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Department of Commerce

The University of British Columbia
Vancouver, Canada

Date 25 September 1990
The thesis presents an analysis of the influence of the international tin agreements (ITA) on the world tin industry between 1956 to 1985. The ITAs, the first of which came into effect in 1956, were jointly operated by tin producing and consuming countries. The International Tin Council (ITC) used a buffer stock and export controls to maintain the price of tin within a band. This experiment in stabilizing tin prices ended in October 1985, when the ITC was unable to continue its operations because it ran out of financial resources.

The study first analyzes the market structure of the world tin industry in some detail. Then an econometric model which attempts to capture the behaviour of supply, demand and price of tin over the 30 year period is constructed. Particular attention was paid to the estimation of the tin production functions for major tin producing countries.

In many of these countries, the output of the tin depended not only on the price of tin but also on the policies of the ITC as well as the internal political environment of the country. The model is then used to simulate a scenario in which the ITC does not intervene in the tin market. The differences in the price and revenue levels between the actual and simulated scenario are computed. The simulation results show that the tin agreements succeeded in their objective of reducing the variability of price and producers' revenue. In addition, the average level of price and revenues under the ITC regime was higher than under the non-intervention scenario. In evaluating policy options, it was shown that the
establishment of a cartel is not viable in the long term for both economic and political reasons. The recommended policy options include improving access to futures markets, providing better transparency of tin market operations, the establishment of government policies which provide better incentives for tin mining and tin using industries in the major tin producing countries and continued efforts in research and development with the aim of lowering costs of production and increasing the uses for tin.
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1. INTRODUCTION

1.1 Overview of the problem

Commodity prices tend to fluctuate much more than the prices of manufactured goods. In the case of many agricultural commodities, price instability usually arises from variations in supply largely caused by changes in weather conditions. In the case of minerals, where supply is more stable, the uncertainty originates mainly from changes in demand caused by business cycles in the industrial world. Since short run demand and supply price elasticities are very low for most primary commodities, small changes in either supply or demand lead to large swings in price. McNicol (1978) calculated the coefficient of variation of prices for 15 commodities and 4 manufactured items over the period 1951-1975. The coefficient of variation for the 15 primary commodities ranged from a low of 0.14 for wheat to a high of 0.61 for sugar. In contrast, the coefficient for the 4 manufactured items varied from 0.06 to 0.13 only.

The production and export of primary commodities is extremely important to the economies of most developing countries. For example, in the 1970s, commodity exports (including oil) accounted for almost 80 percent of the total export earnings of developing countries taken together (Adams and Behrman, 1982). Commodity price instability need not lead to instability in export earnings if the exports of a country are well diversified. However, the exports of many developing countries are concentrated in a few products, the
prices of which often tend to move together. So, in general, export earnings of developing
countries tend to be more unstable than those of developed countries.\(^1\)

Instability of export earnings would not be a serious problem if international capital
markets are perfect. In such a scenario, a country experiencing a drop in export earnings
could borrow from international capital markets and repay the loans when export earnings
are higher than average. Most developing countries have had difficulty in getting sufficient
access to international capital markets. Private financial institutions regard loans to many
of these countries as highly risky, especially after the recent well publicized loan defaults
by some large Latin American countries. International institutions have limited mandates
and even more limited resources to handle the demand for such loans. The International
Monetary Fund’s Compensatory Financing Facility and the STABEX programme operated
by the European Economic Community (EEC) do attempt in a limited manner to help
developing countries cope with fluctuations in export earnings. The STABEX programme,
however, is applied to only 12 commodities and limited to those developing countries
which were signatories to the Lome agreement (Stakhovitch, 1978).

Therefore, it is not surprising that commodity policy has been receiving increased
attention from economists and policy makers, especially after the success of the
Organization of Petroleum Exporting Countries (OPEC) in raising the price of oil in the

---

\(^1\)A related and more controversial issue is the claim by Prebisch (1959) that there has been a secular
deterioration in the terms of trade of primary commodities in relation to manufactured goods. This argument
has not withstood subsequent scrutiny on both theoretical and empirical grounds (Junz and MacAvoy, 1977).
1970s. Developing countries have been urging, particularly within the United Nations Conference on Trade and Development (UNCTAD), for the establishment of an international price stabilization scheme for other primary commodities. On the political level, the establishment of such a scheme has become one of the most important aspects of the call for a New International Economic Order (NIEO). A resolution calling for the establishment of an Integrated Program for Commodities (IPC), initially covering ten core commodities\(^2\) was adopted by UNCTAD IV held at Nairobi in 1976. Since then, the debate on commodity policy has intensified, focusing primarily on such issues as the desirability of commodity price stabilization and the distribution effects of such schemes. Indeed the distribution effect is one of the main concerns of this study.

1.1.1 Desirability of price and export stabilization

There are a number of arguments put forward in support of the desirability of stabilization of price and export earnings. Firstly, some supporters of price stabilization argue that fluctuations in the export earnings of developing countries are an important obstacle to development. For example, Adams and Behrman (1982) claim that:

Public and private planning is more difficult because of resulting instabilities, productive domestic investments are discouraged by uncertainty and risk aversion, policies to deal with the resulting instability divert resources from growth, human and physical capital productivities are lower because of cyclical variations in utilization, and foreign investment is discouraged or is available only at a higher cost because of increased risk. These may induce the use of substitutes by risk-averse foreign importers abroad and thereby

\(^2\)They are cocoa, coffee, tea, sugar, cotton, jute, sisal, rubber and tin.
cause downward movements in the secular terms of trade due to the resulting long-run demand reductions (p. 21).

Empirical studies on the magnitude of this problem, however, have produced inconclusive results. MacBean (1966) and Knudsen and Parnes (1975) found that export instability had a positive, though not a very significant impact on economic growth in developing countries. Using the permanent income hypothesis, Knudsen and Parnes have argued that export instability in these countries increases the average savings rate out of permanent income which in turn leads to higher investment and growth rates. Other empirical studies provide contradictory findings. The mixed nature of these results is due to methodological flaws and to the wide differences that exist among the developing countries (McNicol, 1978). In other words, export instability may be a serious problem to many but not all developing countries. It has also been argued that stable export earnings would improve the debt servicing ability of many developing countries, thus stabilizing the international monetary system (Cline, 1979).

