years ago. Reference to tin mining was made by Arab traders who visited this country around 900 A.D. Arab writers of the 10th and 11th centuries mentioned tin mines in the Malay peninsula and it is clear that tin was exported in Arab ships before 1000 A.D. (Wheatly, 1961). The earliest Chinese writings suggest that early voyagers went to Malaysia mainly for gold, but tin is mentioned many times in the 14th and 15th centuries as an important article of commerce (Hedges, 1964).

The importance of tin in Malaysia was noted by the Portuguese who invaded the country in the 16th century. They found a tin coinage already in use and substituted a tin coinage of their own. The Dutch ousted the Portuguese from Malacca in the 17th century and established stations of control and trade in tin. Penang was ceded to the British in 1786, but they did not begin serious development of the tin industry until a century later. In the meantime, Chinese immigrants, brought by the British to the country in large numbers, began extensive mining. Initially, the tin mining was undertaken by Malays and the smelting was done by Chinese. With the discovery of new reserves in Perak (Larut and Kinta Valley) and later in Selangor, however, Chinese immigrants flocked to the area for employment. Soon tin production, carried out by relatively simple methods, was dominated by Chinese capital, enterpreneurship and labor. By 1870 the Great Larut tinfield in Perak was producing under Chinese management. British control was introduced in 1874 on the pretext of preventing clan warfare in the Chinese mining community, resulting in a massive expansion of the tin mining industry on the Malay Peninsula.

Supported by British interests, Malaysia soon overtook Britain, Indonesia and Australia to become the world's largest producer by 1879 (Wong, 1965). By 1896 Malaysia was producing about 60 percent of world tin output. The increase of output in tin mining was due to the introduction of the gravelpump method (wooden chain method) by the Chinese. The technology of tin mining became more complex in 1912, when the bucket dredge method from Australia was brought in, together with European capital. The establishment of order under British rule, and the construction of a mining infrastructure and a transportation network in the country facilitated further development of the industry. By 1930, European interests including representatives of the United States, Canada, Australia and New Zealand were responsible for 63 percent of the total amount of tin produced in Malaysia. During this time, although there were many Chinese and other native small mining firms, the Malaysian tin industry was essentially managed by three foreign corporations: the London Tin Corporation Limited; the Charter Consolidated Limited; and Osborne and Chappel Limited. These three mining groups accounted for approximately 50 to 60 percent of output of tin-in-concentrate in Malaysia.

The development of the tin mining industry in Malaysia during the Second World War was disrupted by the Japanese occupation from 1941 to 1944, which destroyed many mining infrastructures in the country. The production of Malaysian tin declined considerably during this time.

However, after the war, the development of the industry intensified. The British who came back to Malaysia in 1945, brought many changes in the development policy. The Mining Enactment of 1929 was revamped to facilitate extensive development of tin mining. The more effective policies which evolved during the early postwar period include:

(a) Mining being given priority over other forms of land use, so that deposits of economic significance would not be blanketed;

(b) Mining activity being encouraged to increase revenue to the government;

(c) Conversion of royalties in mining leases (formerly paid to the Rulers of the Malay states) to export duty;

(d) Imposition of legislation concerning mining.

These policies were carried out until the middle of the 1950s when a tremendous change occurred in the development of the tin mining industry (Yip, 1969). The monopolization of the industry by foreign interests was threatened by the increasing political awareness of local Malaysian, especially of Chinese origin. The independence movement during 1956-1957 gave momentum to the Malayanization process, which increased domestic control by restructuring foreign interests in the country.

During the 1960s, Chinese participation in the tin mining industry increased significantly. With their more restricted financial resources, Chinese enterprises continued to utilize the less-capital intensive gravelpump method, causing a cleavage that continues to exist. The production of tin in Malaysian mining increased by almost 20 percent from 1960 to 1965. However, 60 percent of the production still came from 100 foreign controlled mines (British, French, Australian and American, in order to importance), and the remainder came from locally controlled, mainly Chinese, enterprises. By 1967, there were about 1,072 tin mines in operation in Malaysia. Of the total, 66 were dredge mines producing about 24,000 tons of tin annually, 960 were gravelpump mines that produced around 40,000 tons of tin annually (DOM, 1973). The remaining tin was produced by various processes such as opencasting, underground mining and dulang washing. The total amount of output from tin mines in Malaysia, from 1805 to 1970 is shown in Table 8. The figures represent annual production at five year intervals.

Table 8

Production of Tin in Malaysia, 1885-1970

(in thousand tons)

Year	Production	Year	Production	Year	Production
1805	3.4	1865	8.5	1925	48.9
1810	3.4	1870	5.6	1930	68.0
1815	3.8	1875	8.6	1935	43.0
1820	3.8	1880	11.9	1940	84.0
1825	4.2	1885	17.6	1945	3.2
1830	4.7	1890	27.6	1950	58.7
1835	4.7	1895	50.4	1955	62.2
1840	5.4	1900	43.8	1960	52.8
1845	5.4	1905	51.8	1965	64.7
1850	5.4	1910	46.7	1970	73.8
1855	6.5	1915	50.6		
1860	6.5	1920	37.5		

Sources: Schmitz, 1979; Govett and Robinson, 1980.

Malaysia won the position of largest tin producer in the world in 1880 when 11,900 tons of tin were produced. The highest production of tin from Malaysia was recorded as 84,000 tons in 1940; but from 1942 to the end of the decade Malaysia was almost totally cut off from the world in terms of tin supply. However, production resumed gradually throughout the 1940s and 1950s. In the 1960s the production levels were stabilized at around 62,000 tons annually. In the early 1970s the production of tin from Malaysia once again reached a record high. In 1970, 73,800 tons of tin-in-concentrate were produced, which was a peak for the postwar period and had been exceeded only in 1929, 1937, 1940 and 1941. The 1970s have taken shape as a new era for the tin industry in Malaysia.

The Present Situation of the Tin Mining Industry in Malaysia

The present situation of the tin mining industry in Malaysia is vastly different than that in the 1960s and before. Three major factors influenced the current shape of the industry in the country. First, the racial riot of 1969 was the turning point in the overall perspective of development in the country. This incident gave birth to the New Economic Policy (NEP) development strategy in Malaysia, which emphasized a two-pronged attack on development: (i) eradicating poverty among all races in the country, and (ii) restructuring society through equity participation in economic activity. Under the Outline Perspective Plan, 1970-1990, it is intended that the economy will be restructured so that asset ownership will more accurately reflect the ethnic composition of the population. It is targeted that foreigners should own only 30 percent of the country's assets, Bumiputra 30 percent, and the rest of Malaysian 40 percent. Obviously, this policy impacts on the tin mining industry, of which prior to 1970, 60 percent was under foreign control.

Second, the commodity boom of the 1960s persisted in the early 1970's. This sparked a momentum for heavier investment in the tin mining industry, but these efforts had shrunk by the end of 1973, as a result of the oil crisis, which affected the industry adversely. Decline began early in 1974, then, recession, which followed in the middle of the 1970s, eroded the situation further. Production dwindled, and the costs of production escalated rapidly, while the prices of tin were low. These factors affected the shape of the existing structure of the industry.

Third, skeptical over low achievement of the targeted objective of the NEP, and intent on rescuing the industry, the Government increased its interference in tin mining activity. This intervention ranges from indirect influence to more direct involvement, such as passing new policies and the undertaking of mining operations by Government agencies. These factors have changed the shape of the tin mining industry drastically.

In terms of production levels, the early years of the 1970s saw a steady increase in output of tin mines; however, this trend was not sustained. The 1972 production of 76,830 tons was the highest, since 1970. Production decreased in 1973 to 72,260 tons, then to the lowest level in the decade, in 1977, when only 58,703 tons of tin were produced. Table 9 shows the production of tin mines in Malaysia from 1971 to 1983.

Table 9

Production of Tin in Malaysia, 1971-1983

Year	Production	Year	Production
1971	75,478	1978	62,650
1972	76,830	1979	62,995
1973	72,260	1980	61,400
1974	68,122	1981	59,900
1975	64,364	1982	52,300
1976	63,401	1983(f)	42,000
1977	58,703		

Sources: Department of Mines, Malaysia; ITC, 1983.

(f) estimated by the ITC

The production of tin from tin mines in Malaysia declined further in 1980 to around 61,000 tons from a stabilized level of 62,000 tons annually in 1978 and 1979. Production in 1983 was estimated at 42,000 tons, possibly the lowest for the decade (ITC, 1983).

Foreign monopoly of the tin mining industry in Malaysia persisted at least until 1976. Prior to 1976 tin was produced mainly in foreign owned mines. The Anglo-Oriental (M) Sendirian (a subsidiary of the London Tin Corporation Limited) contributed nearly 50 percent of the total production of tin during that time. Of the remainder, 20 percent came from the Associated Mined (M) Sdn. Bhd. (Owned by Charted Consolidated Ltd.) and 12 percent from Osborne and Chappel Sdn. Bhd.; other locally owned mines contributed about 18 percent.

Major restructuring began in 1976, with the formation of the Malaysian Mining Corporation (MMC). The MMC was formed to take over mining operation and management from the Anglo-Oriental and Associated Mines Groups. Pernas Securities (a Government Corporation) owns 71.35 percent of MMC, and Charter Consolidated owns 28.65 percent. The formation of MMC leaves outside the government's control of the tin mining operation only Osborne and Chappel (in whose companies the smelter, the Straits Trading Company, has interest) and smaller individual foreign companies.

By 1976, the Chinese-owned mines had increased in number, but they were mostly unincorporated; therefore, ownership could not be easily restructured (Thoburn,1981). Nonetheless, they were also under pressure to increase Bumiputra participation and were directly affected by NEP and other new leasing policies in various states. For instance, Selangor State, through the corporate investment body Kumpulan Perangsang Selangor Berhad, declared a policy which, in effect, denied the renewal of mining leases to companies with less than 30 percent

Bumiputra shareholders. Berjuntai Tin Dredging and Ayer Hitam were the first companies to be affected by the policy (MAR,1979).

However, towards the later part of the 1970s, as the recession hit the economy harder, the tin industry began to decline further. Escalation in the costs of production, coupled with a depressed commodity market and output quotas imposed by the government brought about another major structural change in the industry. Many firms were closed down due to operational losses. Table 10 shows the numbers of mining firms, according to method of operation, from 1973 to 1983.

Table 10

Numbers of Mining Firms, 1973-1983

(according to method of mining)

Year	Dredge	Gravel-pump	Open-cast	Under-ground	Others	Total
1973	58	873	12	1	30	974
1974	56	932	9	1	27	1025
1975	55	810	12	1	32	910
1976	51	724	11	1	24	811
1977	53	784	12	1	24	874
1978	53	833	22	1	27	936
1979	54	772	21	1	25	873
1980	54	746	28	1	--	829
1981	60	593	35	1	--	689
1982	43	521	43	1	--	608
1983	40	500	40	1	--	581

Source: Department of Mines, 1983.

The total number of all active mines decreased substantially from 1974 to 1983. Most serverely affected were the Gravelpump mines which decreased by about 65 percent from 1973 to 1983. The number of Dredge mines was quite stable until 1982 when it decreased by about 20 percent. In contrast, Opencast mines increased in number from 12 in 1973 to 43 in 1982.

The closing down of mining firms and the increase in costs of production reduced the export of tin-in-concentrates substantially; thus, the Government revenue accruing from this industry shrank considerably. The concern of the Government to revive the industry has prompted efforts to curtail further increase in the costs of production. These efforts include tax revision in relation to the industry, i.e. subsidizing the cost of gasoline, and reducing taxes on imported mining tools. The most significant step taken by the government was to introduce the concept of commodity taxation, which was incorporated in the 1980 Federal Budget. This concept is based on a 'cost-plus approach', in the sense that the cost of production of the commodity will be taken into account and the appropriate duties will be imposed only on prices above the prevailing cost of production (Malaysia, LE, 1981/82).

The schedule of the new taxes is as follows:

Price of Tin per Picul (Ton)	Export Duties	
On First $1,2000 ($19,840)	Ad Valorem	Nil
Plus on the next $50 ($827)	"	20%
Plus on the next $50 ($827)	"	25%
Plus on the next $50 ($827)	"	30%
Plus on the next $50 ($827)	"	35%
Plus on the next $50 ($827)	"	40%
Plus on the next $50 ($827)	"	45%
Plus on the Balance	"	50%

At that time the average cost of production was assessed at $1,110 per picul and the price of tin was around $1,200 per picul ($19,840 per ton). Under the new tax structure, the duty applies only to prices exceeding $1,200 per picul. The scale of duty imposition is higher as the prices move up to $1,500 per picul ($24,803 per ton). After that a maximum marginal rate of 50% is applied.

The new taxation structure has not brought about recovery. The tin industry in 1981 and 1982 was worse off than in 1980 and before. In view of this situation, the government has issued a directive to all the relevant authorities in the country to freeze all new mining leases until further notice (NSTP, Feb., 1983). This measure prevents new entry into the industry, and thus protects the production levels of existing mining firms. Even though this move satisfied miners, the new concept of taxation was attacked by the Chamber of Mines for its deficiencies. The Malaya Chamber of Mines urged the Government to consider modifying the taxation structure and called for revision national policy of the mining industry issues (NSTP, Jun., 1983). An obviously implication is that taxation is not the only issue causing the industry to experience a decline.

Problems Affecting the Tin Mining Industry in Malaysia

Although Malaysia is still the largest tin producer in the world, the tin mining industry no longer occupies the position of central importance to the economy that it did in the 1960s and before. Factors such as the decline in mining production, the closing of mining operations and the lack of new investment, suggest that the tin mining industry is in a precarious position. A combination of problems help to account for this.

These problems are multi-dimensional. Some of them are supply side problems, while others are on the demand side problems. Some may be characterized as endogenous, while others are exogenous. Many of the problems are inherent in the nature of the tin mining industry itself. It is the most non-integrated industry in the country, operated by large numbers of small- and medium-sized independent miners, located mostly in remote areas of the country, and historically subjected to severe institutional intervention. These characteristics compounded with many internal and external problems have brought the tin mining industry practically to its knees at present. This section will summarize some of the major problems.

First is the problem of competition between Malaysia and other producing countries in supplying tin to the world market. Thailand and Indonesia which have similar production structures to that of Malaysia are major competitors; but they have the advantage of a higher grade of ore mined; thus, their costs of production in the long run are lower than those in Malyasia. Competition from other countries, particularly China which is exporting about 20,000 tons of tin annually at prices outside the price ranges of the ITC, could cause a greater surplus of tin on the market. Thus, further aggravating the deterioration of the industry in many producing countries.

Second, on the demand side of the equation, the consumption of tin is threatened by the development of tin substitutes and tin recycling. This competition may cut down the demand for primary tin metal; thus, effecting major structural change in the world tin industry.

Third, the depression in tin prices which has followed the world recession could jeopardize the industry in many producing countries. If the price of tin does not turn upward soon, the tin mining industry, particularly in Malaysia, will face compounded problems. Yet, the efforts of the ITC in supporting the price level have not seemed to work effectively. This, coupled with sales of the US stockpile of tin on the world market would eventually destroy the industry in many producing countries.

Although all the problems mentioned above are external to Malaysia, they have a direct impact on the industry on which the fate of the country rests. These problems compounded by internal problems in the industry have jeopardized its economic stability. The internal problems of the tin mining industry in Malaysia could be summarized as follows:

(1) The Decrease of Investment in the Industry

The level of investment in the tin mining industry has decreased since the beginning of the 1970s. During the early 1970s, there was little investment in the establishment of new mines or in the expansion of old ones. In a number of cases, mining profits were reinvested outside the industry (Annuar,1982). The inadequate level of investment in the industry can be explained by the risky nature of the enterprise, low profit margins and the difficulty in getting new land for mining. These factors have a cyclical pattern in decreasing production.

(2) The Decreasing Efficiency in Mining Operation

There is a tendency to shift the mining operation to a cheaper method at the expense of efficiency. Even though some mines have not changed their method of operation, many firms have reduced their scale of operation. A decrease in the grade of ore reserves from an average of 0.28 kati per cubic yard to 0.15 kati per cubic yard during the past decade is another reason for the decrease in the efficiency of mining operations. The lack of good land (that containing a higher concentration of ore) has caused many operators to mine less profitable land; thus, reducing the efficiency of extraction. Another factor is that the imposition of production quotas to implement export control measures, left many tin mines operating below their full capacity.

(3) Competition for Land Use

Land as a limited resource in Malaysia faces stiff competition for it uses due to population, economic, developmental and political pressures. Frequently, land with mineral potential has been used or earmarked for use other than for mining. This happens because of haphazard land policies concerning mining in any State in Malaysia (Mohd.Salleh, 1977). These policies allow the unsystematic issue of prospecting rights and mining titles, difficulty in renewal of mining leases and poor security of tenure for mining land. Other land problems include the legal complications in obtaining Malay Reserved Land (land specifically assigned to Malays which cannot be transferred to Non-Malays) for mining purposes and matters pertaining to customary and religious practices which hinder the development of the land. The fact that land is controlled by the state has often made the allocation of land to mining operators a politically sensitive issue. More often than not, political factors override other considerations, which results in land being given to "absentee" mining interests.

(4) The Problem of Land Administration

The undue length of administrative procedures for allocating land and issuing licenses and permits, is a negative factor in starting a mining operation. The 6 stage process involves at least 17 persons and the consent of up to 10 State Departments, depending on the area of application. These lengthy and tedious procedures can delay operation for more than two years in the case of new applications, and for more than five years, in the case of renewal of leases (average figures in the State of Perak). The normal duration of a lease granted to mining operators is five years, with the stipulation that operators apply for renewal one year before expiration. However, the renewal process takes years to administer in most of the State Land Offices. As a result may mines operate under expired leases. The end of 1982, about 282 mines were operating 'illegally'. Such uncertainty and lack of security discourages both continuance and expansion.

(5) Taxation and Fiscal Problems

Currently, there are eight taxes, direct and indirect, levied by the Federal Government on the tin mining industry: export duty, export surcharge, income tax, tin profit tax, development tax, sales tax, import surcharge and royalty payments. There is a general agreement that about 70 percent of Malaysian tin mining profit is absorbed in taxes, making the tin industry the most heavy taxed industry in the country (Jaafar, et. al., 1977; Scott,1982). The Federal Government receives 90 percent of the proceeds, leaving only 10 percent to the State Governments. This provides no direct incentive to the State Governments to release new lands for mining. Besides having to pay more than 70 percent of profit in taxes, mining operators are also faced with high interest rates, a credit squeeze, and rigid foreign exchange regulations resulting from poor fiscal policies. Such factors provide little incentive to mine operators.

(6) Lack of Research and Development

Research and development deficiencies exist in every industry in the country, but this problem is particularly acute in the tin mining industry. Most of the current methods of mining have not proved cost effective or economically efficient. A decrease in the quality of ore requires increased efficiency in operation or reduced unit costs in production. There is not sufficient research and development in the area of increasing the value of the mineral before export. Although many attempts have been made to increase the value of the tin, such as processing it into tin-plate or other forms of semi-finished products, those efforts lacked the support of sufficient research.

(7) Lack of Coordinated Action on Mineral Development

Currently, several governmental agencies are responsible for promoting expansion in the industry. The Department of Mines, the Geological Survey Department, the Institute of Mines, the States and Federal Economic Planning Units, to name a few, are responsible for this and each has its own stipulated area of responsibility for mineral development projects. However, more often than not, their functions overlap and there has been insufficient coordination among them to effect action in fostering the development of the tin mining industry. Organizational and staffing problems in most of these government agencies have compounded the difficulty. Perhaps the root of this problem is the lack of a coordinated national policy on mineral development. The Mining Enactment of 1929 and the Land Code of 1965 which are still in use, even after several amendments, are considered out of date now.

(8) Lack of Rapport Within the Industry

The fact that the tin mining industry is the most disparate industry in the country contributed, to a great extent, to a lack of rapport within the industry itself. The existence of differences in policy from one state to another is perhaps responsible for this. In addition, economic, social and political problems have separated miners leading to a lack of mutual support within the industry. A lack of forward and backward linkages between the tin mining industry and other supportive industries in the country has resulted in the relative isolation of mining concerns. The lack of communication between the industry and governmental agencies poses another problem for the dissemination of valuable information which could be helpful to the entire industry.

(9) The Increase in Smuggling Activity

Smuggling of tin is another problem faced by the tin mining industry. This activity is on the rise lately due to heavy taxation and production quotas in Thailand and Malaysia. In general, tin is smuggled in from Thailand and some quantity is also smuggled out to Singapore. In the 1970s, as much as 5,000 tons of tin (equivalent to 7 percent of national output) worth between $110 million and $120 million was smuggled out every year. This was estimated to cost the government between $30 million and $40 million per year in lost revenue (ARB, Vol.6, 1977).

(10) The Increase in the Costs of Production

The increase in the costs of production in tin mining activity since the early part of the 1970s is perhaps the most important single factor leading the tin mining industry into the current 'lock-up'. The massive price increase for oil and other mining materials in the early part of the 1970s, together with the world-wide recession that followed, is still affecting the industry at present. The rapid increase in production costs not only eliminated excess profits, but also left many mining firms stranded, which consequently closed down.

It is felt that this problem contributed most to the erosion of the tin mining industry in Malaysia. Therefore, the issue of production cost increases in the tin mining operation in Malaysia is the crucial issue for this research. It will be the focus of the next Chapter.

CHAPTER IV

THE CONCEPTUAL FRAMEWORK IN MINING ACTIVITY AND THE RESEARCH METHOD OF THE STUDY

Conceptual Framework of the Study

In searching for some conceptual frameworks to be used as the bases in conducting the investigation on the tin mining industry, some underlying principles or theories relating to mining appear to be relevent. Although, many of the studies considered did not use tin mining as a focus, some of them are useful and applicable to the tin mining industry. In this Chapter, only the most relevent concepts or theories will be highlighted for the purpose of establishing the conceptual framework of this research.

The purpose of this search is to up-date research done previously on this subject. Hopefully, some of the previous findings would provide a starting point for this investigation. In this attempt, related concepts or theories will be looked at in three stages: 1) mineral extraction at the firm level; 2) the mineral extracting industry; and 3) the tin mining industry with particular reference to Malaysian tin mining.

Theories of the Mineral Extracting Firm

There are a good number of works done previously to try to establish certain concepts or theories of the behavior of mineral extracting firm. Perhaps the earliest work done on this subject was by Lewis C. Gray in 1914. Gray was basically interested in the taxation of rents from mineral extraction. He developed a simple theory of the mineral extracting firm as an aid to his analysis. He noted that where land or its properties are inexhaustible, land is like labor because its product is lost when not used. Alternatively, when the properties are exhaustible, as in the case of coal deposits, use diminishes the benefits. Gray advocated that the owner of a deposit might well maximize his profits by postponing extraction into the future, perhaps because of an expected increase in the price of the resource, or an expected decline in the prices of the factors of production used in extraction. A more fundamental consideration according to him is that postponement of extraction is often caused by diminishing productivity of factors of production. He also discussed a few modifications of the theory, such as the case in which removal of some resources in one year completely changes the condition of removal in later years. In short, the prices and the factors of production are mainly responsible in determining the levels of extraction (Gray, 1914).

Harold Hotelling in 1931 attempted to devise a theory to analyze questions such as: (1) at what rate should a mine be exploited; (2) how would public ownership differ from private; and (3) how should the proceeds be divided between income and return to capital. He assumed free competition and profit maximization. He focused on the question of the maximum social value of a resource under the assumption that future enjoyment is discounted at the market rate of interest. He deduced that if the resource is exploited competitively, the rate of extraction will be the rate that maximizes value; but Hotelling then pointed to several instances in which the optimal rate of extraction would not obtain. He then, analyzed the question of the results of monopolistic exploitation of an exhaustible resource and compared monopoly solution to socially optimal conditions. Hotelling's primary contribution seems to have been the determination of a basic method of approach to the problem of exhaustible resources (Hotelling, 1931).