A second benefit of price stabilization schemes is that the resulting reduction in price variations is beneficial to risk-averse producers and consumers. Newbery and Stiglitz (1981) claim that this reduction in risk borne by producers is the major direct welfare gain of price stabilization and that it has not been given sufficient attention in earlier studies. However, they suggest that instead of price stabilization schemes, policies aimed specifically at stabilizing income may be more beneficial to risk-averse producers.

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3 See Adams and Behrman (1982, p. 44-53) for a critical review of such empirical studies.
Thirdly, it has also been argued that price fluctuations affect the costs incurred by buyers and sellers. According to McNicol (1978):

Increases in the magnitude of price fluctuations tend to increase cost in three ways. First, as the degree of price instability increases, both buyers and sellers may be led to employ more working capital and hold larger inventories. Second, price instability can increase costs by requiring changes in production rates, creating problems of scheduling the work force, complicating purchasing decisions, and so forth. Third, instability in prices typically implies instability in suppliers' returns, and, as returns become more variable, the cost of capital to suppliers increases (p. 22).

However, he asserts that the effects are small in magnitude.

Fourthly, it has been alleged that the dynamic macroeconomic effects through reduced inflationary pressures that result from commodity price stabilization bring about benefits in a more important way for consumers in the developed world (Cline, 1979). Imported inflationary shocks from rising commodity prices (as in the 1972-74 worldwide commodity boom) provoke macroeconomic policies that in the pursuit of reducing inflation, depress economic activity. As a result, unemployment rises, and real output is lost. Because of noncompetitive pricing by industrial firms as well as the nature of macroeconomic policy making, these output losses attributable to rising commodity prices probably are not fully offset by corresponding output gains once commodity prices fall again. Thus price stabilization would probably create a net macroeconomic gain for industrial countries (p. 17). However, Newbery and Stiglitz (1981), while accepting the argument that the macroeconomic benefits of price stabilization could be significant, are sceptical that these benefits can "be quantified even approximately" (p. 36).
Fifthly, a number of writers have justified market interventions on the ground that commodity markets are imperfect. For example Behrman (1979) states:

"... pure competition clearly does not prevail everywhere outside of international commodity markets; therefore the theory of the "second best" suggests that for purposes of economic efficiency, it may be preferable that it not prevail in international commodity markets either (p. 71)."

While acknowledging the nonexistence of conditions for perfect competition in many commodity markets, others have argued that the costs of intervention may have been systematically underestimated. Newbery and Stiglitz (1981) claim that an important reason for this is that most of the earlier studies assumed that there would be no change in behaviour by producers as a result of the introduction of a commodity price stabilization scheme; however, their behaviour does change. One of the main consequences of these changes is an increase in the cost of operating the buffer stock scheme. Their main conclusion is that "price stabilization schemes have limited efficacy in stabilizing the real spendable income of producing countries and that most of the other benefits associated with the stabilization schemes are transfer benefits which, in many cases, seem to benefit the consuming countries at the expense of the producing countries" (p. 39-40).

Opponents of price stabilization suggest that the problems that arise from price and export instability can be better alleviated by alternative policy instruments. These include the introduction of income stabilization schemes within the country, the establishment of better futures markets and credit markets within the developing countries and allowing easier borrowing for these countries through the IMF compensatory financing scheme. All such schemes have their own benefits and drawbacks.
Nevertheless, theoretical models of price stabilization\(^4\) indicate that price stabilization in commodity markets can potentially improve the overall world welfare; but the distribution of benefits and costs depends upon the precise specification of the model and the nature of the stochastic disturbances i.e. whether they are additive or multiplicative (Turnovsky, 1978). Thus the issue of who benefits from price stabilization is basically an empirical one (Behrman, 1979). In a similar vein, Newbery and Stiglitz (1981) state that in any one of the markets that is being examined "there may be particular features which need to be taken into account to assess the desirability of commodity price stabilization for that market" (p. 46).

1.1.2 The international tin agreements

Attempts to stabilize the price of primary commodities have been carried out for a long time (Rowe, 1965). In the period between the first and second world wars, a number of producer arrangements were implemented to control the price of some commodities. These arrangements yielded mixed results. After the second world war, the international economic order, which was dominated by the United States, was in favour of free trade. This was manifested in the principles laid down in the charter drawn up at a conference held at Havana in 1947-48 to discuss the formation of the International Trade

\(^4\)See discussion in chapter 6 and Turnovsky (1978) for a review of theoretical models of price stabilization.
Organization (ITO).\(^5\) Basically the Havana Charter was strongly in favour of free trade; it prohibited trade restrictions of any kind. However, recognizing that trade in primary commodities was subject to marked swings in prices, Article 55 of the Charter did provide an exception for international commodity agreements (ICA) under certain conditions (Rangarajan, 1978).

Tin was one of the commodities for which an international agreement was negotiated successfully in the 1950s. The first of the six five year agreements, signed by the major tin producing and consuming countries came into effect in 1956. Under its terms, the International Tin Council (ITC) was established to administer the agreement. Both producing and consuming member nations had equal strength in the Council. The purpose of the ITAs was to stabilize tin prices within an agreed upon range by using export controls and a buffer stock.\(^6\) The buffer stock was financed solely by producers. The role of the ITC’s buffer stock manager was to intervene in the London Metal Exchange (LME) and the Kuala Lumpur Tin Market (KLTM) to keep tin prices within the designated range.

The agreement was renewed five times. The sixth International Tin Agreement (ITA) came into effect on 1 July 1982 and was due to expire on 30 June 1987. However, for all practical purposes, the three decade long experiment in stabilizing tin prices by

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\(^5\) The ITO, however, was not established due to the reluctance of many countries to give up their national rights to control trade policy. Instead of it, a body with a more limited mandate in the form of the General Agreement on Tariffs and Trade (GATT) was established. It was felt at that time that the GATT would eventually be part of the ITO when it was formed.