Donald Carlisle in 1954 advanced another point of view on the theory of mining extraction. He pointed out that previously economic theory had concentrated upon the optimal rate of extraction, while in reality the mining firm must decide not only upon the optimum rate of extraction but also upon the optimal amount of the total deposit to extract. No firm would ever extract the entire amount of a deposit. He first examined the decision of the optimal rate of extraction with a given total amount of the resource. In essence, the conclusion is that the highest current rate of profit is obtained by extracting at the rate at which marginal cost equals price. However, uncertainty in mining operations usually complicates the problem. All the uncertainties can affect the optimal level and rate of extraction. Finally, he found that for a given area of mining, the operators tended to turn to higher-grade portions of deposits, and shutting down low-grade stopes in response to a price decline (in the case of mercury mining) (Carlisle, 1954).

Anthony T. Scott, 1967, in discussing the theory of the mine under condition of certainty was also concerned with the firm's optimal rate of extraction from a given, known deposit. He noted that in any current period the firm has a profit curve and user cost curve, indicating the present value of future output specified by each unit of output extracted in the period. Not only does current production use up the deposit and limit future production, but current output also affects future production costs. However, if a mine contains several different grades, the problem is complicated enormously, unless there are uniform deposits of different grades separate from each other. In this case, the better grade will be mined first. Other things being equal, the better the grade the more net income that can be made. He also noted the changes in prices and the price of output also affect the rate of extraction (Scott, 1967).

A reinterpretation of the theory of exhaustion was further developed by Richard L. Gordon, in 1967. Using rigorous mathematical analysis, Gordon developed a model of the mineral extraction firm and from this model reached several fundamental conclusions. He assumed that the firm has available a certain resource in fixed supply and began with the assumption that the resource can be extracted at a constant average and marginal cost. The firm may decide to extract the entire deposit over time, or it may cease extraction before the limit is reached. However, in Gordon's model, the firm may decide to extract nothing during the current period when future conditions are particularly favorable (Gordon, 1967).

The latest work done on this subject was by Gerhard Anders and others in 1980. They claimed that the cost of production or extraction of minerals is based upon two primary components: the underlying production function and the prices of inputs used to produce the mineral. Generally, production or output of the mines in one period depends upon the state of technology and the amounts of resources or inputs used in that period. However, a complicating feature is encountered in the case of the extractive industry. The problem in mineral extraction is that the amount produced or extracted during a specific period affects the productivity of inputs in future period. This type of production relation leads to a cost function in which production in the current period increases the cost of production in future periods. For example, assume the amount extracted in period 1 is X tons. Then the cost of extracting X tons in period 2 will be Y dollars. But with the assumed production function, if less than X tons is extracted in period 1, the cost of extractin X tons in period 2 will be less than Y dollars. If more than X tons is extracted in period 1, the cost of extracting X tons in period 2 will be more than Y dollars. The same results hold for future periods (Anders & Others, 1980). Based on this assumption, they concluded that the true marginal cost of extraction in mining industry is the increase in the current period plus the increase in costs of extracting a given level of output in future periods due to extraction in the current period.

The theory of the mineral extracting firm is concerned primarily with the optimal rate at which some given resource deposit or reserves field should be extracted and secondarily with the optimal total amount that should be extracted. Although there are differences in the types of assumptions made, there is a good deal of agreement in the basic writings.

Theories of the Mineral Extracting Industry

The principles or theories advocated by the above works have explained the general pattern of behavior of a mining firm with regard to decisions concerning the timing and quantity of mineral extraction.

They also provide a basis for analyzing the behavior of the industry in general, although industry-level behavior may be different from that at the firm level. There are several principles governing the behavior of a mining industry as pointed by several writers.

Orris C. Herfindahl's model of the extracting industry showed that the amount of mineral to be extracted by the industry depends on the amount of known reserves of the mineral, which is in turn determined by market forces. The basic determinant that changes the number of properties and the rate of exploration is profit (Herfindahl, 1955). Five variables determine the rate of output and exploration:

(1) demand - changes in demand change price and therefore profits. Profits determine extraction and increases in output;

(2) exploration cost - a change in the cost of exploration changes profit and affects exploration expenditure;

(3) Economics of Scale in Mining - the larger the range of output over which increasing returns prevail, the more rapidly a given property will be exploited and the lower the price of ore;

(4) the rate of discount - the higher the rate of discount, the greater the return to current income, and the more rapidly a given property will be exploited;

(5) the average size of the property - if increasing marginal costs exist after some given output, increased property size leads to a longer mine life. By extending the mine life the owner avoids some diseconomies.

In his later work Herfindahl developed his model further by analyzing the effect of changes in some of the parameters of the model.

He concluded that in the mineral industries, price behavior is consistant with the view that very large quantities in relation to current consumption will be available for a long time at cost near present costs. That is, the mineral industries have not acted as if they are running out of ore. To be sure, firms extract all that is economically feasible from given deposits but they assume the availability of other deposits and technological changes (Herfindahl, 1967).

Ronald G. Cummings, in extending some of the economic theories of resource exhaustion, was concerned with the common property problem. He also considered the problem of costs that are affected by cumulative production. Boundary conditions, i.e. zero rates of extraction, were analyzed. He concluded that production from a common property resource such as a mineral is extended until profits become zero. When costs increase because of cumulative production the rate of extraction is reduced, the production period extended, and the rate of growth in marginal profits reduced (Cummings, 1969).

There is a general agreement that the value of a resource deposit must grow at a rate equal to the market rate of interest. Based on this assertion, Robert M.Solow advocated that the value of a resource is the net price. The net price under competition is the market price less marginal cost. If net price rises too slowly, extraction is accelerated and the resource is exhausted too quickly; if net price rises too fast, owners would delay extraction. He therefore concluded that in tranquil times the equilibrium path would be followed rather well but resource markets would respond quickly to unexpected shocks or sudden surprises, such as an outbreak of war (Solow, 1974).

Perhaps the latest piece of work which is directly related to the behavior of the mining industry was done by Gerhard Anders and others (1980) in discussing the economics of mineral extraction. They developed a model of extraction in the mining industry. They claimed that the output of the mining industry is influenced by several factors. These factors include capital, labor, energy, raw material resources and other inputs. Technology enters the production function because it can increase total output by increasing the marginal productivity of the inputs.

In their empirical analysis, they have employed a generalized cost function to examine some of the properties of the underlying production relation for mineral extraction. Using data drawn from metal mining in Canada for the period 1962-74, they found that changes in the scale of operation would not be expected to affect the relative usages of inputs. In other words, their conclusions were:

(1) changes in the level of production would not change the ratios of input usage, even though the levels of usage would change;

(2) technological change resulted in a relative increase in the usage of capital, and a relative decrease in the usage of labor;

(3) capital and energy were most substitutable for one another; capital and labor were much less interchangeable.

In the final analysis, Anders, et al. claimed that production in any given period is not independent of production in any other period. Since the current rate of extraction affects the amount that may be extracted in the future periods, the cost of extracting a unit of the mineral commodity today depends not only on the current level of usage of the inputs and their prices but also on the levels of input usage in the past and on the impact of current extraction on the future profitability of the deposit.

At this juncture, several conclusions could be drawn from these works mentioned above. First, the behavior of a firm in deciding when to extract minerals and in what quantity depends mainly on the prices of the mineral and on the variability of the cost of production, assuming that the firms are seeking profit maximization. In this situation, a mining firm will continue to extract the mineral until the marginal cost equals price. Second, this aggregate behavior of the mining firms forms the basis of the behavior of the industry as a whole. While it is true that the levels of output of the industry are to a greater extent dictated by the law of supply and demand, several other factors do enter the production function of the industry, which consequently affect the variability of output of the industry. These factors include the size of mining operations, the level of investment in the industry, the state of technology, and the adjustment of the industry to new situations. Lastly, the present rate of extraction is affected by previous rates of extraction, and current rates will affect future extraction. This means that the more mineral extracted now, the greater the cost of extracting mineral in a future period.

Factors Influencing the Productivity of Tin Mining Industry

The term "productivity" here refers to the actual physical output of the tin mining industry. An increase in productivity implies an increase in the actual physical output of the industry with a given quantity of resource inputs; or it implies maintaining the current level of production with a lower level of resource inputs. Conversely, a decrease in productivity means that the actual physical output of the industry has declined with a given resource inputs remaining the same, or the current level of production could not be maintained if the resource inputs are reduced.

In discussing the factors that influence the productivity of the tin mining industry, perhaps the most consideration is that the tin mining industry differs significantly from other mineral industries. Differences include:

(1) It is very small in comparison with other base metal industries;

(2) Tin resources are generally concentrated in less developed countries;

(3) Government control and intervention is much more common in the tin industry than in most other mineral industries;

(4) Tin is the only metal for which there is a producer-consumer association that has the power to affect prices;

(5) Most large tin producers are government-owned companies.

(6) The tin industry does not show the high degree of integration notable in the base metal industries (Govett and Robinson, 1980).

These special characteristics have made the tin mining industry a distinct entity and give some indications of factors influencing productivity in the industry. Although the basic concepts and theories of mineral production discussed above are very much related to the tin mining industry, total generalization of those concepts or theories could be misleading in discussing the productivity of this industry. This is because those concepts and theories derived from studies which were mainly based on other mineral industries.

It is useful, at this juncture, to establish a proper framework in order to systematically analyze the issue of productivity of the tin mining industry. The productivity of the tin mining industry could be examined in its three major component factors: the physical, the economic and the institutional.

The Physical Factors

The physical condition of the tin mines could be an important factor in determining the productivity of the industry. The physical factors include the surface area of mining operations the topography and location of the mines, the climatic influences, the magnitude of ore deposits, the location and the amount of ore, and the engineering feasibility of extracting the ore from the mines. The surface area mined influences the output of mine, not only in terms of its physical relationship, but also in determining the scale of the mining operation and the choice of technology to be used. The bigger the mine, the better the economies of scale could be utilized; thus, higher levels of productivity could be achieved. However, this factor could be constrained by the natural topographic and location of the land mined. Remote location and difficult topographic layout of mines cause various difficulties in the mining operation which would affect the amount of ore to be extracted from the mines. Climatic factors such as rain or lack of water supply would also make the extracting process more complicated.

Perhaps the factor that most directly influences the level of output of the mining activity is the magnitude of ore deposits. The incidence of primary or secondary ore deposits would determine not only the method of operation to be used in the mines but also the capital outlay of the mining firms and the amount of ore to be mined. These physical attributes will determine the feasibility of the mining operation. The more feasible the mines, the more productive they could be in drawing out the minerals from the ground.

The Economic Factors

Given the physical viability of the mines, the most direct factors that could determine the level of output of the mines are the economic attributes. In fact, economic factors determine how much of the mineral is going to be extracted from the mines.

Among the important determinants in this case is the demand for the commodity. The demand for tin is a derived demand, that is, the demand for products that contain tin metal. The demand for tin is closely related to overall industrial growth (Robertson, 1965); thus, the demand elasticity of tin is affected by two factors: saleability and substitution (Hedges, 1964). The saleability of tin metal is not influenced by the supposed increase in the price of tin, because the final consumer is not even interested in exerting a choice, for instance, whether to use a can made of tin or aluminum. Therefore, the influence on the demand for tin is more on substitution. In this case, the price of tin relative to the price of its substitutes become a major determinant in the quality of tin demanded. The real choice on substitution is made by technologists at the manufacturing level, and not by the final consumer.

On the supply side, the producer of tin metal is more interested in the price of the commodity. Theoretically, the higher the price the more mineral will be supplied; however, this situation in the case of tin industry does not prevail. The price of tin is determined not by the forces of the market, but rather by a cooperative arrangement between the producers and consumers through the price setting agreement of the ITC. This imperfect market mechanism has structured the prices of tin of which the producers use to determine the level of output of their mines. In this situation where the industry is the price-taker, the only consideration that is left to the miners is the variability of the costs of production relative to the prices of its final products. The bigger the margin between the costs of production and the prices, the more the mineral will be produced by the industry. Thus, the cost of producing the ore becomes the major economic factor in determining the level of productivity of the tin mining industry.

Other important economic factors which could also influence the productivity of the tin mining industry include the level of investment in the industry, the interest rates on loans, the financial market situation and other economic climates prevailing in a particular context. These factors will influence not only the scale of the industry in which the level of output would be affected, but also the viability of the industry as a whole.

The Institutional Factors

In most of the producing countries the tin industry has traditionally been subject to severe interventions from the government and other institutions. The formation of international institutions such as the ITC and the ATPC, was aimed at regulating the amount of tin to be supplied in the world market and the price for this commodity. The various mechanisms, such as the Buffer Stock scheme, the export controls, and the price setting arrangement directly influence the level of output of this industry. For instance, the "permissible export limit" imposed by the ITC on producing countries, will eventually be translated into a production quota for individual tin mines in the producing countries. This factor influences the productivity of the industry.

There are other institutional factors which constrain the behavior of the industry and could also affect the productivity of the industry. The laws and regulations, the policies and the programs of the government do affect the decision of the miners on how, when and how much to produce from their mines. Other institutional factors that could affect the level of output of the industry include the expenditure of the government, the policy of the banking institutions and customs and religious practices. The personal inertia or the individual preference of the miners could also affect the productivity of the mining operation.

In Malaysia there are strong indications that those physical, economic and institutional factors do affect the level of productivity of the tin mining industry. The fact that many tin mines are on land which contains marginal ore deposits shows that the the level of productivity of the mines in Malaysia has gone down significantly. The decrease of the average grade of ore from 26 kati per cubic yard in the early days of the prosperous Kinta Valley to the current average of .15 kati per cubic yard (Jaafar, 1977) indicated that this physical factor is responsible in determining levels of productivity.

Economic factors such as the rising costs of production in the mining operation, the lower prices of tin metal, the decline in demand and other factors have been claimed as the starting point of problems in the tin industry in Malaysia (Mohd Salleh, 1977). In the Majid and Cheong (1977) study, it was revealed that the Malaysian tin mining industry had become less productive by the middle of the 1970s, as the prices of tin declined while the costs of production increased (cited in Annuar, 1980). A study by Thoburn (1981) on the profitability of tin mining investment revealed that the internal rate of return for tin mining in Malaysia is lower than that in Thailand and Indonesia, due to the higher costs of production in Malaysia. The prevailing unfavorable economic climate has also affected the output in the tin industry in Malaysia.

Various studies have emphasized the impact of institutional factors on the productivity level of the tin mining industry in Malaysia. The land policy implications (Joll, 1977) and the administrative procedures in granting permits and licenses (Walker, 1977) are directly affecting the level of output. Jaafar and others (1977) and Tinker (1977) who have looked closely on the effects of taxation on Malaysian tin mining industry agree that this factor contributed the highest proportion to the increase in the costs of production in mining activity, thus making it the most important decision variable for miners in determining how much ore should be produced.

There is a general agreement among researchers that the productivity level of the tin mining industry in Malaysia has declined significantly. This means, that a higher level of inputs is required if the current level of output is to be maintained. Three important factors are mainly responsible for the decline of productivity. First, the decrease in the prices of the end product of the industry does affect adversely the returns to the investment in the industry. This, in turn, decreases the value of the marginal product of the firms and affects the productivity level of the industry. Second, the increase in the cost of production (the costs of utilizing factor inputs) has made it more expensive to maintain the current level of output of the firms, thus, it affects the productivity of the industry. Third, the degradation of the quality of ore grade in the land mined has resulted in less efficient operations in Malaysian tin mines. This means it is more costly to produce a given amount of ore now than previously. Technology in the mining operation thus becomes another determinant, because it affects the variability of the costs of inputs in the production process. Therefore, the production of ore in the industry is also dependent on the type of technology used in the mining operation.

However, the price factor of the end products of the industry does not enter directly into the production function of the industry although it is related in the calculation of the returns to the factors of production. The price factor is assumed exogenous, since the industry has never had a strong market price orientation. The rationale for this assumption is that the price of tin is almost non-perfectly competitive due to the price setting arrangement of the ITC. In addition, the immobility of capital in mining investment, particularly in dredging and underground mining and a long lead period for the industry to get readjusted to market forces caused tin supply elasticities to be very low, particularly in the short run (Robertson, 1982). The World Bank's estimates of short-run and long-run supply elasticities for Malaysian tin mining industry are 0.31 and 0.81, respectively (World Bank, 1978). A preliminary test conducted by this study on the relationships between monthly prices of tin and output from 1975 to 1979 also showed the relationships (R^2 = 0.044) between them are not significant, at less than a .10 significance level.

The quality of ore grade has a more direct effect on the productivity of the industry, this factor could easily be related and translated into the technology of extraction of the mining firms in the industry, i.e., the better the technology of extraction the lower the cost of production of the industry, thus the quality of ore grade is reflected in the choice of technology. Based on these assumptions, it is, therefore, postulated that the physical output of the Malaysian tin mining industry is influenced largely by the factors of production. <u>That is, the only decision criterion left to mining operators concerns quantities of inputs to be used to produce the ore</u>. In this relation the production function of the industry can be transformed into cost-function, where the physical output (Q) in period t_i is a function (f) of the costs of inputs (C) in period t_i; therefore:

$$Q_{t_1} = f(C)_{t_1}$$

where $Q = \Sigma q$

q = the output of the mining firm.

$C = \Sigma c$

c = the total cost of inputs of the mining firm in producing q.

The Concept of the Cost of Production in Tin Mining Operation

In the most simplistic way, cost is defined as anything that reduces the achievement of the given objectives of the project/firm (Gittinger, 1981). If the objective of a mining firm is profit maximization, anything that reduces the profit is considered as the cost to the firm. In this relation, the concept of cost is applied to expenses paid by the mining operator on the inputs used in the production process. In this context, only the direct costs, which are the actual expenses paid for by mining operators in the production process of the mining operation are taken into consideration. The indirect costs, such as pollution and other social costs are excluded in this study.

Generally, the cost of production in the tin mining operation can be measured in two ways:

(a) the cost of extracting tin metal per cubic unit of ore in the ground. Usually it is measured in katis or pound (lbs) of tin per cubic yard of land, or in kilogram (kg) of tin per cubic meter of land, or

(b) the cost of extracting one unit of ore (tin metal) from the ground. Usually it is measured in pound (lbs), katis, or kilogram.

Each measure has its own significance and implications for the mining operation. The first measurement involves massive calculations of ore units in the ground, which are subject to many errors of estimation. The second measurement is relatively simpler, because it takes into consideration only the costs of producing one unit of ore, dividing the total costs over the total units of output. This research will use the second method of measurement, because it is comparatively easier to handle and more meaningful, especially to the mining operators in deciding the amount of output to be produced from the mines.

The costs of extracting one unit of tin metal from the ground can be divided into two major categories: the capital expenditures and the production costs. The capital expenditures are the expenses paid by the mining operators in bringing in more productive resources or in increasing the production capacity of the current assets of the firms. These expenses are the cost of obtaining and preparing the mines. Production costs are the expenses paid by the mining operators in operating and maintaining the mines in order to produce certain amounts of output. These expenses are considered operating costs which incurred during the life-span of the mining operation. In this research, these two categories of cost are referred as the capital expenditures and the operating expenditures.

In compiling the data on the costs of production of the tin mining industry in the producing countries the ITC Economic and Price Review Panel have distinguished the capital expenditures from the operating expenditures by way of capitalization and depreciation. The capital expenditures are the expenses on items which could be capitalized and depreciated over a number of years. The operating expenditures are the expenses paid on items which could be completely written off during the year of purchase (DOM, Survey Form: 338 Bkp).

The capital expenditure in Malaysian tin mining operation as defined by the Department of Mines and ITC comprises various items: property or land; roads and bridges; water supplies; plants and machinery; buildings; vehicles; and others. Operating expenditures include power, labor, materials, other charges and overhead costs; depreciation; on-property exploration and development; realization costs (processing costs); taxes; and tributes. Although this breakdown of expenses is somewhat comprehensive, these expenses could be grouped into a lesser number of items. Land being one of the most important factors in a mining operation, it is singled out as a separate input factor. Other expenses listed under capital expenditure are included in a second category of fixed costs. For operating expenditure, several factors need to be separated because each of them has its own strength in the production process of the mining operations. Not only are they significant in terms of amounts; they also fit the conventional production function of the mining industry firm. It is therefore proposed that labor; power or energy; materials; and taxes be separated from other operating expenses. With this classification, the costs of major input factors are itemized as follows:

1. Land or Property

   This input factor refers to all expenses paid in obtaining the land or property, the mining leases and licenses for the operation of a mine, and on-land development expenses incurred prior to the operation of the mine. Land is the basic input factor in all mining activity.

2. <u>Labor</u>

Labor input factor includes salaries and wages, payment in kinds (e.g. medical attention, food, accomodation), bonuses and allowances, pensions, and other payments for social services to the labors employed in the mining operation. This includes all the payments made to contract work as well. Labor is the main ingredient in production function, particularly for mines that use labor intensive operations.

3. <u>Capital</u>

The cost of capital input is the sum of expenses paid on capital items, such as road and bridges, water supplies, plants and machinery, buildings, vehicles and others in connection with the preparation of the initial work of a mine. These factors are capable of being capitalized and depreciated over a number of years. Capital is the vital input that determines not only the scale of the operation but also the method of extraction in mining operation.

4. <u>Energy or Power</u>

Under this input factor, all expenses paid for providing electricity, fuel and fuel oil are considered as energy factors in the operation of a mine. The cost of energy is very vital particularly for mines that use a high technology component in extraction.

5. <u>Materials</u>

Since mining activity involves utilizing raw materials such as water, coals, and other consumable materials, therefore this factor is also regarded as a vital factor in the production process. All expenses paid for utilizing raw materials are categorized on the cost of materials in the production process of a mine.

6. <u>Taxes</u>

It has been claimed by many that taxes are the highest expenses paid by mining operators in the production of mineral from the tin mines. These expenses include royalties, export duties, and surcharges made to the government for extraction and exportation of the metal.

7. <u>Other Operating Costs</u>

The remaining cost category in tin mining operation consists of miscellaneous costs. These are maintenance expenses, overhead charges, insurance and security, management claims, depreciation, transport charges to smelters, handling charges, smelting charges and other related operating expenses.

Each of these input factors affects the variability of the physical output of a mine. A determination of the magnitude of the effects of each of these input factors on the output of tin mining industry is the principle goal of this investigation. It has been established in the last section of this chapter that the output of the industry is influenced by the variabilities of the costs of inputs. Therefore it is postulated that the amount of ore to be produced by the industry depends on the costs of inputs used in the production process. In this physical relationship, price is assumed as given and technology is assumed to be embedded in the methods of extraction of mining firms or a group of mining firms which uses a similar method of extraction. Therefore, in a simple production relation of the industry, the quality of ore to be produced is a function of costs of individual inputs in the mining operation, which is summarized as follows:

$$Q_{t_i} = f\ (C_L,\ C_{LB},\ C_K,\ C_E,\ C_M,\ C_T,\ C_O)_{t_i}$$

Where Q is the output of the industry and L, LB, K, E, M, T and O represent the costs of land, labor, capital, energy, materials, taxes, and operation respectively. Since the choice of technology of extraction would also affect the variability of output and input costs, the production function of the mining firms that use certain type of technology is modified in the following relationship:

$$Q_{G_i t_i} = f\ (C_L,\ C_{LB},\ C_K,\ C_E,\ C_M,\ C_T,\ C_O)_{G_i t_i}$$

where G_i = type of technology used in extraction activity of a group of mines in the industry, i.e. dredging, gravelpump, opencasting, and underground mining.