\(^6\) Table 4.1 shows the periods when export control was imposed by the ITC.
means of an intergovernmental agreement between producing and consuming countries came to an end in 1985. On the morning of 24 October 1985, the buffer stock manager informed the London Metal Exchange (LME) that he was unable to continue the price support operations in the tin market because he had run out of funds (Wall Street Journal, 28 October 1985, p. 36). He asked the LME committee to suspend trading to avoid a collapse in price, and trading was stopped for an indefinite period. By the next day, trading was also suspended on the other two major organized markets for tin, the KLTM and the New York market. The price of tin on the KLTM on 25 October 1985, the last day of trading, was M$29.50 per kg. When the market reopened on 3 February 1986, tin was trading around M$17.00 per kg. By the middle of 1986, the price dropped to M$14.00 per kg., less than half the pre-suspension price.

This halving of the tin price has affected the economies of the tin producing countries, though by varying degrees of severity. Others affected by this crisis include the bankers, who lent money to the buffer stock manager on the security of the ITC's tin stocks, and the tin brokers at the LME, who suffered a loss as a result of the buffer stock manager not fulfilling his obligations to them. The affected parties took legal action against the ITC and the LME. After a lengthy trial, the issue was finally resolved in an out of court settlement in March 1990.

The United Nations Conference on Trade and Development (UNCTAD) plan for a Common Fund under the Integrated Programme for Commodities (IPC) has included
tin as one of its core commodities. In UNCTAD's deliberations in 1976, and thereafter, the ITAs have been held up as a model of compromise between commodity producing and consuming nations. However, progress has been very slow in developing similar agreements for other commodities. The demise of the sixth ITA is a major setback for those who support such commodity agreements.

1.2 Purpose of the study

The collapse of the ITA marked the end of the longest continuous period that a commodity price stabilization scheme under an ICA was in effect. As we saw earlier, there is a great need to carry out detailed empirical studies on individual commodity markets to determine the impact of price stabilization schemes on the performance of those markets. More specifically, it is important to determine whether these schemes raise or lower average prices, whether the producers or consumers benefit more, and how the behaviour of market participants changes as a result of these schemes. Thus, this study will focus mainly on evaluating the impact of the ITAs on the performance of the international tin industry over the thirty year period of 1956 to 1985, during which the ITAs existed.

The failure of the sixth ITA and the subsequent sharp decline in the price of tin has compelled tin producing countries to review their strategies. Some nations, including Malaysia, Indonesia and Thailand, are in favour of forming a tin producers cartel to
regulate output in order to obtain better prices. Others, such as China and Brazil, are not interested in joining the proposed cartel, at least for the time being (Far Eastern Economic Review, 13 November 1986, p. 115). So, in addition to the evaluation of the impact of the tin agreements, the study will evaluate the implications of a free market for the major tin producing nations and the viability of a cartel among them.

More specifically, the study will involve the following:

(a) a structural analysis of the post-war international tin industry;
(b) the construction of an econometric model which captures the behaviour of the tin market from 1955 to 1985;
(c) the use of this model to compute the changes in prices and revenue of the main tin producing countries and the change in expenditure of the tin consuming countries; and
(d) an evaluation of the viability of a tin cartel among the major tin producing countries and the implications of a free market regime in the tin industry.

1.3 Overview of the study

An analysis of the structure of the international tin market is provided in chapter 2. The discussion includes a statistical description of production, consumption and trade in tin over the period 1955-1985. In addition, the question of concentration in the tin mining and smelting industry are discussed in some detail. Factors affecting the consumption pattern such as the trends in material substitution and the changing pattern
of uses are also examined. This is followed by a description of the three formal markets
where tin was traded. The existence of the international tin agreements since the 1950s
has been a major influence on the world tin market. The chapter concludes with a
chronological account of the operations and the eventual collapse of the ITAs.

Chapter 3 surveys the literature on econometric modelling of mineral commodities
in general and tin market models in particular. In chapters 4 and 5 we will specify and
estimate a new econometric model for tin. Chapter 4 will concentrate on tin supply
functions while the consumption functions and the stock equations are dealt with in
chapter 5. In chapter 6, the model will be first validated in a dynamic setting; then it will
be used to simulate a market free from interventions by the ITC. The results of the
simulation will be used to evaluate the impact of the tin agreements on tin prices and
producer revenues. In chapter 7, after outlining the developments in the tin industry since
1985, we will discuss the policy options that are available to the tin producing countries.
The final chapter will summarize the findings of the study, discuss its limitations and
suggest areas for future research.

1.4 Significance of the study

By examining the structure of the tin industry in some detail and showing how the
structure influenced the behaviour in this industry, the study contributes to the analysis of
market structure in mineral industries. Another contribution of this study is in the area
of econometric modelling of commodities. The econometric model developed in this thesis is an improvement on earlier econometric models of tin particularly in the estimation of tin supply functions. Country specific institutional and political factors were incorporated into the supply functions in a comprehensive manner to add more realism to the model. A third area to which this study contributes is the field of commodity price stabilization. As mentioned in section 1.1.1, the issue of who benefits from price stabilization is basically an empirical question. Our study provides empirical evidence that the producers benefitted from the ITC price stabilization scheme. This aspect of the study may be of interest to international organizations like UNCTAD which have argued for the establishment of the Integrated Commodities Programme (IPC). Finally, some aspects of this study, particularly the issues of cartelization and improvement of the free market will be of interest to policy formulators and decision makers in tin producing countries.
2. THE MARKET FOR TIN

Tin was one of the first metals known to mankind. Its strategic importance in ancient times was due to the fact that when a small amount of tin was mixed with copper, an alloy that was stronger and harder than pure copper was formed. This was bronze, which was used as early as 3000 B.C. in Sumeria. The importance of bronze is indicated by the term, "Bronze Age", used by historians to describe the period in which bronze arms and tools were dominant.\(^1\) In modern times, tin has a wide variety of uses arising from its combination of special properties. In its pure form, tin is a silvery-white metal which is soft and highly malleable. Its other properties include corrosion resistance, non-toxicity, a bright and shiny appearance, ability to form a variety of complex chemical compounds and a low melting point. Its main uses are in the coating of tinplate, the manufacture of solder and other alloys, and in the production of tin-based chemicals.