This notion formed the basic model of the investigation in this study. Based on this econometric model, the research will attempt to answer a few pertinent questions on the issue of the productivity of the mining firms/industry, both at the present time and in the future. The research methods are discussed in the next section of this chapter.

The Method of the Study

Introduction

The major purpose of this study is to identify those factors that influence the extraction of the tin ore by the tin mining industry in Malaysia. It is also the objective of this study to develop predictive models for explaining the variabilities of the output of tin mines in Malaysia by using certain predictor variables. It has been postulated in the last section that the cost of input factors affect the variability of the level of physical output of the Malaysian tin mining industry. Therefore, this study is intended to establish the relationship between the output level of the industry and the costs of inputs in the production process of the industry. It is hoped that this information will be useful for future policy measures, particularly in taking steps to maintain the productivity of the industry in the country.

It has also been postulated that the choice of technologies in mining operations, does affect not only the level of physical output, but also the cost structure in the industry. Therefore, this study also intends to analyze the different effects generated by the different methods of mining. This information is important, particularly in devising policy measures on the choice of technology which is more favorable to the industry and the country as a whole.

The purpose of this section is to provide details on the study method. The discussion under this section includes the model of the study, the hypotheses, the data for the study, and the data analysis approach.

The Model of the Study

Previous studies of the mineral industries, as presented in the last section, showed that many factors influence mining operators' decisions on how much ore to be extracted at a particular time. It has been concluded that the most important decision variable, in the case of the tin mining industry, is the cost of input factors. It is the cost of inputs that is mainly responsible in determining the level of output of the industry. This notion was developed from a simple production function model introduced by Anders (1980), where the physical output of the industry is a function of various factors of production, which has been translated into the cost function of the industry.

In order to see the effects of the changes in the cost factors on the level of production, this basic econometric model was transformed into a linear regression model. This model assumed that the production of the industry is related to the cost of input factors used in the production process. Therefore, the variations in the production of the industry could be explained by the changes in costs of input factors over the years of mining operations. In this relation, the physical output of the industry is treated as the dependent variable, while the cost factors are the independent variables. The dependent variable is measured in terms of the average unit output of the industry, that is, metric tons of tin-in-concentrate extracted and processed by the mining firms from year to year. The independent variables, the cost factors, include the costs of land, labor, capital, energy, materials, taxes, and other operating costs. These independent variables are measured in terms of Rinngit (Malaysian currency unit) spent to produced a unit (ton) of tin-in-concentrate from the mine. The price of inputs is calculated in 1982 constant prices.

The purpose of using this model is to identify input factors that influenced the variability of the output of the industry for the past years. This regression model also would provide a quantification of the parameters of the association and estimate of the value of output of the industry from known values of one or more input factors. The regression techniques which were used in this study would also permit statistical inferences and testing hypotheses that were postulated in this study.

The general regression equation of the model was set up in the following form:

$$y = b_0 + b_1 x_1 + b_n x_n + \text{error}$$

where y = the physical output of the industry

b_0 = the coefficient of the linear relationship between x_i and y

b_1 = the coefficient of x_i, x_n

x_1 = the cost of land

x_2 = the cost of labor

x_3 = the cost of capital

x_4 = the cost of energy

x_5 = the cost of materials

x_6 = the cost of taxes

x_7 = other operating costs

Since this is a 'closed-ended' model, the variances of the outputs of the industry are assumed to be explained by other factors which are reflected in the errors of the regression analysis.

It is recognized that the embedded assumption of this regression technique that--the relationship between the dependent variable and the independent variables is linear--might not hold true in the case of the tin mining industry. However, this assumption will be examined by determining the significance of the relationship between the variables in the regression analysis result. If the linear relationship has been proved not significant, then the research would anticipate that the output of the industry is not linear with the costs of input factors in the production process.

It has been found earlier that the output of the industry and the costs of inputs in the production process is also influenced by the technological choice in the mining operation. Therefore, this general model was modified to show the effects of different technologies on the relationship between the variables used in the study. In this case the choice of independent variables in the model is dependent on the strengths of the relationship between each input factor and the output of the mines that used certain types of extraction methods. The details of the modification of the model are presented in the analysis of the results in the next Chapter.

The use of this model also would enable the research to create various predictive models for estimating the output of the industry in the future by knowing the value of certain important input factors. This is important particularly for future policy planning. Therefore, in the analysis of the results of the study, emphasis will be placed on the sensitivity of each input factor to changes that consequently would affect the production of the industry. For this purpose various assumptions were made to predict future directions in the tin mining industry in Malaysia.

The Study Hypotheses

Having specified the model of the study where the variables and measurements are identified, several hypotheses were constructed to look at important theoretical relationships between one or more independent variables and the dependent variable.

It is hypothesized that the amount of tin ore produced by Malaysian tin mining industry is influenced by the variability of costs of inputs in the production process. The higher the cost of extraction the lower the amount of ore to be produced.

This general hypothesis suggests that there is a relationship between the output level of the industry and the costs of input factors. Therefore, the mining operator's decision to produce certain amounts of ore is influenced by the costs of input factors. This hypothesis assumes that the industry is in competitive situation and there are no physical or institutional factors that constrain the decision. It is also assumed that each factor of production is in linear relation with the output of the industry. The nature of the relationship is expected to be negative or inverse.

The rationale for this hypothesis is based on the preliminary examination on the data used in this study. The data shows that the amount of tin ore produced by the industry declined substantially year to year since 1973, while the cost of production increased steadily throughout the years beginning in 1973. Previous studies on the subject as shown in the last section also suggested that the increase of the cost of production was mainly responsible for the decline in the output of Malaysian mines. Among the input factors that caused the increase of the cost of production were the energy cost and labor cost. It is also assumed that the increase in the cost of production is not because of the increase in units of inputs used in the production process, but rather due to an increase in the cost per unit input. The rational for this is that the output could have been increased if the unit of inputs increased, but in this case the output decreased consistantly.

It is also suspected that the increase in one or more input factors is related to the variability of other input factors. In this case the nature of the relationship between input variables is expected to be positive, i.e., the increase or decrease of one factor followed by other factors in the same order. Therefore, various specific hypotheses could also be developed to match each individual input factors with the output of the industry. In this case, each cost factor is hypothesized to have influenced the output of the industry. The nature of the relationship would be the same as in the general hypothesis.

This hypothesis is therefore designed to test the strengths of the relationship between output and input variables and between one input variable with other input variables. The result of this test will show the magnitude of the association between the variables and also to prove or disprove the assumption of linearity of this hypothesis.

It is further hypothesized that the strength of the relationship between each individual input factor and the output varies significantly from one method of extraction to another. In this case, the better the method used in reducing the cost of extraction, the more ore will be produced by that method.

This hypothesis assumed that there is a different effect generated in the relationship between output and input factors as a result of choosing a different technology in mining operation. Thus, the nature of the relationship between the variables differs significantly from one method of operation to another. Preliminary examination of the data on the output and costs of inputs in dredge, gravelpump, opencast and underground mines shows that not only do the outputs vary from one method to the other, but also the costs of individual input factors vary. Previous studies also suggested that the choice of extraction technology would affect the level of output of the industry. However, the general trend in almost all the methods of mining shows that the output of the mines seemed to be declining from year to year since 1973, while the costs of certain input factors seemed to increase steadily, but different input factors persisted in different methods of operation.

In this case, each input factor is assumed to have a different relationship with the output of the mine that uses a different method of extraction. For instance, labor may be more strongly related to the output of underground mines than dredge mines, and so other factors in other methods. Therefore, in analyzing the relationship between output of the mines and the costs of inputs, a more specific hypothesis was developed for each method of extraction. The manner in which the hypotheses were developed was similar to the general hypothesis. In this case, the hypothesis is designed to test the strength of the relationship between each individual input factor and the outputs of each method of mining operation. The result of this test will show which specific input factors influence the output of each method of extraction.

The hypothesis advanced above will be tested by using various statistical inferences. A .10 significance level will be used to test the null-hypothesis.

The Data for the Study

An initial data collection procedure was designed to be used for collecting data and information from primary sources, but the difficulties encountered in getting access to the mining firms resulted the abandonment of this process. Instead, this study relies heavily on secondary sources. It is felt that the nature of the investigation in this study permits the use of secondary data. The major sources of the data for the research came from published and unpublished documents gathered from various government agencies and public bodies, such as, the Department of Mines, the Ministry of Primary Industry of Malaysia, the Malaysian Chamber of Mines, the ITC and various state government offices.

In fact, one of the most important sources of the data was the surveys conducted by the Department of Mines Malaysia. The surveys on the tin mining industry in Malaysia were undertaken by the Department in every six months, started from January, 1972. These surveys provide the data on the production and the costs of production from a sample of mines in Malaysia. The questionnaires of the surveys as attached in Appendix C were used by the Department. These surveys were used extensively by this research in generating data and information required for the study.

In order to gather relevant data for this investigation, some modifications were made to the survey's data, particularly in regrouping the data to suit the requirements of the study. Various calculations and conversions on some of the data were done in order to arrive at the standard unit of measurement used in the study. For instance, the surveys conducted by the Department prior to 1980 have used "picul" as a unit of measurement, but after 1980, the unit of measurements were changed to kilograms, therefore, they have to be converted to tons.

Like many other surveys, the data of these surveys are aggregated; the disadvantages of using aggregated data are obvious in this study. The data from the surveys are assumed to be reliable and accurate since the survey samples are wide enough to represent the population, and since the same data are used for official purposes in the country. However, in order to maintain consistency, some modifications on the data were done in this study.

Table 11 shows the samples of the mining firms used in the surveys from 1973 to 1982. The firms were grouped according to the methods of mining operation.

It is noticeable that there are some inconsistencies in terms of the size of the samples from method to method and from year to year. Nonetheless, in overall terms, the samples are representative: ranging from overall 15 per cent to over 60 percent of the population. Some of the mines included in the sample for some years may not be included in other years due to mortality for some reasons, therefore in order to maintain consistency the data on outputs of the sample mines are converted to the average. This means that the actual output of the sample mines as shown in Table 12, are to be divided by the number of sample mines in Table 11.

Table 11

The Samples of Mines in the Surveys, 1973-1982

	Dredge		Gravelpump		Opencast		Underground		Total	
	Total	Sample	Total	Sample	Total	Sample	Total	Sample	Total	Sample
1973	58	53	873	105	12	3	1	1	945	162
1974	56	48	943	104	9	3	1	1	1009	156
1975	55	41	932	91	9	2	1	1	997	135
1976	51	47	724	409	12	2	1	1	788	459
1977	53	32	784	340	12	2	1	1	850	375
1978	53	41	833	348	22	2	1	1	909	392
1979	54	44	772	201	21	2	1	1	848	248
1980	54	39	746	308	28	7	1	1	829	355
1981	60	34	593	256	35	7	1	1	689	298
1982	43	26	521	135	43	9	1	1	608	171

Sources: DOM, 1972 to 1982.

Table 12

Production of Tin From the Sample Mines, 1973-1982

(in tons)

	Production according to Method of Mining				Total
Year	Dredge	Gravelpump	Opencast	Undergound	(Samples)
1973	21,273	6,769	2,165	1,896	32,103
1974	21,045	5,167	1,724	1,845	29,781
1975	19,040	10,155	1,529	1,559	32,283
1976	17,750	20,111	1,538	1,477	40,876
1977	12,430	15,423	1,448	1,362	30,563
1978	16,147	17,343	1,637	1,113	36,240
1979	11,523	12,848	1,593	999	25,964
1980	13,975	16,064	1,692	907	32,638
1981	10,668	16,727	1,696	791	29,882
1982	9,852	10,649	1,431	576	22,508

Sources: DOM, 1972 to 1982.

The data on the costs of inputs are in Malaysian Ringgit at a constant value of 1982. The costs of inputs are calculated on the basis of one unit of output, i.e., Ringgits per ton of output. The data on the average output of the mines and the costs of inputs as they are modified are presented in the analysis in the next Chapter.

Data Analysis Approach

Basically, the data analysis of this study deals with the analysis of the relationships among the dependent and independent variables. The independent variables which are significantly related with the dependent variables will be taken as predictor variables in creating predictive models of the study. The SPSS computer program was used in the analysis of the study.

The analysis of the data is done in various phases. First, the data will be analyzed to check whether there is a need to modify the hypothesis set earlier in this study. For instance, the land factor in underground mining seemed to be irrelevant, since there is no data on land cost available for the study, therefore the land factor is excluded from the analysis. After satisfying that the hypotheses are correctly set, a number of tests were performed to evaluate their significance.

Pearson's Correlation techniques were used to test the strength of the linear relationship between the variables as stated in the hypotheses. The tests were evaluated by using critical t-value at a .10 significance level. The result of these tests enable the research to make conclusions on the hypothesized relationships among the variables.

Based on these results also, the research will select the independent variables to be used in the predictive models of the study. Since, there were many independent variables correlated to each other, a process of eliminating multicollinearity among the independent variables was done for the purpose of choosing the right variables for the model. A rule has been set that if more than one variable correlates with each other at more than .80 coefficient of correlation, only one of them will be selected to fit in the regression model at a time. Therefore, there will be more than one possible model suggested in the study in analyzing the relationship between output and costs of inputs.

Multiple regression or some time simple-regression analyses were conducted on the possible models that resulted from Pearson's Correlation analyses. If more than one independent variable entered into the model, multiple regression analysis was performed to see the simultaneous effects of these variables on the dependent variables. The stepwise option was chosen in order to evaluate the effect of each individual in dependent variables. The significance of the linear relationship between the independent variables and the dependent variable is tested by using the critical F-value at a .10 significance level.

Based on the result of this analysis, the models that yield the highest value of coefficient of multiple determination, R^2 were chosen as the best predictive models among all the possible models suggested. The choice of independent variables in a model is evaluated on the strength of its F-significance value. If a variable is not significant to enter together with other independent variables at a .10 F-value, that variable will be omitted from the model.

Another criterion was used in the selection of the best predictive model of the study, that is the test of serial correlation in the results of the regression analysis. This test is important because the data used in the study are serially arranged. A model which is serially correlated at a critical value of more than a .05 significance level will be discarded because its biases in the estimates is greater than the model that has lesser serial correlation effects. If none of the models are suitable due to the significance presence of serial correlation, then a model which has the lesser serial correlation value will be chosen.

The results of the regression analyses will be used for further analysis in the study. The coefficients generated by these analyses are applied in the attempts to predict the output of the mines in 1983. Here, various expected changes, particularly on governmental policies relating to the mining industry, will be examined and their effects will be discussed.

The results of the analysis will be presented in the next Chapter. The application of the model for prediction purposes will be discussed in Chapter VI.

CHAPTER V

AN ANALYSIS OF THE RELATIONSHIPS BETWEEN OUTPUT LEVEL AND INPUT COST OF MALAYSIAN TIN MINES

Introduction

This study has focused on two major issues which are currently the main concerns of the Malaysian tin mining operation. They are the decline in output of the mines and the increase in the cost of production in mining operations. This study is based on the general hypothesis that there is a relationship between these two variables. Various specific subhypotheses are also developed based on this general hypothesis. Data from the surveys conducted by the Department of Mines in Malaysia are mainly used to test those hypotheses.

The purpose of this chapter is to present the results of the analysis according to the order of the hypotheses discussed in the last chapter. This chapter will first present an analysis of the industry as a whole followed by an analysis of each of the four major methods of mining operations.

The Analysis of the Industry

1973 marks a turning point in the history of the Malaysian tin mining industry when unprecedented changes occurred at various levels of mining operations. The syndrome of declining in output and rise in costs of input in mining operations occurred almost simultaneously. As a result, the industry has suffered a continuous decline in the production of tin-in-concentrates since 1973.

The industry's production dropped to 68,122 tons in 1974 compared to 72,260 tons in 1973. This trend continued until 1977. From 1978 to 1980 production picked up to 62,650 tons annually. But at the end of the 1982, production of the industry stood at 52,300 tons; a decline of about 25 percent compared to the production in 1973. (Table 9 presents the yearly production of the industry from 1973 to 1983.) Perhaps, the decline in the total output of the industry was also a result of the yearly decline in number of mines in the industry. At the beginning of the period studied, 1973, there were 974 mines in operation, but at the end of the period studied, 1982, the number of mines was reduced to 581. (Table 10 presents the numbers of mines from 1973 to 1982.)

This general trend was also reflected in the behavior of the sample mines used in this study. It is important to note here that the data used by the study to characterize the industry were drawn from data on each method of mining operation, as they are presented in later analysis. Since the industry is made up of mines which use various extraction methods the aggregated data from all these methods of mining operation should reflect the nature of the industry as a whole. The average yearly output of the sample mines together with the average costs of input for the industry from 1973 to 1982 is shown in Table 13.

Table 13

Average Output and Costs of Input
Per Ton of Tin for All Sample Mines 1973 to 1982
(In Tons & Malaysian Ringgits)*

Year	Average Output	Land	Labor	Capi-tal	Energy	Mate-rials	Taxes	Opera-ting	Total
1973	198	67	992	357	517	424	779	892	4028
1974	191	131	1422	517	778	801	1201	1520	7070
1975	239	130	2354	431	998	907	1645	1535	8000
1976	90	137	2692	412	1167	1034	2596	1728	9766
1977	82	184	2885	483	1581	1208	4061	2014	12416
1978	92	212	3184	724	1378	1267	4578	2346	13789
1979	105	235	3384	543	1635	1650	5305	3354	16107
1980	92	361	4297	1217	2159	2199	5543	4449	20225
1981	100	205	6223	2116	2237	2864	3456	5032	22133
1982	132	896	5941	2656	3609	2891	2322	5896	24211
Means	132	265	3337	946	1606	1534	3219	2878	13774
Std. Dev.	56	238	1725	808	895	857	1624	1712	6807

*Figures are rounded off and in constant value to 1982.

During the ten year period, the average output of the sample mines fluctuated considerably from year to year. The highest average production of the mines was in 1975 and the lowest in 1977. The decline of the average output of 198 tons in 1973 to 132 tons in 1982 is almost 35 percent. The costs of input, on the other hand, have increased substantially from year to year. The average total cost per ton of output has increased to $24,211 in 1982 compared to $4,028 in 1973, a five-fold increase. The behavior of individual input factors also shows a similar trend although the magnitude of the increase differs from one factor to another.

It has been hypothesized that the output of the industry is influenced by the variability of the costs of input factors. The nature of their relationship is expected to be inverse, i.e. the higher the costs of input the lower the output of the industry. In order to prove this hypothesis, Pearson's Correlation tests were conducted to establish the magnitudes of the relationships between the output of the industry and the individual costs of input factors. These tests have identified input factors that significantly correlate with the output of the industry.

The result of the test is shown in Table 14.

Table 14

Correlation Coefficients For Variables In the Industry Level Analysis

	Output	Land	Labor	Capital	Energy	Materials	Taxes	Operating
Output	1.000							
Land	-.207*	1.000						
Labor	-.5138	.686	1.000					
Capital	-.250*	.812	.906	1.000				
Energy	-.442	.915	.909	.908	1.000			
Materials	-.488	.728	.986	.924	.926	1.000		
Taxes	-.771	.113*	.408*	.084*	.333*	.428	1.000	
Operating	-.446	.793	.955	.923	.946	.988	.4182*	1.000

*Significance at more than a .10 t-value.

The results of the test indicate that all individual input factors except land and capital correlate with the output of the industry at less than a .10 significance level. The coefficients of the correlation between each individual input factor with the output vary from -.20 to -.77. The nature of the relationships is proved to be inverse (negative values). Therefore, the null-hypotheses of no relation between each individual input factor and the output of the industry, which have been set at $r=0$ at less than a .10 significance level, are true in the cases of land and capital. The study concludes that there is an inverse relationship between labor, energy, material, taxes and operating costs and the output of the industry. Taxes proved to be the factor with the highest correlation to output where the value of correlation coefficient was -.77.

The tests also proved that many individual input factors do correlate with each other at less than a .10 significance level. Therefore, in selecting the independent variables to be fitted in the regression equation of the study, multicollinearity among the variables will have to be eliminated. For this purpose, the variables that correlate with each other at $r \geq .80$ coefficient of correlation will be dropped. For instance, Table 14, shows that labor cost is correlated with energy, materials, and operating cost at more than .80 coefficient of correlation; however, only one of these factors will be selected at one time for the regression analysis. In other words, these four factors should not exist together in a regression model.

As a result of this process, four alternative models were developed in order to establish the relationships between input and output factors of the industry. These models are as follows:

Model I: $\text{Output} = b_0 + b_{1(\text{Operating})} + b_{2(\text{Taxes})} + \text{error}$

Model II: $\text{Output} = b_0 + b_{1(\text{Materials})} + b_{2(\text{Taxes})} + \text{error}$

Model III: $\text{Output} = b_0 + b_{1(\text{Energy})} + b_{2(\text{Taxes})} + \text{error}$

Model IV: $\text{Output} = b_0 + b_{1(\text{Labor})} + b_{2(\text{Taxes})} + \text{error}$

The common assumption in the models above is that the relationship between each of those input factors and the output of the industry is linear. For instance, in Model I, it is assumed that the costs of operation and taxes are linearly related to the variability of the output of the industry. The results of multiple regression analyses which were performed on each of the proposed models are shown in Table 15.

Table 15

Results of Multiple Regression Analysis In the Industry Level Analysis

Model	Independent Variables	R^2	F Significance	d-value^f	d-critical*
I	Taxes	.5951	.00	2.02	d_u = 1.6271
	Operation	.6135	.58		d_l < .82
II	Taxes	.5951	.00	2.03	d_u =1.6271
	Materials	.6257	.47		d_l < .82
III	Taxes	.5951	.00	2.18	d_u = 1.6271
	Energy	.6336	.42		d_l < .82
IV	Taxes	.5951	.00	2.10	d_u = 1.6271
	Labor	.6427	.37		d_l < .82

f - Durbin-Watson d value of the regression analysis.
* - critical d_u and d_l value at a .05 significance level where K = 3, T = 10 .

The regression analysis above indicates that each model has particular strengths in explaining the relationship between the dependent variable and the independent variables. The strength of the linear relationship between the variables is expressed in terms of coefficients of Multiple Determination of the regressions (R^2). Apparently, all the four possible models, the values of R^2 are almost the same and only the tax factor shows a significant relationship to the output of the industry. The inclusion of other factors (operating, materials, energy and labor) together with the tax factor was not significant at less than a .10 F-value. Therefore, other factors could be omitted from all the models with no loss of accuracy in predicting the variances of the dependent variable.

The exclusion of other factors from the models also means that the model for predicting the output of the industry will consist of only one independent variable, namely the tax factor. The strength of the relationship between the tax factor and the output of the industry is .595. This means the tax factor is able to explain the variances of the output by 59 percent.

However, due to the serial arrangement of the data used in the analysis from 1973 to 1982, the validity of the regression result might have been influenced by the presence of serial correlation in the sample. Durbin-Watson-d-statistic tests were performed on the models to check the significance of serial correlation. The 'd' value in Table 15 denotes the computed value of serial correlation that is present in its corresponding model. The d_u is the Durbin-Watson critical value of the upper limit at a .05 significance level which is similar to the Q-value of Theil and Negar's procedure (Ostrom, 1978). The study used Theil and Negar's procedure to calculate the d_u because of only ten observations in the study which is less than the minimum required by Durbin-Watson's procedures. The formula is as follows:

$$\text{at } .05 \quad Q = 2\left[\frac{T-1}{T-K} - \frac{1.64485}{T+2}\right]$$

Where Q is the upper limit of the serial correlation; T is the number of observations; and K is the number of predictor variables in the models. The lower limit (d_1) of the serial correlation could not be computed to the exact value because the formula provides only for d_u. However, from Durbin-Watson's table the value of d_1 should be less than .82 because the sample is smaller than 15. The same procedure will be applied for all the serial correlation tests in the study. The criteria for the test is:

If $d > d_u$ accept the null-hypothesis of no serial correlation

If d in between d_u and d_1 - inconclusive

If $d < d_1$ reject the null-hypothesis of no serial correlation

Using Durbin-Watson Criteria, if $d > d_u$ for negative serial correlation which is the case in this analysis (d greater than 2 is negative and d less than 2 is positive serial correlation) the presence of serial correlation in the sample is not significant. Therefore, in all the models above, the presence of serial correlation was not significant.