This chapter provides an overview of the world tin market. A few developing nations produce most of the world's tin, and in some of these countries, the state plays a dominant role in the industry. These, and other issues related to the supply of tin, are discussed in the first section of this chapter. The second section deals with the consumption of tin, including the growing importance of substitution in many of the uses for tin. In the third section, the tin marketing system is examined. One of the most important features of the tin market is the interventions by the International Tin Council

\(^1\)An account of the social and economic history of tin can be found in Hedges (1964).
Table 2.1: Production, price and availability data on selected metals

<table>
<thead>
<tr>
<th>Metal</th>
<th>Production in 1985 (1000 tonnes)</th>
<th>Cash prices on 10 Feb 1987 (US$ per kg)</th>
<th>Average crustal concentration (grams/tonne)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aluminium</td>
<td>15430.2</td>
<td>1.27</td>
<td>83000.0</td>
</tr>
<tr>
<td>Copper</td>
<td>8436.0</td>
<td>1.46</td>
<td>63.0</td>
</tr>
<tr>
<td>Zinc</td>
<td>6918.1</td>
<td>0.90</td>
<td>94.0</td>
</tr>
<tr>
<td>Lead</td>
<td>3547.9</td>
<td>0.57</td>
<td>12.0</td>
</tr>
<tr>
<td>Tin</td>
<td>197.0</td>
<td>9.24</td>
<td>1.7</td>
</tr>
<tr>
<td>Silver</td>
<td>13.4</td>
<td>195.80</td>
<td>0.075</td>
</tr>
<tr>
<td>Gold</td>
<td>1.2</td>
<td>14212.55</td>
<td>0.046</td>
</tr>
<tr>
<td>Platinum</td>
<td>0.2</td>
<td>18638.42</td>
<td>0.0035</td>
</tr>
</tbody>
</table>


and the United States government to influence price movements. The final section provides an overview of these interventions.

2.1 Supply of tin

There are two significant features of the geology of tin that affect the supply of tin ore. The first is the relative scarcity of tin in comparison to other non-ferrous metals. This scarcity is reflected in the production and price levels of non-ferrous metals as shown in table 2.1. Both in terms of production and price, tin holds a position between that of the other non-ferrous metals and the precious metals. Baldwin (1983) suggests that the "levels of production and price reflect, among other things, basic geological endowments" (p. 8). These endowments, shown in table 2.1, are usually expressed in terms of the average degree of concentration in the earth's crust, regardless of site, form, or the accessibility of the mineral. The second feature of interest is the uneven distribution of
tin deposits in the world. Most of the known reserves of tin are found in a few developing
countries located in Southeast Asia and South America. Thus the leading producers of
tin since the end of the last century have come from these two regions.

2.1.1 World mine production of tin

The geographical distribution of mine production of tin since 1929 is shown in table
2.2. Malaysia has remained the largest producer for most of this century, accounting for
35 to 40 percent of the output of the western world. Since 1977, this proportion has been
declining, and in 1985, it reached a low of 23.3 percent. The other important producers
in Southeast Asia are Indonesia and Thailand. Together these three Southeast Asian
nations have accounted for about three-fifths of the western world’s output of tin for most
of this century. This proportion has declined somewhat in the eighties due, in part, to the
export controls imposed by the International Tin Council (ITC).

Traditionally, Bolivia has been an important producer of tin. Its tin mines are
located in difficult, mountainous terrain, between 3,000 to 5,000 metres above sea level.
Tin mining in Bolivia became important only after the decline of silver mining towards the

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2A detailed account of the distribution of world tin reserves is provided in Appendix 1.

3Unless otherwise indicated, the statistical information in this chapter is based on Tin Statistics, which was
published annually by the International Tin Council. Mine production is stated in terms of tin-in-concentrates,
which is the tin content of the utilizable ores.

4The ITC export controls and its effects are discussed later in this chapter.
Table 2.2: Mine output of tin-in-concentrates, 1929-1986 (1000 tonnes)  

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<tbody>
<tr>
<td>Malaysia</td>
<td>73.5</td>
<td>78.5</td>
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<td>38.2</td>
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<td>14.9</td>
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<td>32.5</td>
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<td>24.6</td>
</tr>
<tr>
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<td>10.1</td>
<td>16.1</td>
<td>10.5</td>
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<td>12.3</td>
<td>19.4</td>
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<td>16.4</td>
<td>33.7</td>
<td>16.6</td>
<td>16.8</td>
</tr>
<tr>
<td>Bolivia</td>
<td>47.0</td>
<td>25.5</td>
<td>31.7</td>
<td>28.4</td>
<td>20.5</td>
<td>23.4</td>
<td>30.1</td>
<td>32.0</td>
<td>27.3</td>
<td>16.1</td>
<td>10.5</td>
</tr>
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<td>Brazil</td>
<td>-</td>
<td>-</td>
<td>0.2</td>
<td>0.1</td>
<td>1.6</td>
<td>1.8</td>
<td>3.7</td>
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<td>0.1</td>
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<tr>
<td>Zaire</td>
<td>1.0</td>
<td>9.1</td>
<td>11.9</td>
<td>13.3</td>
<td>9.3</td>
<td>6.3</td>
<td>6.5</td>
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<td>8.8</td>
<td>9.3</td>
<td>11.6</td>
<td>6.9</td>
</tr>
<tr>
<td>U.K.</td>
<td>3.4</td>
<td>2.0</td>
<td>0.9</td>
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<td>1.2</td>
<td>1.3</td>
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<tr>
<td>Others</td>
<td>6.6</td>
<td>14.5</td>
<td>7.9</td>
<td>9.9</td>
<td>7.6</td>
<td>9.4</td>
<td>11.6</td>
<td>16.1</td>
<td>17.8</td>
<td>24.0</td>
<td>17.5</td>
</tr>
<tr>
<td>Total</td>
<td>192.5</td>
<td>198.2</td>
<td>164.7</td>
<td>170.4</td>
<td>138.3</td>
<td>154.8</td>
<td>185.1</td>
<td>180.6</td>
<td>199.2</td>
<td>157.3</td>
<td>138.9</td>
</tr>
</tbody>
</table>