Based on this conclusion, any of the models could be a good predictive model. But, since the decision is that only one input factor, the tax factor, will be used in constructing the predictive model, the choice among the models is immaterial because the model would be comprised of the same variable. Hence, it is postulated that the linear relationship between output of the sample mines in the industry and the tax factor is as follows:

$$y = b_0 + b_{1(taxes)} + error$$

where y = output of the industry

b_0 = the constant of the relationship

b_1 = the coefficient of tax factor

The coefficient of the constant is 218.16 with a standard error of 27.82, while the coefficient of the tax factor is -.02674 with a standard error of .0078. Therefore the research concludes that the predictive equation for estimating the output of the tin industry in Malaysia is as follows:

$$\bar{y} = b_0 + b_1 x_1 + \text{error}$$

where $\bar{y}$ = the estimate of the output

x_1 = the known value of the cost of taxes in the industry

$$\bar{y} = 218.16 - .02674\, x_1 + \text{error}$$

The Analysis of the Mines According to Method of Extraction

It has been hypothesized that the relationship between the level of output and the individual input factors differs from one method of mining operation to another. In this case the choice of one method of extraction may affect output of the mine. Therefore, the level of output of the mine is a result of using various input factors. The production from one method of operation may be influenced by a set of input factors, while the production from some other method may be influenced by other sets of input factors. The intention of this study is to identify what input factors influenced the level of output of each of these methods of extraction. An analysis of the findings is presented by method of mining operation, namely, Dredge, Gravelpump, Opencast and Underground mining.

Dredge Mining

Dredging is considered the most prominent and organized mining activity in Malaysia. This method of extraction has always been associated with big scale, highly technological and capital-intensive operations. It has also been claimed as the most efficient method in terms of recovering the ore from the ground. This method produces the largest output of minerals in terms of a single mining operation. In the overall industry, dredge mining is second largest both in the number of mines as well as in total output.

During the ten year period, 1973 to 1982, the total yearly production of tin-in-concentrate from this method of operation fluctuated considerably. From 1973 to 1976, the yearly production was around 22,000 tons. The output of the mines dropped to around 20,000 tons annually in 1977 and 1978. It dropped further in 1979 to around 19,000 tons, and in 1980 to around 18,000 tons. This trend continued in 1981 and 1982 when the total yearly production dropped to around 17,000 and 16,000 tons, respectively. The number of dredge mines varied a bit from year to year from 1973 to 1982, but in general the number remained consistantly close to 54 mines each year. (The total numbers of dredge mines from 1973 to 1982 are shown in Table 10). In the beginning of the period studied, 1973, there were about 58 dredge mines, but this figure dropped to about 40 mines at the end of the period studied, 1982. The highest number of dredge mines during the decade was 60 in 1981.

The analysis of the output of the sample dredge mines in this study also shows a declining trend during the ten year study period, while the average cost of input, on the other hand, has climbed steadily from year to year. Table 16 presents the average output of the dredge mines and the average costs of input per ton of tin produced from 1973 to 1982.

Table 16

Average Output and Costs of Input Per Ton of Tin for the Sample of Dredge Mines, 1973 to 1982 (In Tons & Malaysian Ringgits)*

Year	Average Output	Land	Labor	Capital	Energy	Materials	Taxes	Operation	Total
1973	401	74	641	458	428	531	780	891	3804
1974	421	98	921	135	605	868	1947	1355	5930
1975	443	32	1058	152	892	986	1604	1456	6181
1976	394	105	1068	159	1005	984	2388	1451	7161
1977	395	82	1401	169	1188	1448	4042	1769	10100
1978	389	189	1351	704	1186	1251	4531	2292	11505
1979	349	259	1339	359	1523	1718	5301	3868	14367
1980	358	38	1792	450	1945	1913	3977	4805	14921
1981	328	155	2365	2397	3239	2612	3325	5263	19357
1982	303	2064	2550	663	3610	3170	2390	5550	20897
Means	378	400	1449	565	1562	1548	3029	2870	11422
Std. Dev.	43	903	617	677	1075	827	1434	1808	5862

*Figures are rounded off and in constant value to 1982.

In 1973, the average output of the sample dredge mines was around 400 tons. Although the yearly average output of these mines increased slightly in 1974 and 1975, it dropped considerably thereafter. At the end of the period studied, 1982, the yearly average output was only around 300 tons; a decline of about 25 percent compared to that of 1973. In general, the costs of input have escalated rather rapidly from year to year, except the land cost factor which showed an unclear pattern. During the ten year period, taxes were the biggest cost in the dredging operation. The second highest individual input cost was the operating cost, followed by energy, materials, labor and capital. The lowest average cost was the land factor. The total cost of input in dredging increased from about $3,800 in 1973 to about $20,800 in 1982; an increase of more than six-fold.

In proving the hypotheses that each individual input factor has a linear relationship to output of the mines, Pearson's Correlation tests were performed. The result of the tests is presented in Table 17 which shows the correlation of coefficients for all variables used in the tests.

This test revealed that all individual input factors used in the sample dredge mines, except taxes, have a significant correlation to variations in output of the mines, at less than a .10 significance level. Therefore, the null hypothesis (no correlation between each individual input factors and the output of the mines, $r = 0$), is true only in the case of taxes. The tax factor correlates with output at more than a .10 significance level; while other input factors correlate inversely with output of the mines at less than a .10 t-value. The strength of the correlation, r, ranges from $-.57$ to $-.90$. Therefore, the study concludes that land, labor, capital, energy, materials, and operating costs are linearly related to the output of dredge mines.

Table 17

Correlation Coefficients For Variables In the Dredge Mines Analysis

	Output	Land	Labor	Capital	Energy	Materials	Taxes	Operating
Output	1.000							
Land	-.646	1.000						
Labor	-.868	.639	1.000					
Capital	-.573	.074*	.640	1.000				
Energy	-.901	.683	.985	.667	1.000			
Materials	-.909	.706	.985	.574	.986	1.000		
Taxes	-.396*	-.106*	.331*	.145*	.246*	.342*	1.000	
Operating	-.913	.541	.927	.599	.930	.943	.434*	1.000

*Significance at more than a .10 t-value.

The tests also showed that input factors correlate with each other at more than a .10 significance level, with the exception of taxes. For instance, in Table 17, labor is highly correlated with energy, materials, and other operating costs. Therefore, in searching for possible models to analyze the linear relationship between output of the mines and input factors, multicollinearities among the variables will be eliminated at $r \geq .80$.

As a result of this process, four possible models were developed where the multicollinearity among the independent variables was eliminated at $r \geq .80$. These models are as follows:

Model I: Output = $b_0 + b_{1(\text{land})} + b_{2(\text{capital})} + b_{3(\text{labor})}$ + error

Model II: Output = $b_0 + b_{1(\text{land})} + b_{2(\text{capital})} + b_{3(\text{energy})}$ + error

Model III: Output = $b_0 + b_{1(\text{land})} + b_{2(\text{capital})} + b_{3(\text{material})}$ + error

Model IV: Output = $b_0 + b_{1(\text{land})} + b_{2(\text{capital})} + b_{3(\text{operating})}$ + error

Assuming that all independent variables in each possible model above are linearly related to the output of the mines, multiple-regression analyses were done on the models. Stepwise regressions were performed on each input factor in each model. The results are shown in Table 18.

Table 18

Results of Multiple Regression Analysis In the Dredge Mines Analysis

Model	Independent Variables	R^2	F Significance	d-value[f]	d-critical*
I	Labor	.7534	.00	1.8499	d_u =2.050
	Land	.7677	.53		d_l < .62
	Capital	.7798	.59		
II	Energy	.8115	.00	1.6961	d_u = 2.050
	Land	.8132	.80		d_l < .62
	Capital	.8134	.90		
III	Materials	.8256	.00	1.9528	d_u = 2.050
	Capital	.8296	.70		d_l < .621
	Land	.9323	.76		
IV	Operating	.9344	.00	2.1246	d_u = 2.050
	Land	.9671	.32		d_l < .62
	Capital	.9786	.48		

f - Durbin-Watson d value of the regression analysis.
* - Critical d_u and d_l value at a .05 significance level, where K = 4, T = 10.

The results of regression analyses in Table 18 show that the strength of each model in explaining the variation of the outputs of the sample mines differs from one model to another. The strongest model is probably Model III and the weakest, Model I where the Coefficient of Multiple Determination R^2 yields .932 and .780, respectively. However, the significance of the presence of each independent variable in a model varies from one model to another. In fact, in all the models, land and capital factors proved of no significance at less than a .10 significance level, when present with other factors. Therefore, these two factors can be abandoned with no loss of efficiency of the models. Only one input factor that shows the highest and most significant R^2 is present in each of the models.

In searching for the best model out of those possible, Durbin-Watson d-statistics tests were performed on the results of the regression analyses. The test results indicates that the presence of serial correlation in the sample used in Model IV is not significant at less than a .05 significance level. The computed value of serial correlation (d) in Model IV, which is 2.1246, is greater than the critical value of d_u, which is 2.050 at a .05 significance level. Using the same criterion as the previous test, the null hypothesis that serial correlation in the sample is zero is accepted in the case of Model IV. For Models I, II, and III, the tests of serial correlation were inconclusive because the d value in each of the model lies between d_u and d_l which are 2.050 and less than .62, respectively. Therefore, Model IV is chosen as the best predictive model for the study.

Model IV assumes that operating cost, land, and capital are linearly related to the output of the dredge mines. However, the inclusion of land and capital factors in the model which are not significant at less than a .10 significance level does not improve the prediction accuracy of the model. Therefore they are omitted from the model without a great loss of efficiency. This means that the proposed model has only one predictor variable i.e., other operating costs. The strength of the coefficient of relation, R^2, of this model without land and capital factors is .93, which means the operating costs in the dredge mines' operation would be able to explain the variation of the outputs of the mines by 93 percent. Based on this, it is postulated that the relationship between the output and the cost of operation in dredge mines is as follows:

$$y = b_0 + b_{1(\text{operating})} + \text{error}$$

where y = output of the dredge mines

b_0 = the constant of the relationship

b_1 = the coefficient of operating costs

The coefficient of the constant is 440.39 and its standard error of estimate is 11.40, while the coefficient of operating cost is -.0216 and its standard error of estimate is .0034. Therefore, the research concludes that the predictive equation for estimating the output in the dredge mines in Malaysia is as follows:

$$\bar{y} = b_1 + b_1\ x_1 + \text{error}$$

where $\bar{y}$ = the estimates output of the dredge mines

x_1 = the known value of operating cost

$$\bar{y} = 440.39 - .0216\ x_1 + \text{error}$$

Gravelpump Mining

Extracting tin minerals by the gravelpump method is probably the most popular mining activity in Malaysia. This method is used largely in small individual operations. It has been characterized as a highly labor intensive operation and cheapest of the four major methods of extraction. It is the least efficient in terms of recovering the ore from the ground but the largest number of mines in the country are gravelpump mines.

In 1973 there were about 873 gravelpump mines. This number had increased to about 935 mines in 1974 and 1975. The number of gravelpump mines has fluctuated considerably. In 1982, (as shown in Table 10), there were only 521 gravelpump mines in the country, a decline of about 35 percent from 1973.

The yearly production of tin-in-concentrate from this type of mining operation remained the highest in the country. In 1973, the total production from gravelpump mines was about 39,000 tons, more than 50 percent of the total production of the country. In 1974 and 1975, the yearly production of these mines decreased to about 35,000 tons per year, and dropped further in 1976 and 1977 to about 30,000 tons annually. The production of the mines for 1978 to 1981 stabilized at about 33,000 tons per annum. At the end of the period studied, 1982, the total production of gravelpump mines for that year was only about 27,000 tons, a decrease of about 30 percent from production in 1973.

In the analysis of output of the sample used in this study, the average output of the mines from 1973 to 1982 does not shown a clear pattern. The cost of production on the other hand has increased steadily from year to year. Table 19 shows the average output and the costs of input of the sample mines from 1973 to 1982.

Table 19

Average Output and Costs of Input
Per Ton of Tin for the Sample of Gravelpump Mines
1973 to 1982
(In Tons & Malaysian Ringgits)*

Year	Average Output	Land	Labor	Capi- tal	Energy	Mate- rials	Taxes	Opera- ting	Total
1973	64	188	950	577	809	510	783	1143	4960
1974	53	425	1552	1471	1532	937	1841	1822	9580
1975	40	482	1760	1303	1826	1001	1650	1655	9677
1976	45	434	1804	1053	2071	1061	2343	1942	10687
1977	44	652	2218	1380	2219	1434	4095	2662	14660
1978	46	658	2938	1551	2550	1665	4557	3168	17087
1979	52	679	3263	1507	2740	1911	5301	4254	19663
1980	49	1244	4426	3304	3674	2359	5706	6337	27051
1981	60	649	5424	3623	4598	2403	3325	7609	27632
1982	66	433	4641	5004	4010	1919	2388	6448	24842
Means	52	584	2898	2077	2602	1520	3199	3704	16584
Std. Dev.	9	278	1507	1407	1181	638	1661	2329	8027

* Figures are rounded off and in constant value to 1982.

The average output of the sample gravelpump mines for the ten year period is 52 tons per year. The average annual output of gravelpump mines ranged from 40 to 66 tons from 1973 to 1982. In fact, the average output of the mines increased toward the later part of the period studied, while the costs of input have escalated rapidly from year to year. The total cost per ton of tin has increased from $4,960 in 1973 to $24,842 in 1982, an increase of about four-fold. This calls into question this study's general hypothesis that the costs of input are inversely related to the output of the mines. It seems rather that the increase in output of the mines is related to the increase in the costs of inputs. Another possibility is that the relationship between the two factors is not really linear.

The results of Pearson's Correlation tests which were performed to establish the magnitude of the relationship between the output of the mines and costs of input are shown in Table 20.

Table 20

Correlation Coefficients For Variables
In the Gravelpump Mines Analysis

	Output	Land	Labor	Capital	Energy	Materials	Taxes	Operating
Output	1.000							
Land	-.332*	1.000						
Labor	.331*	.574	1.000					
Capital	.497	.355*	.884	1.000				
Energy	.264*	.558	.990	.885	1.000			
Materials	.113*	.756	.954	.750	.943	1.000		
Taxes	-.308*	.867	.541	.232*	.518	.761	1.000	
Operating	.403*	.567	.992	.894	.976	.937	.511*	1.000

*Significance at more than a .10 t-value.

The results listed in Table 20 point out that output is significantly correlated with the cost of capital at less than a .10 significance level, with the coefficient of correlation of .497; while, land, labor, energy, materials, taxes and operating costs are not significantly correlated with the output. Another observation is that only land and taxes are inversely related to output; other factors are positively related to output. Based on these tests, the null hypotheses that there is no correlation between output of the mines and each individual cost of input, r = 0, is rejected only in the case of capital cost. However, the relationship between the variables was not strong enough to be able to create a good predictive model.

Since there is only one variable that correlates significantly with the output of the mines, a simple regression analysis was performed to establish the linear relationship between output and capital. The results of regression analysis show that the coefficient of relation, R^2, between the output and the cost of capital is .247 and significant at a .144 F-value.

Since the significance of the relationship is higher than a .10 F-value, the null hypothesis that the relationship between the output and the cost of capital is zero, $R^2 = 0$, is true. Therefore, the research concludes that there is no significant linear relationship between any of the input factors and the output of the sample mines.

In the attempt to create a predictive model for analyzing the output of the gravelpump mines, the study applied data transformation techniques. The data used in this study were transformed into ordinary log and log quadratic (x^2) equations on the dependent variables. Pearson's Correlation tests were again performed on these two newly transformed sets of data. The results of both tests show that output is significantly correlated with land at less than a .10 t-value. The nature of the correlation is inverse. (Note that in the earlier test, capital was significantly correlated with the output.) .

Based on this, a simple regression analysis of the cost of land and output was done. Simple regression analyses which were performed separately on these two sets of data show that the log linear relationships between output and the cost of land in both analyses are significant at a .20, F - value. Therefore, the research accepts the null-hypothesis of no relation between the variables and concludes that there is no significant linear relationship between the output of the gravelpump mine and the cost of land. This means the study could not create any predictive model for gravelpump mines since there is no proven relationship between the output of the mines and the costs of input factors in those mining operations. Some explanations will be offered in the next Chapter.

Opencast Mining

Opencast mining was not as popular as gravelpump mining in the early history of tin mining in Malaysia. This method of extraction calls for sophisticated techniques requiring skilled operators. It is considered the second best method after the dredging for recovering ore from the ground. The annual number of opencast mines in operation in the early 1970s remained quite stable at between 9 and 12 mines (as shown in Table 10). In 1978 the number of these mines had increased to 22. A significant increase in the number of opencast mines occurred in the 1980s. In 1981, there were 35 opencast mines and this number increased to 43 mines in 1982, the highest number of opencast mines ever in operation in the country.

Although the number of mines increased from 9 in 1973 to 43 in 1982, there was no increase in total production. Instead, yearly total production rates seemed to be declining during this ten year period. In 1973, total production from these mines was about 3,600 tons. The yearly production of the mines in 1974 and 1975 dropped to about 2,900 and 2,500 tons, respectively. Production declined further in 1976 and 1977 to about 2,200 tons annually. However, with the significant increase in the number of mines in 1978, the production increased to about 2,800 tons. Yearly production remained stable until 1981 when it dropped to 2,600 tons and remained there despite a sudden jump in the number of mines during 1981 and 1982. These figures indicate a decreasing trend in average output from opencast mines in the period studied.

A similar trend appeared in output analysis of the sample opencast mines used in this study. The average output of the opencast mines in the study's sample shows a considerable yearly decline, particularly in the 1980s, while, production costs rose correspondingly. Table 21 presents the average yearly output and the costs of input of the sample mines from 1973 to 1982.

The average output of the sample mines was not consistent in the 1970s. The highest average output of the mines, 819 tons, was in 1978. In 1980, average output plummeted more than a half from 1979's average. In 1982 the average output dropped further to about 251 tons, a decrease of nearly two-thirds from the average output of the mines in 1973, the beginning of the period studied.

On the other hand, the cost of production continued to increase steadily from year to year, except in 1978. The total cost of production climbed from $3,330 in 1973 to $19,719 in 1982. The highest production cost per ton of ore produced was recorded in 1981 at $20,349. For individual costs of input, however, no clear pattern appears. Some input factors, such as labor and taxes show a rapid fluctuation, while others, such as operating costs and energy show a more stable pattern of increase from year to year.

Table 21

Average Output and Costs of Input
Per Ton of Tin for the Sample of Opencast Mines
1973 to 1982
(In Tons & Malaysian Ringgits)*

Year	Average Output	Land	Labor	Capi-tal	Energy	Mate-rials	Taxes	Opera-ting	Total
1973	772	0	523	216	308	254	861	1169	3330
1974	690	0	824	147	313	492	1870	2240	5887
1975	765	5	3566	140	580	464	1643	2168	8566
1976	615	8	4581	133	768	711	2303	2461	10966
1977	674	0	4119	43	630	368	4037	2450	11657
1978	819	0	3140	26	430	311	4622	2411	10940
1979	797	0	2668	4	588	368	5333	3299	12261
1980	338	161	3363	529	876	1321	6495	4008	16752
1981	261	17	6251	2244	879	2304	3567	5087	20349
1982	251	187	2775	4621	1740	1619	2436	6341	19719
Means	258	38	810	3181	711	821	3317	3165	12043
Std. Dev.	241	72	1498	1683	416	693	1801	1560	5563

*Figures are rounded off and in constant value to 1982.

To search for cost factors that are related to the variation of the output of the mines, Pearson Correlation tests were performed on all the variables. The results show that labor and taxes are not significantly correlated with the output at less than a .10 significance level. The coefficients of correlation for all the variables are shown in Table 22.

However, the costs of land, capital, energy, materials, and operating proved to be significantly correlated with the output of the mines, at less than a .10 t-value. Their coefficients of correlation, r, range from -.79 to -.92. The cost of materials has the highest correlation with the output of the sample mines. Therefore, the null hypotheses of no correlation between the output of the mines and the individual costs of input, r = 0, at a .10 significance level, is true only in the case of labor and taxes. The research then concludes that land, capital, energy, materials and operating costs are significantly correlated with the output of the sample mines. The magnitude of the correlations proved to be inverse, as hypothesized.

Table 22

Correlation Coefficients For Variables In the Opencast Mines Analysis

	Output	Land	Labor	Capital	Energy	Materials	Taxes	Operating
Output	1.000							
Land	-.795	1.000						
Labor	-.382*	.018*	1.000					
Capital	-.849	.701	.197*	1.000				
Energy	-.841	.819	.344*	.900	1.000			
Materials	-.920	.561	.585	.750	.689	1.000		
Taxes	-.129*	.286*	.336*	-.118*	.106*	.172*	1.000	
Operating	-.882	.742	.431*	.884	.898	.855	.307*	1.000

*Significance at more than a .10 t-value.

Table 22 also shows that multicollinearities among the cost factors do exist. For instance, the cost of capital is correlated significantly at less than a .10 significance level with the costs of energy and operation. Therefore, in developing models for regression analysis, the multicollinearity problem will be eliminated at $r \geq .80$. As a result of this process, the research was able to develop three possible models where intercorrelation among the variables is eliminated. These models are as follows:

Model I: Output = $b_0 + b_{1(\text{land})} + b_{2(\text{capital})} + b_{3(\text{materials})}$ + error

Model II: Output = $b_0 + b_{1(\text{energy})} + b_{3(\text{materials})}$ + error

Model III: Output = $b_0 + b_{1(\text{land})} + b_{2(\text{operating})}$ + error

With the assumption that each individual cost factor in each model above is linearly related to the output of the mines, multiple-regression analyses were performed on each of the models. The results of the stepwise regression analysis are shown in Table 23.

Model I is possibly the strongest model for explaining the variances of the output of the mines. The value of coefficient of multiple determination of this model, R^2 is .966. Model III seemed to be less efficient. However, the inclusion of capital in Model I and land in Model III proved to be insignificant. The significance of F - test for both factors are higher than the acceptable criterion of this study. Therefore, these two factors are omitted from the models with no loss of efficiency of the model.

In selecting the best predictive model, the study performed Durbin-Watson tests on the results of those regression analyses. This test shows that the presence of serial correlation in the sample of Model II is not significant at less than a .05 significance level. The result of the tests for Model I and II was inconclusive because the d value lies between d_u and d_1. Therefore the null-hypotheses of no serial correlation in the sample, at a .05 significance level, is true only in Model II.

Table 23

Results of Multiple Regression Analysis
In the Opencast Mines Analysis

Model	Independent Variables	R^2	F Significance	d-value[f]	d-critical*
I	Materials	.8457	.00	1.9510	$d_u = 2.050$
	Land	.9590	.003		$d_l < .62$
	Capital	.9655	.331		
II	Materials	.8457	.00	2.2911	$d_u = 1.627$
	Energy	.9271	.02		$d_l < .82$
III	Operating	.7786	.02	1.6079	$d_u = 1.627$
	Land	.8222	.23		$d_l < .82$

f - Durbin-Watson d computed value of the regression analysis.
*- the critical values of d_u and d_l at a .05 significance level, where K = 4,3; T = 10.

Model II assumes that the cost of materials and energy is linearly related to the output of the mines. It is therefore postulated that the relationship between the output of opencast mines and the costs of materials and energy is as follows:

$$y = b_0 + b_{1(\text{material})} + b_{2(\text{energy})} + \text{error}$$

where y = output of the opencast mines

b_0 = the constant of the relationships

b_1 and b_2 = the coefficient of materials and energy

The coefficient of the constant (b_0) of the above model is 930.87 with a standard error of 48.19, while the coefficients of materials and energy are -.2257 with a standard error of .049 and -.2286 with a standard error of .082, respectively. The predictive equation proposed by this study for estimating the average output of the opencast mines in Malaysia is as follows:

$$\bar{y} = b_0 + b_1 x_1 + b_2 x_2 + \text{error}$$

where $\bar{y}$ = the estimates of the output

x_1 = the known value of the cost of materials

x_2 = the known value of the cost of energy

$$\bar{y} = 930.87 - 0.2257\ x_1 - 0.2286\ x_2 + \text{error}$$

Underground Mining

Underground mining in Malaysia is the least utilized of the four major methods. Underground extraction is not only very expensive involving a heavy capital outlay and sophisticated technology, but is also inappropriate for alluvial deposits which constitutes 95 percent of total tin deposits in Malaysia. From 1973 to 1982, there was only one underground mine in the country. The operation of this mine and its total output, compared to that of any other single mine is significantly more extensive. Since, the sample for the analysis of this method consists of only one mine, the actual instead of average output is considered.

The production of tin-in-concentrates from this mine from 1973 to 1982 has declined persistently from year to year. The increase in the costs of production has been equally steady. Table 24 shows the actual output and the costs of individual input factors in the underground mining operation from 1973 to 1982.

Table 24

Average Output and Costs of Input
Per Ton of Tin for the Underground Mine,
1973 to 1982
(In Tons & Malaysian Ringgits)*

Year	Average Output	Land	Labor	Capital	Energy	Materials	Taxes	Operating	Total
1973	1896	0	1855	177	522	398	690	368	4010
1974	1845	0	2389	314	661	905	1948	665	6882
1975	1559	0	3031	126	695	1177	1681	857	7567
1976	1477	0	3313	302	844	1382	3352	1057	10251
1977	1362	0	3800	341	9688	1582	4053	1160	20625
1978	1113	0	5306	612	1346	2243	4582	1514	15603
1979	999	0	6268	297	1681	2602	5280	1999	18129
1980	907	0	6705	583	2142	3203	5992	2647	22173
1981	791	0	10849	188	3472	4137	3605	2921	25173
1982	576	0	13797	329	5076	4854	2075	5239	31370
Means	1253	0	5821	327	2613	2249	3326	1843	16178
Std. Dev.	447	0	3919	100	2878	1452	1707	1457	8915

*Figures are rounded off and in constant value to 1982.

The output of the mine declined from 1,890 tons in 1973 to 576 tons in 1982; a set-back of more than 60 percent. The cost of production, on the other hand, shows an opposite trend. The total cost of production increased from $4,010 in 1973 to $31,370 per ton of output in 1982, an increase of seven-fold. Individual cost factors followed a similar pattern except land and energy factors. The cost of land from 1973 to 1982 is recorded as zero, because there were no land related expenses incurred. The land has been under lease to the company since 1950s, and expenses such as quit rents and land improvement programs, were lumped together as operating costs when the data were obtained by the Department of Mines. Sufficient information was not available to sort out the relevant costs; therefore, in this analysis, the land factor will be excluded.

In an attempt to establish the relationship between the output of the mine and the individual cost factors, the Pearson's Correlation test was performed on all the variables, except land. The results in Table 25 show that the costs of capital and energy are not significantly correlated with the output at a .10 t-value. Therefore the null hypotheses of no correlation between each input factor and the output, $r = 0$, are true in the cases of capital and energy costs. The research concludes that the costs of labor, materials, taxes, and operation are significantly related to the output of the mine. The value of coefficients of correlation for all these variables ranges from -.55 to -.96, proving that the relationships are inversely related.

Multicollinearity among the variables correlated with the output also proved to be high. Labor, materials and operating costs are highly correlated with each other. Therefore, by applying the same procedure to eliminate multicollinearity at $r \geq .80$, the study was able to develop three possible regression models for this type of mining operation. These models are:

Model I: Output = $b_0 + b_{1(\text{labor})} + b_{2(\text{taxes})}$ + error

Model II: Output = $b_0 + b_{1(\text{operating})} + b_{2(\text{taxes})}$ + error

Model III: Output = $b_2 + b_{1(\text{materials})} + b_{2(\text{taxes})}$ + error

Table 25

Correlation Coefficients For Variables
In the Underground Mine Analysis

Output	1.000						
Labor	-.927	1.000					
Capital	-.354*	.150*	1.000				
Energy	-.363*	.333*	.072*	1.000			
Materials	-.966	.988	.238*	.336*	1.000		
Taxes	-.555	.243*	.689	.202*	.380*	1.000	
Operating	-.8996	.977	.195*	.345*	.957	.210*	1.000
	Out- put	Labor	Capi- tal	Energy	Mate- rials	Taxes	Opera- ting

*Significance at more than a .10 t-value.

Again with the assumption that each individual cost factor in each model is linearly related to the output of the mine, a multiple-regression analysis was performed on each of the models. The result of the analysis is shown in Table 26.

All three models yield a very high coefficient of multiple determination, R^2, and significance at less than a .10 F - value. The inclusion of each independent variable in all the models also proved to be significant and contributed toward a better R^2. Therefore, the null hypotheses of no linear relationships between the output and the independent variables in each $R^2 = 0$ are accepted, in all cases. Therefore, the study concludes that there is a linear relationship of each of these input factors to the output of the mine.

Table 26

Results of Multiple Regression Analysis
In the Underground Mine Analysis

Model	Independent Variables	R^2	F Significance	d-value[f]	d-critical*
I	Labor	.8590	.00	2.8203	du = 1.6271
	Taxes	.9741	.00		dl < .82
II	Operation	.8093	.00	3.0222	du = 1.6271
	Taxes	.9490	.03		dl < .82
III	Materials	.9329	.00	2.8252	du = 1.6271
	Taxes	.9739	.01		dl < .82

f - Durbin-Watson d value of the regression.
* - critical d_u and d_l values at a .05 significance level, where K = 3, T = 10.

The tests of the presence of serial correlations in the results of the regression analyses of the models also proved that they are not significant because the value of computed d is greater than the value of d_u. Therefore, any of these models could be used as a predictive model. However, the study resorted to another criterion for selecting the best from the three models. All the models show a negative value of serial correlation, none of them significant, but the one nearest to zero serial correlation should be the best model. Zero negative serial correlation according to Ostrom (1978) is when the d value is approaching the d_u value; in this case, Model I possessed the least effect of negative serial correlation. Based on this criterion, Model I is selected as the predictive model for the underground mines.

Model I shows that the costs of labor and taxes are linearly related to the output of the mine, thus, it is postulated that the relationship between these variables is as follows:

$$y = b_0 + b_{1(labor)} + b_{2(taxes)} + \text{error}$$

where y = the output of the underground mine

b_0 = the constant of the relationship

b_1, b_2 = the coefficients of labor and taxes

The coefficient at the constant (b_0) is 2115.27 with a standard error of 62.28; the coefficient of labor is -0.09593 with a standard error of 0.00714; and the coefficient of taxes is -0.0915 with a standard error of 0.0164. Hence, the predictive equation for estimating the output of the underground mine in Malaysia is as follows:

$$\bar{y} = b_0 + b_1 x_1 + b_2 x_2$$

where $\bar{y}$ = the estimated value of output

x_1, x_2 = the known value of labor and taxes

$$\bar{y} = 2115.27 - 0.09593 x_1 - 0.09150 x_2 + \text{error}$$

Conclusion

Based on the results of the analysis, the study concludes that the output of the tin mining industry as a whole is related inversely to all input factors except capital. The tax factor proved to be the variable with the highest correlation to the output of the industry. This factor is also highly correlated with other input factors, but in constructing the best predictive model for this industry the use of this factor together with other input factors in a model proved to be less effective.

The research also proved that there is a difference in the nature of the relationship between each input factor and the output of the mines for each method of extraction. In dredge mines, all individual input factors except taxes are related inversely to the output of the mines. However, operating cost proved to be a better predictor variable in estimating the output of the mines. In gravelpump mines, even though only capital and land (after data transformation) were related to the output, the strengths of their relationships were insignificant; therefore, the construction of a predictive model was not possible. In opencast mines, only the costs of labor and taxes proved to be insignificantly related to the output; the rest of the input factors are related to the output. However, the costs of materials and energy proved to best predict the output of the opencast mines. In underground mines, with the exclusion of the land factor in the analysis, factors other than capital and energy were significantly related to the output of the mine. The cost of labor and taxes proved to be the best variables for explaining the variations of the output of the mine.

CHAPTER VI

PROJECTION OF THE OUTPUT AND FUTURE DEVELOPMENT OF THE TIN INDUSTRY IN MALAYSIA

Introduction

One of the objectives of this study is to create a model that reliably represents tin mining activity in Malaysia in respect to the amount of minerals to be produced by tin miners. In the last chapter, the study created various predictive models based on the observed relationships between certain input factors and the output of the sample mines. However, the study could not establish a strong and meaningful relationship between any of the input factors and the output of the gravelpump mines, therefore, there was no predictive model developed for this type of mining activity.

One of the purposes of this chapter is to test the reliability of those models against a real situation, particularly non-sample mines. This test serves two purposes. One, it makes use of the models to forecast the outcome of the dependent variable where the values of some independent variables are known. Two, it evaluates the accuracy of the forecast by comparing the outcomes of the forecasts with the actual data on the output of the mines. The predictive equations developed earlier in this study are utilized in this phase.

It is the purpose of this chapter also to discuss the rising cost of production in relation to other related problems in the industry. In doing this, the focus is centered on the implications existing governmental policies have on the cost of production as well as on the production of the industry as a whole.

As shown in the previous analyses, different methods of mining operation produce difference levels of output, and the choice of mining method affects the relationship between output and input factors. Therefore, this chapter also intends to discuss the effects of technological choice on the level of output specifically, and on the industry, in general.

This chapter will first address the problems of application of the models for projection, and reliability of those models, then, discuss the implications of various governmental policies on the tin mining industry and finally address the issue of technological choice in the industry.

The Application of the Models for Forecasting

The main purpose of creating predictive models in this study is to forecast the output of the mines in the future. The models developed in this study were based on data collected from a set of sample mines; therefore, they obviously reflect only the nature of the data and the samples they represent. However, through inductive processes, certain generalizations could be made applicable to mines outside the samples. This is what this study intends to do.

A 'forecast' in this study is defined as the attempt to make scientific statements about a non-sample situation on the basis of the relationships determined from sample observation (Klein, 1971). The principle goal in this attempt is to extrapolate beyond the confines of the sample and thereby make generalizations to a non-sample situation. Forecasts of this type have at least two distinct uses. First, they can be used to evaluate the models whose parameters have been estimated earlier. Second, a forecast can be used to make inferences concerning the policy implications of certain type of changes expected to affect the dependent and independent variables of the models.

In applying the models for forecasting, certain requirements must be met. One of the most important ones is that the value of the parameters in the models must reflect the true value of the population. Although this requirement is probably not fullfilled in the case of the model for the industry, for the purpose of projection, it is, assumed that this requirement is met in the construction of all the models.

Another important requirement is that the model's parameter be stable because the reliability of the model depends on the accuracy of the parameters. The accuracy of the parameters, in turn, depends on their stability over time. In reality the value of the parameters would change over time, but for the purpose of this projection, it is assumed that they are stable, at least for the duration of the projection period.

Within these limitations, the proposed predictive models are tested to forecast the output of the industry, as well as the output of the dredge, opencast and underground mines, for 1983. Data on the actual output of the mines in Malaysia for 1983 were recently obtained from the latest Economic Reports issued by the Treasury of Malaysia (LE, 1983/84). These data will be used to compare to the results of the forecasts.

There are two ways to compare the actual production and the forecast production of the mines for 1983. One is to average the output of the mines. The figures generated by the application of the models are the average output of the mines. Therefore, in this case, the actual total production for 1983 is divided by the number of mines in order to be compared to the results of the forecast. The second way is to take the total output of the mines. This can be done by multiplying the figures derived from the forecasts by the number of mines in 1983 to get the estimated total output of the mines and comparing this with the actual data. Each has its own significance. The study uses both ways.

The data for 1983 show that the number of mines in the country has decreased to 568 from 608 in 1982. The total production of all the mines in Malaysia for 1983 was about 41,000 tons, an average output of 72.2 tons per mine irrespective of the method of extraction. Of those mines, 42 were dredge mines which produced about 13,000 tons of tin in 1983; that is an average output of 309.5 tons per mine. The 458 gravelpump mines in 1983 produced about 21,000 tons of tin, an average output of 45.9 tons per mine. The 40 opencast mines in 1983 produced about 5,500 tons of tin, an average output of 137.5 tons. The mines using other methods of extraction produced about 1,000 tons of tin in that year. The results of the forecast will be compared to these data.

The discussions in this section are presented in two phases: the industry and the methods of mining operation.

Forecast: Output of the Industry for 1983

The model which has been constructed to predict the output of the industry is comprised of a single predictor variable, namely the tax factor which shows a relationship to variance in the output of the sample mines for the industry. The strength of the linear relationship between these two variables was .60, meaning that the use of the tax factor in explaining the output of the mines accounts for only 60 percent of the variations. Assuming that other factors are constant or have no effect on the output, the output of the industry can be predicted from the variations in the taxes. Other variations in the output should be explained by other factors.

The regression equation generated for the model is as follows:

$$\begin{aligned} \bar{y} &= b_0 + b_1 \text{ (taxes)} \\ &= 218.16 - 0.0267 \text{ (taxes)} \\ & \quad\ (27.80) \quad (.0078) \end{aligned}$$

The figures in the parentheses are the standard error of b_0 (constant) and b_1 (coefficient of taxes).

The estimated value of output ($\bar{y}$) can be calculated if the value of taxes is known. Since there are no exact data available on the amount of taxes paid by the mining operators in 1983, the study has to resort to estimating the value of taxes. This requires selected information.

One of the most important pieces of information is the changes in taxation policy in 1983 on the amount of taxes to be paid by mining operators. Other important information required to estimate the value of taxes is the current price of tin in 1983. This information is important because the quantum of tax is calculated on the price of the commodity. As discussed in Chapter III, if the price goes up the amount of tax to be paid by the operator will rise correspondingly. Other information required is the average cost of production for 1983.

Examination of the government's budget for 1983 shows that there was no change in the tax policy that could have an impact on the amount of taxes to be paid by mining operators. In fact, the same tax structure, as it applied to the mining industry in 1981 has prevailed throughout 1983. Since there is no indication of changes in tax structure, the research assumes a similar procedure was followed in calculating the quantum of tax for 1983.

Information on the cost of production for 1983 was not available. Therefore, the study makes inferences from the price factor in 1983, which is available, of the amount of taxes to have been paid by the operators. In this case, the amount of taxes paid by the operators in 1982 in comparison to the price of tin for that year will be used as the base. The amount of taxes paid in 1982 was about $2,322 per ton of ore produced; this was based on the price of tin of $30,150 per ton for that year. The price of tin in 1983 went up to about $31,000 per ton, an increase of 2.8 percent compared to that of 1982. By the same token, the tax quantum should increase proportionately. If this assumption is correct, the amount of taxes paid for every ton of ore produced in 1983 would be $2,972.

The insertion of this value in the regression equation above, yields the point estimation value of the average output of the mines for 1983 as 138.8 tons per mine. Taking into consideration the error terms in the parameters of the equation, 27.8 for the constant and .008 for the coefficient of the tax factor, the estimated value of the average output of the mines in 1983 falls between the range of 87.8 and 189.8 tons per mine. The difference between this value and the data for 1983 where the average output of the mines was only 71.2 tons is great. In fact, it falls outside the range of the forecast values.

If this result is used to estimate the total production of the industry, then, the only information required is the number of mines in the industry. Given the number of mines in 1983 was 568, the forecast total production of the industry would fall between the range of 107,000 and 50,000 tons. The point estimation was 79,000 tons. The result still falls outside the forecast range.

The most obvious explanation for the discrepancy between the forecast value and the actual value of the output of the industry for 1983 is probably due to sampling errors in the study. As said earlier, the construction of the predictive model for the industry is based on aggregated data derived from samples of various methods of mining, biased in number towards dredge, opencast, and underground mines, while under representing gravelpump mines. This is evident in the analysis where the average output of the sample mines is much higher than the average output of the total mines in the country. For instance, the average output of the sample mines for 1982 was 274 tons, while the average total output for that year was only 86 tons. Therefore, the use of this model reflects the bias towards samples which were strongly represented.

The other reason for the discrepancy is the weakness of the model itself with only 60 percent predictive accuracy. In other words, the model constructed to represent the industry was not based on a strong relationship between the variables. This is clearly evident in the analysis where the only input factor that correlated with the output of the industry was the tax factor, while the tax factor in other analyses (analyses on the output of mines according to method of operation) never showed a strong relationship to the output, except in underground mines where a weak relationship was evident.

Had the model been based on a sampling procedure which accurately represented the industry, the predictive ability of the model would have been better. But this was not possible because of the way the survey data were aggregated. However, the distortion factor in the model is explained by the inclusion of data on the gravelpump mines. Probably, if these data were taken out, the model would be more reliable.

Based on this finding, the research concludes that the predictive model for the industry which was constructed on the basis of the relationships determined from sample observation could not be generalized accurately to the non-sample mines. The application of this model to forecasting presents a misleading conclusion.

Forecast: Outputs of the Mines According to Methods of Extraction

The study has shown in the last chapter that method of operation causes not only variation in the output of the mines but also generates a different kind of relationship between output and input factors. This has caused the study to develop a separate predictive model for each method of mining based on the relationships determined from sample observations in each method. The reliability of those models is tested by the same procedure used in the evaluation of the model for industry.

Output of the Dredge Mines

The model which has been constructed to predict the output of the dredge mines in Malaysia is comprised of a single predictor variable, called "other operating costs." It was these costs that varies the most in relation to the output of the mines. The strength of the relationship between these two variables was .93, meaning that 93 percent of the variation in the output of the mines could be accurately explained by these costs. Assuming other factors remain constant, or have no effect on output, the output of dredge mines can be predicted from variation in these costs. Other variations in output should be explained by other factors.

The regression equation developed by the model is as follows:

$$\begin{aligned} \bar{y} &= b_0 + b_1 \text{ (Operating)} \\ &= \underset{(11.4)}{440.4} - \underset{(.003)}{0.0217} \text{ (Operating)} \end{aligned}$$

The figures in the parentheses are the standard errors of b_0 (constant) and b_1 (coefficient of operating cost).

The estimated value of output ($\bar{y}$) could be calculated if the value of operating cost is known. The real operating cost paid by dredge operators in 1983 is not known, therefore the study has to estimate the value of this factor. Various items such as transportation costs, insurance charges, smelting fees, tributes to the land owner and other operating costs constitute this cost factor (see Chapter IV); therefore, a close examination of each of these items must be done in order to arrive at a reasonable estimate of these costs. This was not possible due to a lack of data for 1983. However, a reasonable estimate can be arrived at by looking at the consumer price index for some items which fall under the category of these costs. The consumer price indexes for transportation charges, maintenance charges for durable goods, and charges for other services which actually make up the major portion of these costs in dredge mining showed an increase of 3.1 percent in 1983 compared to the base year, 1982 (LE, 1983/84). These other operating costs of dredge mining should increase proportionately. If this assumption is correct, then the estimated other operating costs is $5,722 per ton of ore produced in 1983 compared to $5,550 in 1982.

The insertion of this value in the above equation yields a point estimation of the average output of dredge mines of 315.2 tons per mine. Taking into consideration the standard errors of the parameters of the model, 11.4 for the constant and .003 for the coefficient of operating cost, the range of the average output of the mines for 1983 was between 305 and 327 tons per mine. The actual average production of dredge mines in 1983 was 309.5; which means that the forecast average output of the dredge mines falls within the range. Calculating from the number of dredge mines in 1983, 42, then the forecast total output of the mines falls between 12,900 and 13,700. The actual total output of the mines was 13,000 tons. The point estimate for total output is 13,280 tons, 280 tons is excess.

Although the result of the forecast was not accurate on a point to point basis, the estimated value falls well within range. Based on this finding, the study concludes that the predictive model is reliable for forecasting purposes. This also means that observations on the sample mines used in this study can be generalized to non-sample situations.

The success of the predictive model is a result of the accurate population representation of the samples.

A Note on the Model for Gravelpump Mines

The result of the analysis on the data collected from samples of gravelpump mines showed that only capital cost was related to the output of the sample mines. But the relationship between those two variables was not strong enough to construct a linear predictive model for the mines. Similar results were derived from the analysis of the transformed data, i.e. a significant linear relationship even in the form of logarithm, did not exist between the output of the mines and any of the input factors. Why there were none is an important question.

One of the answers lies in the nature of gravelpump mining which is different from other types of mining operation. Gravelpump mining relies heavily on traditional, Chinese small-scale operations which are energy oriented in technique and labor intensive. Coupled with this is the fact that many of the gravelpump mines are operated on the dredge-out-areas where there is greater risk of discovering left over ores, which are not really dependent on the productivity of the input factors. The theory that the more input in the production process, the more ore recovered may not work in this situation. It may occur that much ore is recovered with little input, or vice versa. If this is true, then the output of the mines does not necessarily depend on the costs of input factors; output many depend on other factors, such as production quotas, prices of the minerals and the availability of ores in the dredge-out-areas, etc. Therefore, the hypothesis that the output of the mines is related to the costs of input factors was not true in the case of gravelpump mines.

The other answer to the question lies in the nature of the samples of the mines used in this study. Because there is a big difference between gravelpump mines, probably a bigger sample is needed in order to be really representative.

The quality of the data from the sample mines themselves is probably another reason for the sampling error. As said earlier, gravelpump mining is generally operated by small scale less-organized firms and in many cases the operator is not subject to public scrutiny; therefore, there is a tendency to neglect record keeping in the firms, as well as to purposely manipulate the data reported to the authority. It seems the data on the actual output of the gravelpump mines were under reported. According to Mr. Hew See Tong from the All-Malaya Chinese Mining Association, the operators of the gravelpump mines managed to sell only 55 percent of production (NST, January 1984). The data reported by the miners may have been only the amount of ore that they have sold, rather than the amount of ore they produced.

Another reason for under reporting the actual amount of output of the mines could be related to the increase in smuggling of tin activities in the country. A special task-force was sent by the ITC in 1983 to study the smuggling activity in South East Asia. The ITC suspected that smaller operators who are not properly accountable to any public bodies smuggle out their products to avoid the heavy taxes levied on the export of tin in the county (NST, January 1984). If their suspicions are true, the figures for gravelpump mining data are not accurate or useful for any purpose.

Had the data reflected reality, this study would conclude that the nature of gravelpump mining is not so different from other types of mining operation. Perhaps there are some input factors which relate to the output of the mines as anticipated by the general hypothesis of the study.