Notes:  
*The figures given in this table excludes production from the centrally planned socialist countries.*  

... end of the last century. By the early twenties, Bolivia was producing one-sixth of the world's output. The 1929 output of 47,000 tonnes, which represented about 25 percent of world production, has never been exceeded. During the Second World War, Bolivia became the most important source of tin for Allied nations, due to the Japanese occupation of Southeast Asia. Following the 1952 revolution, and subsequent nationalization of the large tin mining companies, Bolivia's tin output has been unstable, reaching a low of about 18,000 tonnes in 1958. During the sixties, production recovered, reaching over 30,000 tonnes by 1970. In the seventies, production was stagnant and has been declining since 1981. The fall in output is mainly due to the exhaustion of the better grade ores and the political and economic troubles in the country.
In the last decade, Brazil has emerged as a major tin producer. In 1975 its output of 4,500 tonnes accounted for only 2.5 percent of the western world production; by 1985, the corresponding figures increased to 26,500 tonnes and 16.7 percent, respectively, making Brazil the second largest tin producer in the world. In 1988, it became the largest tin producer. The main reason for this phenomenal growth in output is the discovery and subsequent development of extensive deposits of exceptionally high grade ores in that country. Moreover, Brazil's non-participation in the International Tin Agreements enabled it to expand its production without being restricted by the export controls imposed by the ITC in the early 1980s.

Nigeria and Zaire accounted for about 10 percent of the world output until the late 1960s, but have become less important sources of tin in the last two decades. Among the industrialized countries, Australia is the only important producer, accounting for an average of about 5 percent of the western world's output since 1970. Tin output in the United Kingdom has increased somewhat in the early 1980s as a result of a revival in the Cornish tin mining industry, no doubt helped by the high prices during this period. A new Canadian tin mine, with a planned production of 4,500 tonnes of tin concentrates, started operations in 1986 in East Kemptville, Nova Scotia.
Among centrally planned economies, only China and the U.S.S.R. are important tin producers. According to the estimates in *Metal Statistics*, China’s output has been between 16,000 and 18,000 tonnes in the 1980s. If that is true, then in 1985, China would have been the fourth largest tin producer in the world, after Malaysia, Brazil and Indonesia. According to some trade sources, within the next few years Chinese output of tin may exceed 30,000 tonnes. As for the Soviet Union, many of its mines are located in permafrost or near permafrost regions in Siberia and in other northeastern parts of the country, where the cost of operations is high. Estimates of Soviet production vary widely depending on the source. The U.S. Bureau of Mines (1985, p. 848) estimated the Soviet Union’s tin production in 1983 to have been 37,000 tonnes whereas *Metal Statistics* estimated it to be less than half of that at 17,000 tonnes. Whatever is the true output, it has not been sufficient to meet its own demand; the Soviet Union has been a net importer of tin since the sixties.

In recent times, an important source of supply has been the tin concentrates that have been smuggled out of Indonesia, Malaysia and Thailand, to avoid the high export taxes and royalties as well as the ITC export controls. Smuggled tin or tin from "unspecified origins" as it is often labelled, has been estimated by the ITC to be as high as 16,550 tonnes in 1983. However, with the removal of export controls in 1986 and reduction of taxes in Malaysia and Thailand, tin smuggling has declined sharply.

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5 The major difficulty in discussing tin production in the socialist countries is the unavailability of reliable data on production and consumption.

6 *Malaysian Tin*, April 1986 and *Mining Magazine*, January 1986, provide more details.
2.1.2 Production technology and costs

There are three main methods of mining: dredging, gravel pumping and underground mining. Dredges produce about a quarter of the western world's output of tin. They are found mainly in Southeast Asia. In Indonesia and Thailand, both offshore and onshore dredges are used, while in Malaysia only onshore dredges are used. About half of the western world's tin is produced by gravel pumps. They are used extensively in Brazil, Indonesia, Malaysia and Thailand. Underground mining methods account for about 15 to 20 percent of the western world's output of tin. Practically all of Bolivia's output is from underground mines. Other countries with underground tin mines are Australia, China and the United Kingdom.

In general, dredges and underground mines operate with low variable costs and high fixed costs while gravel pumps have a relatively higher variable cost and lower fixed costs. Despite these differences, in the short run, the fixed costs and shutdown costs are sufficiently high in the entire industry to discourage temporary closures of the mines. In the medium run, however, gravel pump mines with their relatively lower fixed and shutdown costs are more flexible in expanding and contracting their output in response to perceived long term changes in prices.

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7A more detailed account of the costs and technology used in the tin mining and smelting industry is provided in appendix 2.
2.1.3 Structure of the tin mining industry

The industry structure varies greatly from country to country, and this is largely due to the unique political and economic environment that exists in each country. In this subsection, after reviewing the industry structure in the major tin producing countries, some general observations will be made on the worldwide tin mining industry.

Malaysia. Mining activity in Malaysia, by type of mine for selected years, is shown in table 2.3. Gravel pump and dredging operations, together, have accounted for more than 80 percent of Malaysia's production. The gravel pump sector is highly competitive. Most of the mines are owned by Chinese Malaysian entrepreneurs. In general they are independent from one another in ownership and control. The dredging sector is dominated by the Malaysian Mining Corporation (MMC), which is a holding company having varying degrees of ownership interest in most of the dredging companies and mine management agencies in Malaysia. In recent years, through its subsidiaries, MMC has been responsible for more than 35 percent of Malaysia's output of tin concentrates. Though the shares of MMC are traded in the local stock exchanges, the Malaysian government has a controlling stake in MMC. In addition to the federal government, some state governments are also increasing their participation in the tin mining industry, particularly in the dredging sector.
Table 2.3: Mining activity in Malaysia for selected years

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</thead>
<tbody>
<tr>
<td>Dredges</td>
<td>55</td>
<td>31.6</td>
<td>54</td>
<td>29.7</td>
<td>30</td>
<td>30.8</td>
<td>29</td>
<td>30.6</td>
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<tr>
<td>Gravel pumps</td>
<td>810</td>
<td>54.7</td>
<td>746</td>
<td>56.1</td>
<td>353</td>
<td>52.3</td>
<td>207</td>
<td>50.2</td>
</tr>
<tr>
<td>Others</td>
<td>45</td>
<td>8.9</td>
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<td>66</td>
<td>11.5</td>
<td>43</td>
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<tr>
<td>Dulang washers</td>
<td>-</td>
<td>4.8</td>
<td>-</td>
<td>5.3</td>
<td>-</td>
<td>5.4</td>
<td>-</td>
<td>6.2</td>
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<tr>
<td>Total</td>
<td>910</td>
<td>100.0</td>
<td>852</td>
<td>100.0</td>
<td>449</td>
<td>100.0</td>
<td>279</td>
<td>100.0</td>
</tr>
</tbody>
</table>

Notes: *The number of mines is a year-end figure while the percentage of output of tin-in-concentrates is for the whole year.  
*This includes open cast and underground mines.  

As can be seen from table 2.3, there has been a sharp decline in mining activity in the 1980s. The number of dredges that were operating at the end of 1985 was about half the 1980 figure. In the gravel pump sector, the reduction has been even more pronounced. Only about a quarter of the gravel pump mines that were operating at the end of 1980 were still functioning five years later. This is a continuation of a trend that began in the early 1970s.

Malaysia's tin production reached a high of 76,830 tonnes of tin-in-concentrates in 1972 and, since then, it has been on a generally downward trend. In 1985, Malaysia's output was only 36,884 tonnes. A number of factors have contributed to this slump in the tin mining industry. According to Baldwin (1983):

This decline in mine production is commonly attributed to three closely linked causes: increased taxation; the lack of availability of new tin-bearing land under stringent licensing policies; and, underlying both, efforts to promote ownership and management of Malaysian business enterprise by the
An additional factor is the export controls imposed by the ITC in the 1980s. The closures in the gravel pump sector have accelerated since the October 1985 tin crisis, due to the sharp drop in tin prices. The price reduction has affected gravel pump mines more than dredges because of the difference in their cost structures. Since November 1985, for many Malaysian gravel pump operators, variable cost has been higher than the price of tin and there is very little hope that the price will increase sufficiently in the near future to cover variable costs. Thus, many of the operators have been forced to close down. According to a Malaysian Department of Mines report, of the 345 gravel pumps that were operating at the end of September 1985, only 161 remained in operation four months later; it was expected that "the situation will continue to worsen over the next few months" (Sumun, 1986, p. 14).

With the decline of the gravel pump sector and the domination of the dredging sector by companies that are controlled by federal and state governments, the role of the public sector in the tin mining industry has increased. This heightens the possibility that political rather than economic factors may dominate decision-making in the tin mining industry of Malaysia.

**Thailand.** Table 2.4 shows the number of mines and the share of output of the various sectors of the Thai tin mining industry. Aside from the dredging sector, the industry is composed of many small mines, mostly owned and operated by Thais of Chinese descent.
Table 2.4: Mining activity in Thailand for selected years

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<tbody>
<tr>
<td></td>
<td>No. of mines</td>
<td>Output (%)</td>
<td>No. of mines</td>
<td>Output (%)</td>
<td>No. of mines</td>
<td>Output (%)</td>
<td>No. of mines</td>
</tr>
<tr>
<td>Dredges</td>
<td>15</td>
<td>16.6</td>
<td>33</td>
<td>12.9</td>
<td>28</td>
<td>23.1</td>
<td>24</td>
</tr>
<tr>
<td>Gravel pumps</td>
<td>244</td>
<td>39.9</td>
<td>392</td>
<td>29.6</td>
<td>324</td>
<td>30.2</td>
<td>279</td>
</tr>
<tr>
<td>Suction boatsb</td>
<td>1986</td>
<td>22.9</td>
<td>2230</td>
<td>42.6</td>
<td>11</td>
<td>24.2</td>
<td>14</td>
</tr>
<tr>
<td>Othersc</td>
<td>275</td>
<td>15.6</td>
<td>317</td>
<td>12.0</td>
<td>329</td>
<td>18.7</td>
<td>297</td>
</tr>
<tr>
<td>Dulang washers</td>
<td>-</td>
<td>5.0</td>
<td>-</td>
<td>2.9</td>
<td>-</td>
<td>3.8</td>
<td>-</td>
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<tr>
<td>Total</td>
<td>2520</td>
<td>100.0</td>
<td>2972</td>
<td>100.0</td>
<td>692</td>
<td>100.0</td>
<td>614</td>
</tr>
</tbody>
</table>

Notes: *The number of mines is a year-end figure while the percentage of output of tin-in-concentrates is for the whole year.

bThe figures for 1984 and 1985 are the number of mining concessions rather than the number of boats.

cThis includes open cast and underground mines.


The dredging sector is composed of offshore and onshore operations. The onshore dredges are owned by private firms, incorporated in Thailand, in which there is some foreign participation. Under a 1980 law, tin mining firms must have a minimum of 70 percent Thai ownership.