Output of the Opencast Mines

In the analysis of the output of the opencast mines in the last Chapter, the study found that the costs of materials and energy were strongly related to the output of the mines. Based on this observation, the study has constructed a predictive model comprised of these two factors as predictor variables. The strength of the multiple relationship between these two factors (together) and the output of the opencast mines was .93. This means the variation in the output of the mines could be explained by these two input factors as strongly as 93 percent of the variations. Incidently, the strength of this model is equal to that of the model for the dredge mines. Assuming other factors remain constant or have no effect on the output, the output of opencast mines can be predicted by knowing the variations in the costs of materials and energy used by the mines. Other variations will be explained by other factors.

The regression equation of the predictive model was as follows:

$$\bar{y} = b_0 + b_1 \text{ (materials)} + b_2 \text{ (energy)}$$

$$= 930.8 - 0.2257 \text{ (materials)} - 0.2286 \text{ (energy)}$$

$$(48.19) \quad (.049) \qquad\qquad (.082)$$

Figures in the parentheses are the standard errors of b_0 (constant), b_1 (coefficient of materials) and b_2 (coefficient of energy).

Based on the above equation, the value of estimated output ($\overline{y}$) can be calculated if the costs of materials and/or energy are known. The actual costs of materials and energy in the operation of the opencast mines for 1983 are not known, therefore, they have to be estimated. Various information is required in order to estimate how much opencast mining operators paid for these two factors in 1983. A thorough examination of items that made up each of the input factors needs to be done. This is not possible due to lack of data. However, consumer price indexes for 1983 have helped this study to roughly estimate the costs paid by those mining operators. The consumer price index for semi-durable goods (materials used in this type of mining operation) in 1983 has gone up by an average of 2.9 percent compared to their prices in 1982 (LE, 1983/84). Therefore, the cost of materials in opencast mining operations for 1983 is estimated as $1,666 per ton of ore produced compared to $1,619 in 1982.

The cost of energy is much simpler to estimate because energy prices were controlled by the government. Electricity, gas, and fuel-oil, constitute energy costs; therefore, the increase in the prices of these items affected the increased energy cost in mining operation. In 1983, the prices of these items have increased by an average of 5.5 percent from 1982's prices (LE, 1983/84). Therefore, taking 1982 as the base, the cost of energy in the mining operation for 1983 is estimated to increase to $1,836 per ton of ore produced from $1,740 in 1982.

Inserting these values in the above equation yields a value of point estimate average output of the opencast mines of 135.2. Given the standard errors of estimate for the constant as 48.19 and for the two variables as .049 and .982, the predicted average output of the mines would therefore range from 180 to 90 tons per mine. From 1983 data, the actual average output of the opencast mines was 137.5 tons, therefore, the result of the point estimate is closer to the actual average of the output which is only about 2 tons above the forecast value.

Using the forecast to estimate the total output of the opencast mines, i.e. by multiplying it with the number of mines in 1983 which was 40, will give a point estimated total output of 5,400 tons. The actual total output of these mines in 1983 was about 5,500 tons. The range forecast was between 7,300 and 3,500 tons, thus the result of the forecast is well within the range.

Based on these findings, the study concludes that the predictive model proposed for estimating the outputs of the opencast mines by using the costs of materials and energy factors is reliable. The observations made on the sample mines could also be generalized to the nature of the non-sample opencast mines. These conclusions are possible because the sample used in the study accurately represents the true value of the population.

Output of the Underground Mine

Analysis of the output of the only underground tin mine in Malaysia in the previous chapter showed that the costs of labor and taxes were strongly related to the output of the mine. The costs of labor and taxes have proved to be the best predictor variables for estimating the output of the mine. The strength of the relationships between these two factors and the output of the mine was .97, which is almost perfect. This means the model should be able to explain 97 percent of the variation in the output of the mine. Assuming that other factors remain constant or have no effect on the output, the output of this mine can be predicted from variations in these two costs. If the same trend persist as has been evident the last ten years, the model is expected to work very well.

The regression equation off the model was as follows:

$$\begin{aligned}\bar{y} &= b_0 + b_1 \text{ (labor)} + b_2 \text{ (taxes)} \\ &= \underset{(65.28)}{2115.29} - \underset{(.007)}{0.0959} \text{ (labor)} - \underset{(.016)}{0.0915} \text{ (taxes)}\end{aligned}$$

The figures in the parentheses are the standard errors of b_0 (constant), b_1 (coefficient of labor) and b_2 (coefficient of taxes).

The equation above will give the estimated value of the output of the mine ($\bar{y}$) if the values of the costs of labor and/or taxes are known. Therefore, in estimating the output of the mine in 1983, the data on the costs of labor and taxes paid by the operators of the mine must be obtained. Due to the absence of actual the study has to resort to estimating them from certain available information.

For the amount of taxes estimated paid by the miners in 1983, the study uses the same procedure as it did in estimating the taxes for the industry earlier on. Based on this procedure, the amount of taxes paid by mining operators was estimated to increase by 2.8 percent in 1983 from that in 1982. Therefore, the estimated value of taxes is $2,656 per ton of ore produced compared to $2,075 in 1982.

Although the above equation can be solved with tax value data, the study would rather estimate the cost of labor before calculating the estimated value of the output. This is because there is information available for the study to make a good estimate of the cost of labor for 1983. Based on the consumer price index for 1983, the cost of labor, specifically for the mining sector, has increased by about 8 percent compared to the base year of 1982. Thus the cost of labor in 1983 is an estimated $14,900 compared to $13,797 paid in 1982 for one ton of ore produced.

Assuming those estimated figures are correct, then by inserting them in the above equation, the value of point estimated output of the underground mine in 1983 can be obtained as 445 tons. Taking into consideration the standard errors of estimate in the equation, the output of the mine for 1983 is estimated to range between 510 to 380 tons. The actual output of the mine for 1983 was about 500 tons. Thus the forecast output is within the range of the estimated value.

Based on this finding, the study concludes that the proposed predictive model for the underground mine is reliable for purposes of forecasting. It is important to note here that this model was constructed from data from one mine, in fact, the only mine of this kind in Malaysia. Therefore, generalizations of the model to the non-sample mines of this type cannot be done.

The Implications of Existing Mining-Related Policies

In the previous chapter and in the last section of this chapter, the study shows how changes in the costs of certain input factors and taxes have affected the levels of production at both the industry level and mine levels. In this section, the matter of how changes in the level of production are expected to occur as a result of the implementation of certain existing government policies is discussed. Some of those policies may have certain impacts on the level of production directly or on the costs of certain input factors which consequently affect the level of production. Due to the limitation of this study, a complete discussion on the whole spectrum of policy implications is not possible; the study instead, will select only those policies which are directly relevant to this issue. For the purposes of clarification, the study will first describe the nature of the existing mining related policies.

The Mining-Related Policies

The government has no tin mining policy as such; however, there are a number of policies which by implication govern tin mining activities in the country. This is the reason why the term "mining-related policies" is used instead of "tin mining policies."

From discussions with some interested parties on this subject, it is clear that a tin mining policy can mean different things to different people. To the mining operators, it might mean fiscal incentives such as fuel and power subsidies, tax concessions and lower export duty; to the environmentalist it might mean rigid controls on mining operations so as to preclude the slightest possibility of damage to the environment; to the government planner it might mean maximizing revenue collected from mining; and so on. Although tin mining has been carried out in Malaysia for hundreds of years, until now there has been no policy comprehensive enough to govern such diverse interests.

However, from the point of view of general socio-economic development it is very clear that the emphasis has shifted from heavy reliance on tin mining to alternative mineral exploitations in the country, such as oil, copper and others. In this light, the Malaysian government has adopted a policy that mineral resources of the country should be exploited for the benefit of the country as a whole, rather than be regarded as unrestricted private property. As a general guideline to this broad policy, it was further stated that a higher value should be added if possible to the mineral resources before they are exported (FMP, 1981).

In order to achieve the objective of those policies the government has employed various policy instruments, such as taxes, subsidy and incentive programs, regulation and procedures, and even increased various direct and indirect government participation in the mining enterprises. Some of those policies are temporary in nature, such as production quotas and new land leases freezes. Those measures have certain implications on the industry, but the main concern of this study is those policies which are permanent in nature.

These policies have numerous implications for the mining industry, as well as for the economy of the country as a whole. This section examines some of those implications in the context of the tin mining industry.

The Taxation Policy

As described in Chapter III, the tin mining industry is probably the only industry in the country which has been taxed heavily. There are eight kinds of taxes levied on this industry. About 70 percent of the profits from this industry go to taxes. Among the highest of these taxes are the royalties, export duty and surcharges imposed on exportation of tin-in-concentrates. These direct taxes are normally called realization taxes. These taxes have been considered in this study as expenses which the mining operators have to pay in order to export the final products. The study has also determined the relationships between these expenses and the amount of ore extracted by the tin miners. At the industry level, the study has concluded that the higher the taxes imposed, the lower the production of the industry.

Although other indirect taxes imposed on this industry may have a similar impact on the output level of the industry, this study limits its discussion to the implications of the direct taxes. The existing cost-plus taxation policy specified certain amounts of taxes to be paid when minerals are exported. The formula for determining these amounts is based on prevailing tin prices and the average cost of production in gravelpump mining operations. This policy has many implications for the production of tin in the country.

First, not imposing any tax burden on the production of the mines until a market price is reached which exceeds the assessed average cost of production yields one important benefit: the miners will not be taxed if tin prices fall below $19,800 per ton. The spirit of this policy intends to lessen the tax burden on the marginal tin miners. This policy worked rather well in early 1980 when tin prices were around $30,000 per ton, but when tin prices shot up around $35,000 per ton towards the later part of that year, the burden of taxes was strongly felt by the miners. They, in fact had to pay even more taxes than what they had paid before. This kind of tax arrangement has aroused dissatisfaction among the miners. They also claim that the existing taxation policy, especially when tin prices are high, has deprived them of an opportunity to mine lower cut-off grade deposits, to increase the total tonnage mineable, to prolong the life of the mine and ultimately to increase total national revenue (COM, 1983). As a result of this, the miners in fact would be better off selecting higher cut-off grade deposits, leaving the lower cut-off grade deposits untapped. This could hinder the development of those lower grade deposits which might be even more costly to exploit in the future.

Secondly, the calculation of export duty under the existing taxation policy was supposedly to have no direct impact on the economic evaluation of marginal resources, so that those resources could be effectively exploited together with the higher grade deposits. But the existing policy, which necessarily involves computation of the average cost of production, in fact implies that marginal reserves still be rendered uneconomic by considering the tax factor in the overall cost of production. For example, if the ruling tin price is $33,000 per ton, the assumed duty will be $5,734, leaving a net price of $27,266 per ton after duty is deducted. This net price is actually a devaluation of the value of the reserves of tin. In the case of marginal areas of tin reserves, the resource will become uneconomical if costs of production are at or above this level. What can happen, of course, is that average recovery rates will be depressed, because it is not economical to install machinery to extract all the tin available. Therefore, while this cost-plus taxation structure in principle, appears to advocate the devaluation of resources, in practice, the fact that an average unit production cost must be calculated in order to apply this structure may prejudice the development or complete exploitation of reserves.

Thirdly, the policy of employing gravelpump average cost figures as the basis for determining the average cost of production in the calculation of taxes is not really the best procedure. The study was not based on a well-researched sample and the figure obtained could be subject to potentially significant margins of error (Scott, 1980). This study also concurred with Scott's finding, where the data collected by the Department of Mines on the sample of gravelpump mines were found to be of little use and believed to contain distortions. Therefore, reliance on these data for policy formulation is not appropriate. Because of the diverse nature of mining in Malaysia, the use of an average cost of production based on only one method may not be relevant to the mines which fall into the above-average cost category.

Fourth, under the existing taxation policy, a uniformity of taxation is imposed on the output of mines irrespective of tin content. For the purpose of export duty, all tin-in-concentrates are assumed to assay at 75 percent tin metal. This assumption implies that duty is paid at the same rate for any products less than 70 percent S_n as export duty is based on the weight of tin concentrate regardless of tin content. It appears that application of duty on this basis unduly penalizes those sectors of the industry which find the cost of extracting a 75 percent tin metal product excessive. This is typically the case in underground mining and hard-rock opencast mining which only produces a product containing less than 70 percent tin. Yet this sector is subject to the same duty as other sectors of the industry more readily able to produce concentrates of 75 percent (or above) tin metal.

Last but not least, the tax rates under the existing policy are not comparable to those of Thailand and Singapore. Export duty in Malaysia is much higher than that in Singapore and much lower than that in Thailand. This has caused difficulty in implementing this policy, because it encourages tax evasion. One of the effects of this was increased smuggling activity -- tin concentrates are smuggled into Malaysia from Thailand and smuggled out to Singapore from Malaysia -- in order to avoid the heavy taxes in Malaysia and Thailand. This not only effects a loss in revenues to the governments, but also a distortion in the industry and world market.

If the existing taxation policy continues, the future of the tin mining industry will be affected adversely. The recovery in tin prices would not help the tin miners. It may also hinder the efficient development of resources, particularly those reserve areas of the marginal deposits.

Subsidy and Other Incentive Programs

While the government imposes various taxes on tin mining activities, it has also provides various subsidy and incentive programs to aid the development of this industry. Those programs range from direct assistance such as subsidizing the cost of diesel to less direct assistance such as contributing to ITC buffer-stock funds for the purpose of stabilizing tin prices. The magnitude of all those programs on the tin industry is considerable but the focus of this paper centers only on the most recent changes in some of those programs.

One of those incentive programs which has a direct effect on the future of the tin mining industry is the tax allowances for some input in the mining operations. Reducing, and in some cases exempting from import taxes on some equipment and materials was in fact a great help in cutting down the cost of production. By placing some of the mining materials, such as spare parts, cement, etc. under price controls was yet another assistance extended by the government to the miners. Above all, the direct energy subsidy program was really important in aiding this industry because energy is one of the major inputs in mining operations.

Two kinds of energy is used in mining: one is electrical power, the other is diesel-generated power. The importance of energy in the mining operation differs considerably from one method to another. Electrical power is usually used in a big mining operation such as dredging and underground mining. Because it is comparatively cheaper than diesel-generated power, that portion of energy cost out of total production cost is not so significant. But in a smaller mining operation such as gravelpump and opencast, where diesel-generated power is mainly used, that portion of energy cost out of the total production cost is usually very significant. The study has also shown that energy cost, particularly in the opencast mining operation, has a strong relationship to the output of the mines. Therefore changes in the cost of energy will definitely affect the level of output of the mines.

Realizing the significant increase in the price of energy, particularly diesel in the beginning of 1974, the government instituted a subsidy program to reduce the burden of increased energy costs. This program covered both electricity and diesel costs. A two-tier price system was introduced on both sources of power. The subsidy program for diesel alone has cost the government nearly $75 million a year. As a result of this, the energy cost to mining operation was not increased, but as world prices rose toward the later part of the 1970s, the cost of energy, particularly in diesel-oriented mining, went up considerably. Therefore, many diesel-powered gravelpump mines have been shut down.

The recent change in government policy which could have an even more devastating effect on energy costs was the withdrawal of diesel subsidies. In the early part of this year, 1984, the government announced the withdrawal of this program. Three reasons were given for the withdrawal. First, the government felt that the true beneficiaries of this subsidy program were not really the target group, i.e. the poor. Miners are the rich in the country. Second, the government can no longer afford this subsidy. The withdrawal of this program will save the government more than $500 million in the next five years. Lastly, the price of diesel on the world market has gone down, therefore subsidy is no longer necessary (NST, January 1984). This new policy will certainly impact, not only on the production of the mines, but also on the structure of the industry itself.

The change in diesel price will definitely alter the cost structure in the mining operation. This is because the increase in the price of diesel even by 5 cents per gallon (i.e. without the subsidy program) would mean a significant increase in the total production cost of diesel-oriented mining. The most affected sectors of the industry will be the gravelpump and opencast mining. Historically, the cost of diesel in these sectors of mining would constitute about 30 percent of the total production cost. An increase in this cost will force more marginal mines to be closed. These sectors of the industry have contributed more than 60 percent of the total production; the closing of those marginal mines will reduce the total production of tin in the country.

The increase in production costs resulting from the withdrawal of the subsidy program will create an effect similar to that of the increase in taxes on the value of the marginal reserves of tin in the country.

Another implication of this new policy is an increase in the use of electricity in mining operation. This will lead to a change in the structure of the industry. In order to use electricity in the mining operation, bigger and more powerful equipment is needed. Therefore, traditional opencast and gravelpump mines which are small-scale in nature will have to give way to newer equipment and probably bigger scale operations such as dredging. Since, the technological level is still inadequate for the operation of more sophisticated mining machinery, dependence on foreign technology is inevitable. Furthermore, it is neither practical nor possible for all the mines, particularly the small-scale gravelpump operations, to use electricity because of inadequate electricity supply and mining machinery, at present.

Equity Participation Policy

In striving to fully exploit natural resources for the benefit of the country as a whole, the government of Malaysia has employed the measure of equity participation. Equity participation was initiated with the implementation of the New Economic Policy which covers a period from 1970 to 1990. Among other things, this policy aims at restructuring equity participation in all enterprises to reflect the racial composition of the country. Tin mining enterprises which were traditionally controlled by foreigners are among the sectors most affected by this policy.

Equity participation in tin mining enterprises takes various forms, such as:

1. An increase in control over foreign owned mining, through restructuring the companies or taking over those companies, as in the case of the Malaysian Mining Corporation.
2. An increase in the participation of indigenous people in the existing companies or in the formation of new companies.
3. Direct participation of the government in tin mining activities, either on the basis of a joint venture or state owned operation, as in the case of Kumpulan Peransang Selangor.

The implications of these policies for the production of tin are great. First, the restructuring or taking over of foreign mining companies could create an unhealthy investment climate in the country which may be counter productive to foreign investment. This will not only result in the driving away of existing foreign capital in the country, but also it may discourage the transfer of mining technology to the local people. The lack of local capital and technology especially in more sophisticated mining operations will definitely affect the productivity of the industry.

Secondly, the participation of indigenous people in tin mining enterprises either on their own or in joint-venture with foreigners or other local Malaysian would not necessarily contribute toward the betterment of the industry itself. The lack of capital and expertise among the indigenous people could lead to disaster. At best, the indigenous people would be able to participate in gravelpump mining which by nature is riskier than other methods of operation. The Malay Chamber of Mines has revealed that comparatively indigenous mines were less productive than other mines in the country. Although ownership of the mines may have no relationship to productivity, inadequate management makes a difference.

Thirdly, the participation of the state either directly or indirectly could create unnecessary bureaucratic ties to the mining operation. More often than not rigid bureaucratic procedures in state owned mining operations have out weighted efficiency criteria in the operation. This will certainly affect the productivity of the mines concerned. Although the involvement of the state would mean an increase in capital investment in the industry which otherwise would be lower it also implies that there is a tendency to encourage capital intensive and large-scale enterprises in the industry. This may be good for production, but it also increases competition with small-operators, particularly indigenous miners whom tend to lose the most in the process.

The implementation of the equity participation policy varies in nature from state to state because mining is essentially a state prerogative. In an extreme case, the Selangor State Government has declared a very explicit policy towards equity participation in mining operations. In this State, all applications for new mining land made by foreign or majority foreign-owned companies must go through a joint-venture proposal with the Kumpulan Peransang Selangor which will hold 70 percent equity. Application for new land by local companies for areas in excess of 500 acres must be made on a joint-venture basis also with the Kumpulan Peransang Selangor holding 51 percent equity. For lease renewal applications, the state will issue the leases to the Kumpulan Peransang Selangor which in turn sub-leases to the original owners and any other miners working the land. This arrangement will certainly increase the cost of production, because the sub-leasee has to pay certain tributes to the leasor. In essence, the policy implies that mining leases will no longer be issued to the private sector, and the clear intention of the policy is to ensure the state government a greater share of the benefits arising from an exhaustible resource (Scott, 1980).

In this particular case, the policy definitely serves to constrain the development of the tin industry. The State of Malaya's Chamber of Mines has protested that this policy runs counter to the federal government's pledge to encourage and support private and foreign investments and to create a climate in which private enterprises will flourish (Year Book, 1978).

While equity participation in mining activities is well intentioned in some aspects, it inhibits further development of the industry in others. This increases the uncertainty of reviving the industry in the future.

Other Related Rules and Regulations

At present, there are numerous rules and regulations governing the administration of mining activity in the country. Some of them are implemented by the states and some are implemented by the federal government. The federal legislation relating to tax, company law, labor, etc. are examples of those by which producers abide. At the state level, the Mining Enactment of 1929 and the National Land Code of 1965 are currently still in use although they are already showing signs of age.

In the past, the government's role has been that of a landlord whose main emphasis has been to ensure efficient collection of revenue through various agencies such as Customs and Excise, the Inland Revenue Department, and land offices in the states. The Department of Mines has played the role of a policeman, ensuring compliance with mining laws related to land usage, safety and disturbance of the environment. Although many attempts have been made to change these roles, those attitudes have undergone very little alteration.

However, there is a significant attempt at present to reduce various frictions created by the imposing of regulations relating to mining activities. The proposed Draft National Mining Act and Draft Mining Control Act are still in the process of reconsideration having been turned down by the National Land Council in 1983. The purpose of these Acts is to streamline procedures governing prospecting, alienation, the issue and renewal of leases and the conversion of mining land and thereby, effect a more coordinated policy with state governments. In essence the two Acts form a National Mining Code. At the time of writing of this section, those two Acts are still in an embargo stage therefore detailed analysis of the implications of these Acts cannot be made.

However speculations on the production of the industry if those two Acts were to be implemented can be made. One of the questions that are commonly raised by tin producers is the issue of the length and size of land to be leased for mining purposes. At the moment, there is no standard criterion for determining the length and size of the leases. Each state uses its own discretion. Land is of critical importance in mining; not only the mineral content but also the length of tenure and the size of the land play a vital factor in determining the production of the mines.

The fact that the quality of ore deposits in Malaysia is diminishing now has made the length of tenure and the size of land even more important. The length of tenure in mining has never been standardized in the country. In some states the standard length of the lease is 5 years subject to a number of renewls thereafter. This practice is unfavorable to many producers because five years is too short a time for any big investment to be materialized. For instance, the "lead time" for dredging takes about three years before actual production can begin. If the investors are not guaranteed the renewal, the level of investment will certainly be constrained and thereby limit the potential aggregate mining output. The uncertainty of tenure also will cause producers to ignore the marginal reserves of the deposits, because the pressure of time will encourage them to exploit only higher cut-off grade deposits, leaving the lower ones untapped.

The size of the land to be mined is also a critical factor in determining the level of investment in mining operation. In order to use a more efficient method of mining such as dredging and opencasting, larger area is needed. The present allocation procedure does not adequately consider this aspect. This will certainly affect the planning of the investors in regard to the amount of investment to be committed. The practice of leasing a smaller land area in some states appears to be justified on the grounds of widening participation in mining activity, but smaller land area allocations would discourage economics of scale, thereby constraining mining output.

The price of land is yet another factor in the development of the tin industry in the country. This issue has never been resolved on a national level. The rates of payment on mining land are left to the discretion of the states. On the whole, the rates range from \$15 to \$200 per acre on new land issued by the states and from \$100 to \$150 per acre on land converted from other uses, and from \$20 to \$150 per acre on renewed land. This inconsistency effects the production cost of the mines from state to state, and even of mines within the same state. This, of course, has a bearing on the production level of the mines.

If the proposed Acts were accepted and implemented in the manner intended probably many of the uncertainties and much of the disorganization could be overcome, making revival of the industry more probably in the near future.