The offshore dredging sector is dominated by the government-owned Offshore Mining Organization (OMO), which has formed joint ventures with foreign and local firms to develop the offshore deposits. Offshore dredging firms face problems from suction boat operators who often mine in the waters leased to the dredging companies. In fact, most of the tin smuggled from Thailand is suspected to originate from suction boat operators. The sharp decline in the price of tin since October, 1985 has forced many of these operators to close down, thus mitigating the problem of smuggling.
Indonesia. For all practical purposes, the Indonesian tin industry is a state monopoly. The dominant firm, P.T. Tambang Timah, is fully owned by the Indonesian government and is responsible for most of the country’s output of tin. The remaining few operations in the industry are joint ventures between P.T. Tambang Timah and foreign firms. State control of the tin mining industry is not a recent development in Indonesia. Even under Dutch colonial rule, the tin industry in the Netherlands East Indies (as Indonesia was then known) was almost entirely owned and controlled by the colonial government. At the end of 1984, there were 209 gravel pumps, 17 offshore dredges and 10 onshore dredges operating in Indonesia. In 1984, gravel pumps accounted for 61 percent of total output, offshore dredges for 31 percent and onshore dredges for 8 percent.

Bolivia. Until 1952, about three quarters of Bolivian tin output was under the control of three large mining companies. In that year, they were nationalized and brought under the control of a single government owned organization, the Corporacion Minera de Bolivia (COMIBOL). In 1985, COMIBOL accounted for 62.2 percent of Bolivian output. The rest of the industry is in private hands and can be broadly divided into two categories: the medium-sized company-owned mines, which accounted for 23.4 percent of the 1985 output, and the small mines, generally owned by individuals and cooperatives, which were responsible for the remaining 14.4 percent of the output.

The medium-sized mines are quite large compared to the Southeast Asian mines. They have an average output several times that of a typical gravel pump mine in Malaysia.
They are generally more efficient than the small mines or COMIBOL operations, and have more modern equipment, as well as higher safety standards. The small mines are relatively primitive operations with low productivity. Many of these mines rework tailings left by the COMIBOL mines. Some work on veins which are too small to be operated efficiently by COMIBOL or by the medium-sized mines. In recent years, the whole industry has been operating in very difficult conditions due to the political and economic turmoil that is being experienced in Bolivia. The effects have been particularly serious for COMIBOL, which operates the large underground mines.\(^8\)

**Brazil.** The Brazilian mining industry is relatively new and is privately owned, with some foreign participation. One notable feature is the high degree of concentration, with the Paranapanema group producing about two thirds of Brazil's output in 1984 and 1985. Most of the mines are located in the remote regions of the upper Amazon basin. Gravel pumping is the preferred method of mining in Brazil. As mentioned earlier, the grade of the ore in the newly discovered mines is of high quality and hence the cost of production is the lowest of all the major producers of tin. With its low cost structure, the Brazilian tin industry has been expanding rapidly in the 1980s.

**Australia.** As in Brazil, there is a very high degree of concentration in the Australian tin industry. According to Baldwin (1983, p. 177), Renison Consolidated Goldfields Ltd.,

\(^8\) Ayub and Hashimoto (1985) provide a detailed account of the political economy of the tin mining industry in Bolivia.
which operates the large Renison underground mining complex in Tasmania, produced nearly half of Australia's output in 1980. Another quarter of the output was accounted for by the second largest firm, Aberfoyle Ltd. With the collapse in the price of tin since October 1985, Aberfoyle and many other smaller mines have been forced to scale down their operations. At the same time, the removal of the ITC export controls in 1986 has allowed the more efficient Renison mine to expand its output, so as to operate closer to its full capacity, thus lowering its unit cost of production. Thus, the domination of the Australian tin mining industry by Renison has further increased.

**Overall structure.** One of the most interesting features of the global tin mining industry is the limited role played by multinational corporations. This is in sharp contrast to the situation with other minerals. Multinational firms were more prominent before the second world war. Since then, they have been replaced, largely by government-controlled firms, in many tin producing countries. The most dominant multinational in the tin industry, at present, is the Billiton group, which is controlled by the Royal Dutch Shell company. Billiton companies operate in Brazil, Indonesia, Thailand and Zimbabwe. The Billiton group is also extensively involved in the marketing and trading of tin. Other important multinationals are the Consolidated Gold Fields Ltd, which has ownership interests in the Renison mine in Australia as well as in tin mining companies in South Africa, and the Rio Tinto Zinc Corporation, which has interests in Malaysia, Brazil and the United Kingdom. Baldwin (1983, p. 181), using the most generous estimates of production and capacity

---

figures, has calculated the combined output produced and controlled by the top five private international tin mining companies to be less than 9 percent of the total western world production.

In comparison to the limited role of the multinational firms, there is a high degree of state participation in the industry, particularly in Indonesia, Bolivia and Malaysia. Baldwin (1983) has estimated that the government owned organizations in Malaysia, Indonesia, Thailand, Bolivia, Nigeria and Zaire accounted for about 36 percent of the western world output of tin-in-concentrates. In the last few years, tin production in Brazil where the industry is completely controlled by the private sector, has increased sharply; at the same time, Bolivian output, particularly that of the government controlled COMIBOL, has dropped. This means that the market share of government controlled firms would recently have declined.

More than half the output of the western world is produced by privately owned firms which are not multinationals. Ownership and control is very diffused in this sector. As we saw above, there is a large variety in the scale of operations, ranging from the small suction boats in Thailand to the large underground mines in Australia and Bolivia. Though many of the smaller mines have ceased operations following the sharp decline in the price of tin since October 1985, the world tin mining industry as a whole is very competitive, and will likely remain so given the recent market events.
Table 2.5: Smelter output of tin metal, 1950-1985 (1000 tonnes)*