The Choice of Technology in Tin Extraction Activity

The technology of tin extraction in Malaysia has developed through various phases. The Chinese method of gravelpumping which was brought in during the early part of the 19th century suplanted the traditional method of 'panning'. When Western interests became dominant in the tin industry, various newer methods of extraction were introduced. These included underground mining, opencasting and dredging. Until now, all these methods of mining were practiced in tin mines in the country. Although the panning method is no longer practiced in new mines, but it is still very much in use, generally to complement other methods of mining, particularly dredging. The gravelpump method is the most popular, followed by dredging and opencasting. The least popular is underground mining. It is the purpose of this section to discuss the choices of extraction methods and their impacts on the industry, specifically in relation to the level of production of the industry.

Although the study has excluded technological factors in the analysis of production of the mines, their relationship to the overall performance of the industry seems to be very relevant. The study has shown that the various methods of extraction employed by the mines caused the variation in the output of the mines because each method of extraction has a different capability in producing the minerals. Thus, the total production of the industry could be affected by the choice of method of extraction.

Of the four major methods of mining analyzed in this study, underground mining has proved to contribute the most to the total production of the industry in terms of average output of the mines. For the last ten years, the yearly average output of this method of mining was about 1,253 tons. The dredge method has produced a yearly average of 378 tons, and opencast and gravelpump methods, each produced a yearly average of only 258 and 52 tons, respectively. Of total aggregated output for the last ten years, gravelpump mines contributed more than 55 percent while the output of the underground mine was less than 3 percent. The remainder, consisted of the output of the dredge mines (about 25 percent) and the opencast mines (about 17 percent). From the efficiency standpoint, (efficiency is defined in terms of the least cost per ton of ore produced), the data indicates that each method has a different efficiency level. Of the four methods, dredging proved to be the most efficient because the average total cost per ton of ore produced during the last ten years was only $11,400. The average cost for opencasting, gravelpumping and underground mining was $12,000, $12,500 and $16,000, respectively.

Based on this analysis, the aggregate output of the industry can be changed if the methods of mining in the industry are altered. The output of the industry can be varied from time to time by the choice of extraction methods at a particular time. The data showed that the number of mines using each method of extraction has changed from time to time (see Table 11). The number of gravelpump and opencast mines varied the most during the last ten years. While the number of dredge mines changed very little from year to year; and the number of underground mines remained the same throughout the ten year period. The aggregate output of the industry followed the changes in choice of extraction method. If more mines would use better technology such as dredging and opencasting, the aggregate output of the industry would consequently be higher.

The choice of extraction method, however, does not depend solely on the capability criterion. There are other considerations that dictate the choice of technology in tin extraction activity. Essentially, there are three major factors affecting choice of extraction method: the suitability of the method for certain purposes of extraction, the feasibility of the method in certain situations, and the acceptability of the method in certain institutional conditions.

The Suitability of the Methods of Extraction

The suitability of the method of extraction concerns mainly physical and engineering features. Certain methods of extraction are suitable only if certain conditions are met. First, the location and content of ore deposits will essentially dictate the choice between underground mining and other mining methods. If the ore deposits are found in primary lodes, then, the only choice of extraction method is underground mining. Because the incidence of primary lodes in Malaysia is limited (only 5 percent of the total known deposits), the choice factor for underground mining is not generally relevant. However, the choice to go ahead with underground mining in the case of primary deposits depends on other factors, such as economic viability, government approval, and other factors.

If the ore deposits are found in secondary sources, i.e. alluvials, then the choice of the method becomes very important because dredging, opencasting and gravelpumping are all suitable for extracting those minerals. Generally, if the mineral deposits lie in flat ground and the content of ore is lower grade, the dredging method is more suitable than other methods; if the mineral deposits are found in higher ground or a hilly area, the choice of opencast mining becomes more suitable. The choice for gravelpump mining is usually made in the case of shallow deposits just beneath the surface, especially in land left from dredge mining. Therefore, over 85 percent of the gravelpump mines now work on the dredged-out-tailings.

Second, the location of the land relative to the availability of the required infrastructures, such as electricity, water supply and major road networks is a decisive factor. If the land is located near to developed areas, normally, the choice is between dredging and opencasting. The choice for gravelpumping, however, does not necessarily depend on this factor, since it is by nature a smaller operation and more self-contained, appropriate for remote areas.

Third, the choice of extraction method will also be influenced by the size of the land to be mined. Generally, dredging and opencasting methods require a bigger piece of land in order to make them suitable for operation. It is observed that most of the dredge mines in Malaysia operate on land which is more than 500 acres, while the opencast mines operate on a smaller area, but larger than gravelpump mining areas. Although the physical condition of the land and deposits will indicate the most suitable method of extraction, the choice of method will also be influenced by the feasibility of a method in a given situations.

The Feasibility of the Methods of Extraction

The feasibility of a method of extraction is mainly construed from the economic and financial viability of the method in a given situation. Certain methods of extraction are economically and financially feasible if certain situations prevail. The most important consideration in choosing the method of extraction, is probably the level of profit that is expected from their investments. The level of profit is related to the amount of capital and risk involved in each of the methods of extraction. In terms of the capital-risk spectrum, the four major methods of extraction can be placed on a continum with the gravelpump method at one end and dredging and underground mining at the other. Opencast mining is in between. Each of these methods has its own advantages and disadvantages in terms of capital and risk.

The advantages of gravelpump mines are relatively small-scale operation by private individuals; short lead time between the first significant expenditures and the first income from actual mining; and relatively modest investment with less capital required per ton of annual tin produced than in other methods. A fair sized gravelpump mine would cost less than a million Ringgits. The disadvantages of this method are that its operating costs are relatively high, and most of the gravelpump mines are highly dependent on energy, particularly diesel which has not been stable in price. However, because of low capital (fixed) costs and high operating (variable) costs, this method is easier to discontinue and recommence. As long as a gravelpump mine operates with a margin that just exceeds the variable costs, it will most likely continue its operations; once costs exceed the proceeds, the operation of the mine is not likely to continue. Therefore, this method entails little risk.

Because of this, gravelpump mining has historically functioned as a balancing factor in supply and demand; when tin prices increased, marginal gravelpump mines, previously closed down, went into operation again, and such mines subsequently ceased operation when tin prices went down for prolonged period of time. Although, generally the profit level from this type of mining operation is lower than dredging or opencasting, in times of high tin prices, the profit made can be considerable because the amount of investment is relatively small.

At the other end of the spectrum are the large-scale, capital-intensive tin mining operations dredging and underground mining. These methods of mining are characterized by long lead time; large capital investment per ton of annual production; relatively low operating costs; difficulty in stopping and recommencing operation; and economical mining of large volume or low grade deposits. This also means that once expenditure in such investments is underway there is, in most cases, no point of return. The cost of this type of mining operation ranges from a minimum of $10 million to more than $100 million. Investments of this nature are therefore the result of careful long-term planning rather than a response to a short term prospects (Block, 1981). Because of larger investments and more efficient operation, the profit generated from these mines are normally much more than that from other methods; but the risks involved are much higher.

Between those two extremes, there are the medium-range less capital-intensive tin mining operations such as opencast and higher level gravelpump mining. The nature of the capital requirements and risk involvements are moderate, depending on the scale of operation. Usually, an opencast mine would cost between one and three million ringgits.

These feasibility considerations are of prime importance to producers in deciding the method of operation. However, the final choice depends on various other constraining factors, such as government policy, regulations, etc.

The Acceptability of the Methods of Extraction

The acceptability of the methods of extraction is determined by social, political and other institutional considerations prevailing in certain situations. Although there is no stipulated policy on the choice of technology in tin mining operation as such, various existing policies regarding the equity participation, land allocations, employment, regional development, and other factors, as discussed in the previous section, would certainly have a major impact on the choice of technology in mining industry and thus be important. These factors provide certain constrains or encouragements towards choosing certain methods.

Smaller areas given out for mining leases will certainly favor the choice of gravelpump mining methods over the dredge method. However, the withdrawal of diesel subsidies on the other hand seems contrary to expansion objectives, because gravelpump mines will be affected the most. The government policy of developing more remote areas of the country would certainly discourage the choice for dredge mining due to a lack of required infrastructures in remote areas. The safety regulations which are imposed in the mining operations, and most stringently on gravelpump mines because of their danger element, would definitely inhibit the choice for gravelpump mining.

Given those constraining factors, mining in the future will most likely be dominated by the opencast method. The repercussions of this choice are many. One of the important issues that has often been discussed by policy makers is the appropriateness of the technology used in mining operations in the country. Most discussions of appropriate technology in this case are concerned with employment creation, income distribution, self-sustained growth, and the alleviation of poverty in the belief that economic growth accompanied by continuing (or rising) unemployment and inequality cannot be considered development. In this connection, the choice of (or the tendency to choose) the opencast mining method seems to be more relevant than the choice of other methods. The fact that this method is equally as labor-intensive as the gravelpump and less dependence on capital and foreign technology as is dredge mining, has given it an advantage. In addition, the utilization of locally made materials in this type of mining operation, as high as 40 percent (COM, 1983), seemed to sustantiate the choice of this method of operation.

On the whole, considering the pros and cons of each of the methods of mining and the constraint factors in the physical suitability, economic feasibility and institutional acceptability, the real choice open to the miners is to select a mid point between the least and the most efficient methods, namely the opencast mining. Probably, this is the reason why the number of opencast mines kept on increasing significantly from year to year, since 1975, while the numbers of other methods of mining, particularly gravelpump and dredging were decreasing from year to year.

If this trend were to continue in the future, the situation of the industry would certainly be more stable. This is because opencast mining is relatively more efficient and more permanent in nature than the gravelpump mining; hence the production level of the industry could be increased and stabilized. Secondly, due to its less capital intensive character and higher adaptability to electrical power which could increase its efficiency, make this method more acceptable and reliable for the industry.

CHAPTER VII

SUMMARY, CONCLUSION AND RECOMMENDATIONS

Summary

The Problem and the Research

Mining was one of the earliest human activities. Tin mining started early and continues in many parts of the world. Most of the tin ores are mined in developing countries and consumed in developed countries. As such, tin trading has become one of the important instruments in the formation of various international organizations. Tin is the only commodity that has its price subject to international controls. This has caused numerous problems particularly to the producing developing countries. This is because many producing countries depend on this industry as a source of foreign exchange, employment, and national income.

Beside many problems inherent in the nature of mining itself, the tin mining industry in most developing countries also faces other external and internal problems. Many of the external problems such as competition among the producers, depressed tin prices, the decrease in consumption, and the emergence of tin substitutes, are beyond the control of the producing countries. Internal problems in the producing countries themselves, such as lack of investment, the decline in efficiency, the competition in land uses, the administrative problems, lack of research and development and lack of coordinated action on mineral development are among the reasons which depressed this industry further. The worsening situation of the tin industry as a whole and specifically in Malaysia began in the early part of the 1970s.

There are two forces which led the Malaysian tin mining industry into its present unfortunate situation. They are the decline in tin prices and the rising costs of production which occurred almost simultaneously. The productivity of tin mines has declined considerably and consequently many mines have been shut down either permanently or temporarily. The decline in production and the closing of mines means a loss in government revenues, employment, and profits to the tin producers.

The decline of tin prices is a world wide phenomenon over which no single country like Malaysia has any strong influence; let alone the tin producers who have always been the price-takers. Therefore, the major concern in many producing countries, especially in Malaysia, is increasing costs of production. In fact, the costs of production (input factors in the mining operation) are the only decision criteria left to the miners in deciding how much tin ore will be produced. This notion has formed the basic tenet of this investigation.

The following questions were important in this study: how relevant are the costs of input factors in determining the levels of output of the miners? What kind of relationships do these two variables have in affecting each other? How susceptible are those cost factors to changes? Beside answering these questions the study also had various other specific objectives to pursue which include identifying the cost factors, establishing the relationships between the output levels and the costs of input factors, analyzing the differential effects generated by the choice of different methods of extraction in the mining operation, and, most importantly, the creation of various predictive models to reflect the behavior of the industry in terms of producing the ores in the future.

The thesis of this study is that the costs of input factors are the major determinants on how much ore is produced by the mines. Various hypotheses were developed to test the thesis. The general hypothesis has been that the output of the mines in the industry is strongly influenced by the variability in the costs of input factors. This hypothesis assumed that the cost factors are inversely related to the output of the mines, in the sense that the higher the costs of input factors the lower the outputs of the mines. The thrust of the study was to identify what input factors influence the levels of output of the mines in the industry and to establish those relationships.

Since the levels of output and the variability in the cost factors are also affected by the choice of methods of extraction, the study has further hypothesized that the relationships between the levels of output and the costs of input factors varies significantly from one method of mining to another. This hypothesis assumed that different methods of mining require different types of input factors. The rationale for this is that factor substitutions are possible by exercising a choice of different methods of mining operations. Therefore, the thrust of the study was to identify what input factors influence the levels of output of each of these different methods of operation, and to establish those relationships. For this purpose, the industry has to be disaggregated according to the methods of extraction. Four major methods have been identified: the dredge, the gravelpump, the opencast and the underground mining.

The survey data collected by the Department of Mines, Malaysia from 1973 to 1982 were extensively used in this study. The data on the outputs of the mines have been transformed into the average outputs. This was done for the purpose of obtaining standard criteria of measurement, due to unequal sample sizes used in the surveys from year to year. The same procedures were used on the costs of production, where the costs of each input factor were divided by the total output of the sample mines, in order to get the cost per unit of output produced (1 ton). For the purpose of meaningful comparisons, costs were converted to a constant price of 1982.

Based on the data indicated, the study divided the costs of tin production into 16 items. For the purpose of simplicity, these items have been regrouped into two major categories, namely the capital (fixed) expenses and the operating (variable) expenses. The capital expenses were divided into land and other capital expenses (including machinery, infrastructure, and others). Land was considered separately because it is the most important item and has special implications in mining. The operating costs were divided into five items: labor, energy, materials, taxes, and other expenses. This division is important in order to see the differential effects of each input factor, particularly in relation to the choice of methods of extraction; this shows the different orientation of the methods toward certain types of input factors.

The model of the study was mainly regression analysis. The average outputs of the mines were treated as the dependent variable and the costs of input factors were the independent variables. Various statistical analyses were performed on the data in order to create predictive models. These analyses include Pearson's correlation tests, multiple-regression analyses, Durbin-Watson-d-Statistics tests and prediction tests. These tests served different purposes in the study and were performed in two phases: aggregated data for the industry and individual data for each of the four major methods of mining operation.

The Findings

The Analysis of the Industry

The data to reflect the behavior of the industry were derived from various sample mines, according to the methods of operation. Evidently, the samples were not proportionate either from year to year or from method to method. Therefore, the aggregated data for the industry may be biased towards certain types of mining operations. This is unavoidable, due to the nature of the survey data used in this study. Within these constraints, the study found that:

(1) Output in the industry has fluctuated from year to year, while, the cost of input factors showed a persistent yearly increase.

(2) The cost of all input factors except land and capital were significantly related to the level of output of the industry. The strength of the relationships between the costs of input factors and the output of the industry varied from -.44 to -.77 coefficients of correlation. The input factor that correlated the strongest with the variations in the output of the industry was taxes.

(3) Multicollinearity did exist significantly between those input factors that correlate with the output, especially between labor, energy, materials and operating costs. However, taxes did not correlate significantly with any of those input factors.

(4) Based on those relationships, four separate predictive models were developed where taxes were taken together with each of the correlated input factors (labor, energy, material and operating costs). However, the presence of other input factors with taxes was not significant in all the four models, therefore, taxation was the only variable that significantly related linearly to the output of the industry. Thus, the predictive model was created based on this relationship.

(5) The reliability of this predictive model was tested by comparing the forecast output through utilizing the model's equation with the actual output data for 1983. The result showed that the margin of error in prediction was great. This was due mainly to the sampling errors and the quality of certain data used to represent the industry. Therefore, the research concluded that the proposed predictive model for the industry could not be generalized to the non-sample mines in the industry.

The Analysis of the Mines According to Methods of Operation

The analysis of the mines was done based on separate data for each of the four major mining operations. The data were collected from various samples of the mines from year to year. The size of the samples was also not equal from year to year and not proportionate from method to method. However, it was felt that the samples for dredge, opencast and underground mines were sufficiently represented to reflect the reality of those methods, while the samples for gravelpump mines were inadequate and the quality of the data was doubtful.

The results of the analysis are as follows:

The Dredge Mines

(1) The dredge mines were the most efficient method of mining. This method is the second largest in terms of numbers. It contributed the second highest in terms of national output. The average output of the dredge mines ranged from about 300 to 400 tons from year to year. On the whole, there was a clear pattern of decreasing average output from 1973 to 1982, while the costs of input factors showed a considerable increase from year to year.

(2) The cost of all the input factors except taxes have a significant correlation with the variations in the output of the mines. The strength of the relationships between each input factor and the output ranged between -.57 to -.91. The operating costs proved to be the highest correlated variable with the output.

(3) Multicollinearity among the input factors was high, particularly between labor, energy, materials and operating costs. However, land and capital did not correlate significantly with each other or with any of the other input factors.

(4) Based on those relationships, the study has developed four predictive models, each including land and capital together with labor

or energy or materials or operating costs. However, in all the models, the presence of land and capital factors together with those other input factors were not significant. Therefore, the predictive models could have only one of these factors: labor, energy, materials and other operating costs.

(5) For the study a model was chosen which constituted the operating costs as the independent variable. This was considered the best predictive model because it has shown not only the strongest coefficient of determination but also the presence of serial correlation in the sample was the least compared to other models.

(6) The reliability of this model was tested by the same procedure as in the industry's model and the study found that the actual output of the mines for 1983 fell well within the range forecast using the regression equation of the model. The study therefore, concluded that the proposed predictive model for the dredge mines was reliable and could be generalized to the non-sample dredge mines in the industry.

The Gravelpump Mines

(1) The gravelpump method is the most popular among the four major methods of mining. The output from these mines contributed the highest to the total production of the country. However, this method of mining proved to be the least efficient. The average output of this method ranged from 40 to 66 tons annually. There was no clear indication of the decrease in the average output of the mines; in fact, towards the later part of the study period the average output increased. The costs of production on the whole, however, showed a much clearer pattern of increase from year to year.

(2) The cost of all input factors except capital, showed no significant relationship with the output of the mines. Capital costs proved to be the only variable that correlated positively with the output. The hypothesis of an inverse relationship was rejected. The result of regression analysis on capital costs and output also proved not significant. The original data was subsequently transformed into ordinary log and log quadratic. The result showed that only the land factor correlated with the output of the mines, but the strength of their relationship was not significant in the regression analysis. The study therefore rejected the linear relationship between any of the input factors and the output of the mines.

(3) There are two possible reasons for this. First, the nature of this method of mining is indeed different from other methods of mining; thus linearity between output and input factors did not exist. Second, the distortions of the data in the surveys may be due to sampling errors and/or inaccurate reporting. Both reasons may be valid, but it is strongly felt that the second reason was mainly responsible.

The Opencast Mines

(1) Opencast mining had become more popular by the beginning of the 1980s. This was proved by a sudden increase in the number of mines from 22 in 1979 to 35 in 1980 and to 43 in 1982. However, the average output of the mines persistently decreased during these years. The worst situation was in 1980 when the average output decreased to less than half of that in 1979. The costs of production, on the other hand, have increased considerably from year to year. The cost of land showed only marginal change and fluctuated with no clear pattern.

(2) The cost of all input factors except labor and taxes showed a significant relationship with the output of the mines. The strength of their relationship ranged from -.79 to -.92. The cost of materials was correlated the highest with the variation in the outputs of the mines.

(3) Multicollinearity among the input factors was high, particularly between land and energy; capital, energy and operating costs; and materials and operating costs. Based on these relationships, the study created three possible predictive models for this method of mining operation.

(4) Based on the result of the regression analysis performed on all three models, the presence of capital and land factors together with other factors were not significant. The study therefore choses the model that constituted materials and energy factors. Although this model demonstrated lesser strength of predictive ability compared to the model which constituted materials and land factors, the presence of serial correlation in the later model proved to be higher than that in the earlier model. The predictive model then constructed was based on the relationships between materials and energy and the output of the mines.

(5) The reliability of this model was tested and it was found that the prediction for the output of the mines in 1983 nearly matched the actual data for 1983. The study concluded that this predictive model is reliable and that the model could be extended to generalize to the non-sample opencast mines in the industry.

The Underground Mines

(1) For the last ten years, there was only one underground mine in the country. It is anticipated that the number of underground mines will increase in the future for there were a number of primary tin deposits found in many places in the country. The output of the mine has decreased substantially from year to year during the last ten years; while the costs of production on the whole have increased considerably; capital cost has shown an unclear pattern. Land cost was excluded in the analysis due to unavailability of data.

(2) The cost of all the input factors, except capital and energy, were significantly related with the variations in the output. The strengths of their relationship varied from -.55 to -.92. The cost of labor was correlated the highest with the output.

(3) Multicollinearity among those input factors was high, particularly between labor, materials and operating costs. Taxes did not correlate with other input factors. Based on these relationships, the study created three possible predictive models for this mine where taxes were analyzed together with either labor or materials or operating costs.

(4) The result showed that all the three models could be a good predictive model. The study, however, choses the combination of labor and taxes as the best predictive model because it demonstrated not only the strongest relationships but also contained the least effect of serial correlation in the sample.

(5) The reliability of the predictive model was tested by comparing the outcome of the estimate with the actual data on output for

1983. It was found that the actual output fell within the range forecast. The study, therefore, concluded that the predictive model is reliable.

The Implications of the Existing Mining-Related Policies

The existing tin mining-related policies have both direct and indirect effects on the levels of output of the mines as well as on the overall performances of the industry in the country. The study has discussed the influence of four of the most important policies on the levels of output and on the performance of the industry in general. These policies were the taxation system, subsidy and other incentive programs, equity participation measures, and other specific rules and regulations pertaining to tin mining activities in the country.

(1) The existing cost-plus taxation policy on exportation of tin-in-concentrates seemed to be unpopular among the majority of the producers. The main complaint was on the mechanism for determining the cost elements in the formula which was rather unsystematic and unscientific. This has an adverse effect on the efforts of the producers, particularly in mining the marginal ore deposits. Enforcement of this policy will certainly reduce the total output of the industry.

(2) Other subsidy and incentive programs which have been developed to help the miners in easing the burden of the increase in the cost of production seemed to favor development in the industry. However, the withdrawal of a diesel fuel subsidy beginning in 1984 will definitely affect most of the energy-oriented mines, such as gravelpump and

opencast. Thus, the level of output of the industry is expected to decrease further in the future as the cost of energy increases.

(3) The equity participation policy in mining seemed to be pursuing a different objective, contrary to the objective of improving the tin industry. The effects of this policy were discouraging: not only could it lead to the decrease in productivity of the industry but it also encourages unnecessary competition in the industry.

(4) The unsystematic procedures in land allocations, particularly as to the size and the length of tenure of the leases among various states have made major differences in the costs of production of the mines between the states and consequently affect the productivity of the mines differently. However, the movement towards standardizing these procedures which is in progress will hopefully overcome these problems.

The Choice of Technology

(1) The choice of technology has made the difference in terms of the levels of output of the mines. It also showed that different methods of extraction depend on different sets of input factors, thus the cost structure in the mining operation was affected by these choices. By using the efficiency criterion, the dredge method proved to be the best among the all methods of mining. However, the choice of technology did not depend solely on this criterion, for there were other important considerations which dictated the final choice of the extraction method.

(2) Three important considerations were discussed in the study. They were the physical suitability of the method in a given location,

the economic feasibility of the method in a given situation, and the institutional acceptability of the method in a given condition. All these factors constrained the choice of technology in extraction activities.

(3) However, given the location, the situation and condition the tendency in the choice of technology seemed to favor the opencast method of operation. The choice of this method over the others would certainly affect not only the production but also the structure of the industry as a whole. The future of the industry is expected to be improved by the choice of this method. This is because not only did this method prove to be more efficient than the favorite method (gravelpump) but also more permanent in nature, which could possibly stabilize the industry in the future.

Conclusions

Based on the above findings, the study concludes that the costs of various input factors in mining operation do influence the level of output of the mines. In general, the relationships between the costs of various input factors and the outputs of the mines are inversely related; i.e., the higher the cost of those input factors the lesser the output of the mines. On the industry level, the costs of labor, energy, materials, taxes and other operating expenses proved to be significantly related to the output of the industry. The general hypotheses of these relationships, however, were rejected in the case of the costs of land and capital.

On the individual methods of mining operation, the relevancy of the costs of input factors in influencing the level of outputs varied from one method to another method. In the case of dredging, the hypotheses of those relationships have been proved for all input factors except taxes. In the gravelpumping, however, the study failed to establish a significant meaningful relationship between any of the input factors and the outputs of the gravelpump mines. In opencasting, the hypotheses of a similar relationship were rejected in the cases of the costs of labor and taxes. And in underground mining, those hypotheses were rejected in the cases of the costs of capital and energy.

This shows that the outputs of the mines as a result of choosing a different method of extraction were influenced by a different set of input factors; thus, the strength of the relationship between each input factor and the outputs of those mines also varied considerably from one method to another. Therefore, the hypothesis of the significance variation between input factors and the outputs of the mines in using the different methods of extraction has been proved beyond doubt.

The predictive models which were created based on those observations have clearly shown the magnitude of the relationships between certain input factors and the outputs of the mines. Although some of them (particularly the gravelpump and the industry model) were less reliable than others, in general they portrayed the kinds of relationships that existed between some of the input factors and the output of the mines. Even though they did not suggest any kind of causal relationship between them, but the effects of the variations in the costs of those input factors, to a certain extent, have influenced the variability of the outputs of the mines.

The variations in the costs of input factors have been influenced not only by the choice of technology of extraction, but also by the impacts of certain policies and other consequences. The choice of technology has dictated the dependence of certain methods of extraction on certain types of input factors. While the impacts of certain policies were felt differently by the producers as a result of choosing different methods of operation, they also influenced the choice of the technology itself.

Recommendations and Suggestions

Recommendations for Policy Action

As shown by the study, the problems of the decreasing production in Malaysian tin mines and the increase in the production costs in those mining operations are interrelated, in the sense that one influences the other. Since the variability in the costs of production, to a certain extent, was affected by some of the policy measures taken by the government, the major problem of the industry vis-a-vis the increase in costs of production could be approached in two ways.

First, government could introduce various policy instruments that have a direct effect on the costs of input factors in mining operation. These instruments could include modification of taxation and fiscal structures, creating incentives for the producers through more positive subsidy and protection programs, etc. Second, by introducing certain measures to influence the choice of technology in mining operations, which ultimately will have a positive effect on the costs of production. Although each of these initiatives could play an important part in the revitalization of the industry, they would require distinctive policy approaches and different policy instruments.

In order to achieve these objectives, various modifications of existing mining related policies and perhaps, introduction of new policies are needed. For this purpose a number of policy actions are recommended.

The General Policy

Although there are various general policies which cover tin mining activities in the country, the lack of a more specific policy on mineral development, particularly in relation to tin mining industry, has led in an unclear direction. As a matter of necessity, a more comprehensive and intergrated policy on this industry is needed. Such a policy should encompass clear guidelines with respects to investment incentives, the role of the public agencies and protectionism in the industry. Since the industry is made up of various interrelated components such as exploring, extracting, processing, marketing and manufacturing, policies should reflect these linkages. In other words, there is a need to devise a comprehensive and integrated approach to the development of this sector of the economy.

Perhaps the time has come to reconsider the importance and significance of this industry in the context of the overall development policy of the country. The worsening economic situation, the decreasing ore reserves and the ever increasing costs of production may have led to a decreased emphasis on this industry. Decreased productivity does not mean that the industry should be abandoned, but efforts for reviving the industry should focus more on making use of existing situations to capture more benefits out of it. Perhaps the government should encourage more activities which lead to increased value added to the minerals, instead of exporting them in the ingot form. This would induce a wider local utilization of the minerals, as well as more manufacturing activities in the country.

Also important in this connection are the benefits which could be derived from the forward and backward linkages of this industry. Probably, this aspect could be more important than the reviving of the industry itself. To these ends more specific policies are needed particularly for the purpose of encouraging the use of local materials, expertise and skill. More importantly, such policies should also consider the wider implication of the industry to the society (including social as well as environmental effects) which at the moment have been neglected.

In short, there is a need to plan a more integrated development of this industry rather than simply to retain the status of the largest tin producer in the world.

Specific Policies

In the attempts to revive the tin mining industry, particularly in increasing the level of productivity and decreasing the costs of production, various policy actions are recommended.

1. Priority should be established in exploration activities, particularly in the non-traditional mining areas. Land is the key to exploration and mining. Existing practice in the granting of prospecting rights is geared mainly to small scale alluvial mining and does little to promote bold initiatives. Legislation should be

introduced under which broad tracts of land can be made available for exploration and protection of the producers' rights. A sufficiently long period is necessary to allow the completion of the various exploration stages. Special allowances should be introduced to compensate for losses due to unsuccessful mining explorations. At the same time, the role of the government in exploration activity should be widened; this ultimately would facilitate the creation of a national mineral data system.

2. Land allocation procedures and other administrative arrangements should be improved. A standardized and streamlined policy in regard to the land size, land fees, and the length of tenure of the leases should be established, so that a more confident investment and a more efficient method of mining could develop. In very large or very remote projects where infrastructure costs are very high, government and industry should be prepared to work together and share the burden of developing infrastructures not only for the project but for the long term development of the surrounding area.

3. Efforts to encourage a more suitable and favorable climate for mining should be vigorously articulated, especially in reducing the element of risks in mining operation. For this purpose, taxation and fiscal policies should provide enough incentive for further development of the industry. The existing taxation structure has various disadvantages, particularly in promoting the productivity of the mines, and should be improved. Perhaps, alternatives to royalties and export duties should be searched and replaced by a profit principle, i.e. the tax quantum should be based on profits rather than on a price-minus-cost principle. Policies for equity participation in mining ought to be

restudied because this policy could be counter productive to the efforts of reviving the productivity of the industry.

4. A more direct assistance in reducing the burden of the increase in the costs of certain input factors in mining operation should be provided. However, a blanket assistance such as subsidy on energy does not really help the industry as a whole, because the advantages of this program are felt only by those energy oriented mines; therefore a more wide-spread assistance such as exempting import duties on equipment, spares and other consumable items should be provided which would benefit the industry as a whole.

5. Facilities and encouragements for improving some of the obsolete methods of mining operations should be developed. Activities on research and development on various aspects of mining should be promoted with the objective of developing not only better, more efficient methods of mining operations but also for achieving other objectives such as increased employment, sound environmental effects, and the appropriate use of technologies. The government, through the imposition of various policy mechanisms, could play a very important role in influencing the choice of a more favorable technology in the tin mining industry. Research and development activities should also extend to making or finding more new uses of tin metal, so as the demand for this commodity will be increased in the future.

6. Stop-gap measures such as the imposition of production quotas and the freeze of new mine leases, should be utilized judiciously so as not to create a long term effect on the industry. While taking these measures, the government should also find better solutions to the problem of rapid fluctuation of tin prices. This could be done through

concerted efforts in government-to-government negotiations, especially among the producer countries. Perhaps the old ideas of creating the local stockpile programs, the establishment of a tin cartel or the use of a tin stockpile as a monetary reserve, which have long been propagated by many producing countries, should be considered further for use as a last resort.

Suggestions for Further Research

As a result of limiting the scope of this study to the issue of physical relationships between the output level and the direct costs of input factors in mining operations, the study was unable to provide a more meaningful interpretation of the real issues facing the industry. This is because in reality the decisions to produce certain amounts of ore could have been made based on more important decision variables other than the direct costs of input factors. Such variables could be the price, the demand elasticity of this mineral. Furthermore, in reality the total costs of production should extend beyond the monetary value of those selected input factors. Perhaps various other social costs such as environmental degradation, hazards, etc. could have been equally important in the decisions concerning production of ore. Therefore, it is recommended for future research that those factors should also be looked into, for they could provide a more complete analysis of the problem in mining activity.

Even if one chooses to focus on the physical relationship between output level and input factors as portrayed in the models of this study, specifically in the industry's model, it is felt that technological factor should be included together with other input factors in the model. This is because this factor really contributed to the variations of input costs. The inclusion of this factor in the model could be done by adding technological variables such as the depletion rates associated with certain types of technology, depreciation of equipment as a result of choosing certain types of technology and penalties imposed on the producers for polluting the environment as a result of choosing certain types of extraction techniques. With the introduction of this factor, the original production function as formulated in this study should be altered as follows:

$$Q = f\,(L,\ LB,\ C,\ E,\ M,\ T,\ O;\ TC)$$

where Q = the quantity of output

L = Land; LB = Labor; C = Capital; E = Energy; M = Materials;

T = Taxes; O = other operating costs; and TC = Technology

TC = (dl, dc, pe)

where dl = depletion rates of ore as a result of using a certain method of extraction

dc = depreciation on equipments used by certain methods of extraction

pe = penalties imposed on environmental pollution

It was observed that the depletion rates of ore in the ground are different from one method of mining to another. Therefore, the choice of this different method could change the life expectancy of a mine and thus affect the rate of extraction. The depreciation of mining equipment also varies from one method to another and could easily be quantified. The penalties imposed on environmental pollutions could be translated into the amounts of deposits paid by the miners to the government, which varies from one method to another. These three factors were excluded in the study due to unavailability of complete data.

Although the result of the study did not show a significance of serial correlation in the sample, it is believed that this problem may arise if more observations were taken. If the data were broken down into half-yearly or quarter-yearly intervals, which would result in more observations, the presence of serial correlation could be more significant. If this is the case, the study needs a different method of analysis, probably the time series analysis. In fact, it is highly recommended that time series analysis be used if one uses serially arranged data as in this study. The use of this method would certainly answer the question of period interdependency in mining operation, which is an essential aspect in most mining activity.

Another aspect which could be important in output analysis of the mining activity is the determination of optimal rates of extraction which has been ignored in this study. In fact, this aspect could have been the most needed study in the attempts to revive the industry. One of the possible methods to do this is to apply a linear programming model. This requires the transformation of the data into their real physical terms, which the study was unable to do due to the nature of the data which have been transformed into monetary terms.

The major weakness of this study, in addition to the inherent problems of the regression analysis, is the reliance on secondary data. This has caused a number of problems. First, the problem of aggregated data of the surveys disclosed a more detailed information required by this study, particularly on the ranges of the actual output level of the mines and the costs of input factors in the real operation of those mines. The data on the average were less valuable. Second, the reliability of the data is doubtful. This is not only because they have been processed into aggregated form, but also the procedures in which they were collected. It is believed that many vital information was hidden due to the fact that it was collected by government officials and for official purposes. Third, the differences in the sample sizes from year to year and from method to method have caused some serious sampling errors in the study. The samples of the study should have been more proportionate to the population if valid generalizations were to be made to the non-sample situation. This could not be done in the study due to the reliance on the secondary data.

Therefore, it is recommended that for future studies data should be collected from primary sources and the question of sampling should be thoroughly looked into so that the reliability of the data and the representativeness of the samples should not become the major problem in the study.

APPENDICES

APPENDIX A

The Sixth International Tin Agreement

(4th September, 1981)

PREAMBLE

The parties to this Agreement, recognizing:

(a) The significant assistance to economic growth, especially in developing producing countries, that can be given by commodity agreements in helping to secure stabilization of prices and steady development of export earnings and of primary commodity markets;

b) The community and interrelationship of interests of, and the value of continued co-operation between producing and consuming countries in order to support the purposes and principles of the United Nations and the United Nations Conference on Trade and Development and to resolve problems relevant to tin by means of an international commodity agreement, taking into account the role which the International Tin Agreement can play in the establishment of a new international economic order;

(c) The exceptional importance of tin to numerous countries whose economy is heavily dependent upon favourable and equitable conditions for its production, consumption or trade;

(d) The need to protect and foster the health and growth of the industry, especially in the developing producing countries, and to ensure adequate supplies of tin to safeguard the interests of consumers;

(e) The importance to tin producing countries of maintaining and expanding their import purchasing power; and

(f) The desirability of improving efficiency in the use of tin in both the developing and industrialized countries, as an aid to the conservation of world tin resources;

Have agreed as follows:

CHAPTER I -- OBJECTIVES

ARTICLE 1

Objectives

The objectives of this Agreement are:

(a) To provide for adjustment between world production and consumption of tin and to alleviate serious difficulties arising from surplus or shortage of tin, whether anticipated or real;

(b) To prevent excessive fluctuations in the price of tin and in export earnings for tin;

(c) To make arrangements which will help to increase the export earnings from tin, especially those of the developing producing countries, so as to provide such countries with resources for accelerated economic growth and social development, while at the same time taking into account the interests of consumers;

(d) To ensure conditions which will help to achieve a dynamic and rising rate of production of tin on the basis of renumerative return to producers, which will help to secure an adequate supply at prices fair to consumer and to provide a long-term equilibrium between production and consumption;

(e) To prevent widespread unemployment or under-employment and other serious difficulties which may result from maladjustment between the supply of the demand for tin.;

(f) To improve further the expansion in the use of tin and the indigeneous processing of tin, especially in the developing countries;

(g) In the event of a shortage of supplies of tin occuring or being expected to occur, to take steps to secure an increase in the production of tin and a fair distribution of tin metal in order to mitigate serious difficulties which consuming countries might encounter;

(h) In the event of a surplus of supplies of tin occuring or being expected to occur, to take steps to mitigate serious difficulties which producing countries might encounter;

(i) To review disposal of non-commercial stocks of tin by Governments and to take steps which would avoid any uncertainties and difficulties which might arise;

(j) To keep under review the need for the development and exploitation of new deposits of tin and for the promotion, through inter alia the technical and financial assistance resources of the United Nations and other organizations within the United Nations system, of the most officient methods of mining, concentration and smelting of tin ores;

(k) To promote the development of the tin market in the developing producing countries in order to encourage a more important role for them in the marketing of tin; and

(l) To continue the work of the International Tin Council under the Fifth International Tin Agreement (hereinafter referred to as the Fifth Agreement) and previous International Tin Agreements.

APPENDIX B

Distribution of Malaysian Tin Deposits

Location	Main Deposits	Type of Deposits
Perak	Kinta	Mainly alluvial cassiterite; some lode cassiterite
	Klian Intan	Veins & stringers of cassiterite
	Selama	Small lodes & alluvial cassiterite
	Temengor	Small lodes of cassiterite
	Taiping (Larut)	Alluvial cassiterite
	Sungei Sipat	Alluvial cassiterite; rare lodes
	South Larut-Matang-Kindings	Small quantities of alluvial cassiterite
	Tapah and Bidor	Alluvial cassiterite; rare lodes
	Sungei Slim and Sungei Bernam	Alluvial cassiterite
Perlis	Kati Bukit	Alluvial cassiterite
Kedah	Sintok	Lode deposits of cassiterite and wolframite
	Ula Muda	Alluvial cassiterite
	Baling	Small lode deposits of cassiterite and wolframite; also alluvial cassiterite
	Gunong Jerai	Alluvial and near-alluvial cassiterite
	Kulim	Alluvial cassiterite and small amounts of lode cassiterite and wolframite

Kelantan	Sungei Yai and Sungei Betis	Alluvial cassiterite associated with scheelite
Pahang	Sungei Lembing	Lode cassiterite; some alluvial and eluvial cassiterite
	Gambang	Alluvial and eluvial cassiterite
	Sungei Endau	Small amounts of alluvial cassiterite
	Gunong Gapis	Numerous small occurrences of vein and lode cassiterite
	Bentong	Numerous small lode and placer deposits traces of wolframite and scheelite
	Manchis	Small amounts of alluvial cassiterite and small veins
Selangor	Ulu Selangor	Alluvial and lode cassiterite; some wolframite
	Kuala Lumpur	Extensive alluvial cassiterite
	Ulu Langant	Alluvial cassiterite; veins of cassiterite and wolframite
Negri Sembilan	Jelebu	Alluvial cassiterite; small quantities of fold and some cinnabar; lode cassiterite and wolframite
Trengganu	Bukit Yong	Alluvial cassiterite
	Bukit Bidong Darat	Wolframite with some cassiterite
	Bukit Lentor	Wolframite and cassiterite in alluvium and lodes
	Bukit Besi	Iron ore with appreciable amounts of fine grained disseminations of cassiterite

	Sungei Kemaman	Lode and Alluvial cassiterite, wolframite and scheelite
	Seremban	Alluvial cassiterite
Malacca	Malacca coast	Cassiterite in sea bed and beach sands associated with ilmenite, tourmaline, rutile, zircon, and anatase
	Jasin	Alluvial cassiterite; tourmaline-cassiterite veins
Johore	Bakri	Alluvial cassiterite associated with columbite-tantalite
	Jemaluang	Shallow alluvial and eluvial cassiterite derived from quartz veins; some associated wolframite
	Konta Tinggi	Shall alluvial cassiterite; small quantities of molybdenum; iron ore containing cassiterite
	Bukit Pelali	Alluvial cassiterite

APPENDIX C

Explanatory Notes

For Questionnaire

(Please read carefully before completing the questionnaire)

Expenditure

The questionnaire sets out only the principal headings for capital expenditure and production costs. Each heading consists of a number of items. Capital expenditure and production costs should be supplied only as totals against each heading.

TABLE B. CAPITAL EXPENDITURE

Information is asked for in Table B of the questionnaire to distinguish between capital expenditure and production costs. Capital expenditures should NOT include items completely written off during the year of purchase but only those capitalized and depreciated over a number of years.

1. Property - mining Leases and Licenses - capitalized
   Exploration and development, capitalized are to be included here.

2. Roads, bridges
   Infrastructure not completely written off in the year in which the expenditure is made but is, instead, capitalized and depreciated over a number of years.

3. Water supplies
   Equipment for water supply not completely written off in the year in which the expenditure is made but is, instead, capitalized and depreciated over a number of years.

4. Plant and machinery
   Machinery not completely written off in the year in which the expenditure is made but which is, instead, capitalized and depreciated over a number of years, including dredges, draglines, bulldozers and other earth moving equipment, but excluding transport equipment.

5. Buildings
   Those buildings not completely written off in the year in which the expenditure is made but are, instead, capitalized and depreciated over a number of years are to be included here.

6. Vehicles
Items not completely written off in the year in which the expenditure is made but are, instead, capitalized and depreciated over a number of years, including mainly trucks and other transport equipment, but excluding large items of mining equipment, e.g. dredges, draglines, etc.

7. Other
Specify what is included under this heading.

TABLE C. PRODUCTION COSTS

The following is a detailed breakdown of cost items which should be taken into consideration under each major heading of production costs.

1. Power
Electricity.
Fuel & Fuel Oil.

2. Salaries and labour including contract work (to be shown under item 1 or 2, and separately - if substantial).
Wages and salaries
Payments in kind (i.e. medical attention, food, accomodation)
Bonuses and allowances.
Pensions, health and social services and schemes, provident funds.

3. Materials
Consumable parts and stores repairs and maintenance. (NOT capitalized).

4. Other charges and overheads
Insurance and security. Lubricants and lubricating oil, explosives, firewood. Hiring of machinery/equipment, stationery and office equipment. Management, consultation, accounting, secretarial, audit and legal fees, Premiums and rent on leases. Rent for office premises. Bank charges and interest on loans. Entertainment, donation grant. Transport and traveling, including transportation of ore waste and overburden. Other items normally not included under C.1, C.2 and C.3.

5. Depreciation

6. On-property exploration and development (written off) DO NOT include exploration and development expenditure off the mining property).

7. <u>Realization costs</u>
   Transport to smelter, handling charges, insurance o ore in transit.
   Smelting charges.
   Deductions for losses.
   Penalties for impurities.

8. <u>Total</u>

9. <u>Royalties, Export Duty and Surcharges</u>
   Do Not include income tax or other taxes deductable from net operating profit.

10. <u>Tributes</u>
    These refer to payments on output made to the leaseholder.

TABLE D. SUPPLEMENTARY INFORMATION

Certain supplementary information is asked for in Table D of the questionnaire to enable an analysis to be made of the cost headings in relation to production of tin metal.

1. Tin concentrates produced in kilograms.

2. Proceeds from by-products (produced and sold) in quantity and value.

3. Volume of ground worked during period in cubic metres. This entry should include overburden and waste stripped. For hardrock mines, "cubic metres" should read "tonnes".

4. Average recovery of tin concs. in kilograms per cubic metre.

5. Average percentage of tin metl content of concentrates produced.

GENERAL

1. Jabatan Galian undertakes to keep all particulars supplied confidential and destroy, if necessary, all returned questionnaire after use. Hence there is no need to have the particulars audited before submission.

2. The questionnaire is to be completed and returned for all tin mines, whether or not they have reached stable production or are in the process of shutting down. Particulars are required as long as expenditure has been incurred.

<u>NB: If information for any items not available, please comment.</u>

CONFIDENTIAL

Questionnaire on Tim Production Costs

(1.7.81-31.12.81)

PARTICULARS OF MINE

TABLE A

1. Name of Mine:____
2. Tin Control No.:______________________________________
3. Mining Methods: # Dredging/Gravelpump/Opencast/Underground/Other
4. Locality: Mukim ________________ Daerah ________________
5. Total reserves*:__________ Hectares. Average depth:________ metre
6. Area worked*: ______________________________________Hectares
7. Estimated life of mine as from the beginning of the period above:________
8. Total labour force (inclusive of contract labour) as at end of period
or when mine last operated: ________________ persons.
9. Total Kilo Watt employed as at end of period or when mine last operated ________________ K.W.

*In case of hard rock mines, quote tonnage only.
#Delete if not applicable.

TABLE B

CAPITAL EXPENDITURE1)

Heading	Period 1.7.81 to 31.12.81 $
1. Property - Mining lease and licenses - capitalized (include exploration and development capitalized	
2. Roads, bridge	
3. Water Supplies	
4. Plant and machinery2)	
5. Buildings	
6. Vehicles3) (specify)	
7. Other (specify)	
8. Total	

1) Incurred in the period stated. Refers to capital expenditure not completely written off in period when expenditure is made but is instead capitalized and depreciated over a number of years.
2) Including dredges, draglines, bulldozers and other earth-moving equipment, but excluding transport equipment.
3) Mainly trucks and other transport equipment, but excluding large items of mining equipment, e.g. dredges, draglines, etc.

Comments:

TABLE C — PRODUCTION COSTS

Heading	Period 1.7.81 to 31.12.81 $
1. Power[4)]	
2. Salaries and Labour[4)]	
3. Materials incl. spare parts NOT capitalized	
4. Other charges and overheads (specify)	
5. Depreciation	
6. On property exploration and development	
7. Realization costs	
8. Total	
9. Royalties, Export Duty and Surcharges	
10. Tributes	
11. Grand Total:	

4) Contract work to be shown under item 1 or 2, and separately if substantial.

COMMENTS:

TABLE D **SUPPLEMENTARY INFORMATION**

		Period 1.7.81 to 31.12.81
1.	Tin concentrates produced	kilograms
2.	Proceeds from by-products	Tonnes $
3.	Volume of ground work (inclusive of overburden)	cu.metres.
4.	Average recovery	Kg.per cu.metre
5.	Average metal content of concentrates produced	%

COMMENTS:

I/We confirm that the particulars given above are correct to the best of my/our knowledge and have/have not been subject to audit.

Signature

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