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<tbody>
<tr>
<td>Malaysia</td>
<td>69.9</td>
<td>71.8</td>
<td>77.6</td>
<td>73.6</td>
<td>91.5</td>
<td>83.1</td>
<td>71.3</td>
<td>45.5</td>
</tr>
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<td>Indonesia</td>
<td>0.4</td>
<td>2.0</td>
<td>2.0</td>
<td>1.2</td>
<td>5.2</td>
<td>17.8</td>
<td>30.5</td>
<td>20.9</td>
</tr>
<tr>
<td>Thailand</td>
<td>-0-</td>
<td>-0-</td>
<td>0.2</td>
<td>5.6</td>
<td>22.0</td>
<td>16.6</td>
<td>34.7</td>
<td>18.0</td>
</tr>
<tr>
<td>Bolivia</td>
<td>0.4</td>
<td>0.1</td>
<td>1.0</td>
<td>3.5</td>
<td>0.3</td>
<td>7.6</td>
<td>17.5</td>
<td>11.4</td>
</tr>
<tr>
<td>Brazil</td>
<td>0.1</td>
<td>1.2</td>
<td>1.3</td>
<td>1.4</td>
<td>3.6</td>
<td>6.5</td>
<td>8.8</td>
<td>24.7</td>
</tr>
<tr>
<td>Nigeria</td>
<td>-0-</td>
<td>-0-</td>
<td>-0-</td>
<td>9.5</td>
<td>8.1</td>
<td>4.7</td>
<td>2.7</td>
<td>1.0</td>
</tr>
<tr>
<td>Zaire</td>
<td>3.3</td>
<td>3.1</td>
<td>2.5</td>
<td>1.8</td>
<td>1.4</td>
<td>0.6</td>
<td>0.3</td>
<td>0.1</td>
</tr>
<tr>
<td>Australia</td>
<td>2.0</td>
<td>2.0</td>
<td>2.3</td>
<td>3.2</td>
<td>5.2</td>
<td>5.3</td>
<td>4.8</td>
<td>2.7</td>
</tr>
<tr>
<td>U.K.</td>
<td>29.0</td>
<td>27.7</td>
<td>26.8</td>
<td>16.8</td>
<td>22.0</td>
<td>11.6</td>
<td>5.8</td>
<td>7.5</td>
</tr>
<tr>
<td>Netherlands</td>
<td>21.4</td>
<td>27.0</td>
<td>6.5</td>
<td>18.4</td>
<td>5.9</td>
<td>1.8</td>
<td>1.1</td>
<td>5.3</td>
</tr>
<tr>
<td>Belgium</td>
<td>9.7</td>
<td>10.6</td>
<td>8.4</td>
<td>4.3</td>
<td>4.3</td>
<td>4.6</td>
<td>2.8</td>
<td>-0-</td>
</tr>
<tr>
<td>U.S.A.</td>
<td>32.6</td>
<td>22.7</td>
<td>13.7</td>
<td>3.1</td>
<td>4.5</td>
<td>6.4</td>
<td>3.0</td>
<td>3.0</td>
</tr>
<tr>
<td>Others</td>
<td>3.8</td>
<td>4.3</td>
<td>5.9</td>
<td>8.1</td>
<td>10.5</td>
<td>11.8</td>
<td>15.3</td>
<td>15.9</td>
</tr>
<tr>
<td>Total</td>
<td>172.6</td>
<td>172.5</td>
<td>148.2</td>
<td>150.5</td>
<td>184.1</td>
<td>178.4</td>
<td>198.6</td>
<td>156.0</td>
</tr>
</tbody>
</table>

Notes: *The figures given in this table excludes production from the centrally planned socialist countries.

2.1.4 The tin smelting industry

Smelter output of tin metal for selected years is shown in table 2.5. Since the 1960s, the trend has been for the producing nations to increasingly smelt their own concentrates and export the tin metal rather than the concentrates. In 1960, 55 percent of the western world production of tin-in-concentrates were exported to other countries for smelting; in 1970 and 1980, the proportions were 30 percent and 16 percent, respectively (Baldwin, 1983, p. 163). The change in the ranking of the five top countries in terms of smelter output in 1955 and 1985, as shown in table 2.6, confirms the shift of the smelting industry to producer nations.
### Table 2.6: Ranking of mine and smelter output by country in 1955 and 1985

<table>
<thead>
<tr>
<th>Rank</th>
<th>Mine output</th>
<th>Smelter output</th>
<th>Mine output</th>
<th>Smelter output</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Malaysia</td>
<td>Malaysia</td>
<td>Malaysia</td>
<td>Malaysia</td>
</tr>
<tr>
<td>2</td>
<td>Indonesia</td>
<td>U.K.</td>
<td>Brazil</td>
<td>Brazil</td>
</tr>
<tr>
<td>3</td>
<td>Bolivia</td>
<td>Netherlands</td>
<td>Indonesia</td>
<td>Indonesia</td>
</tr>
<tr>
<td>4</td>
<td>Zaire</td>
<td>U.S.A.</td>
<td>Thailand</td>
<td>Thailand</td>
</tr>
<tr>
<td>5</td>
<td>Thailand</td>
<td>Belgium</td>
<td>Bolivia</td>
<td>Bolivia</td>
</tr>
</tbody>
</table>

**Source:** International Tin Council, *Tin Statistics*, various issues.

The shift is in response to the desire of the newly independent countries to capture as much as possible of the potential value added from their production of minerals. In the case of tin, it was not too difficult to translate this desire into action, since barriers to entry "are of only negligible to moderate significance in tin smelting" (Baldwin, 1983, p. 162).

According to Baldwin (1983) there are no important economies of scale beyond the capacity of a single reverberatory furnace, which is estimated to be about 1,000 tonnes per year. Treatment of the high grade alluvial ores is a relatively straightforward technical process; it is only in the treatment of complex ores there appears to exist a moderate technical barrier to entry.

This addition of new smelting capacity in tin producing countries has led to the current situation of excess capacity in the industry. In 1982, the smelting industry in the western world operated at less than 60 percent of its annual capacity of 308,500 tonnes (Bleiwas *et al.*, 1986, p. 50). At the individual country level, the situation is even more acute. Malaysia has two smelters, each of which has a capacity of about 60,000 tonnes per
year, making them the largest two tin smelters in the world. Together they produced only 45,500 tonnes in 1985 which implies a capacity utilization of only 38 percent.

Another consequence arising from the building of new smelters in tin producing countries has been the increasing degree of government ownership or control in the smelting industry. In Bolivia and Indonesia, the new smelters are owned and controlled almost exclusively by government-owned firms. In Malaysia, MMC, the government-controlled giant tin mining company, owns a large minority interest in both smelters. Among the top five producer countries, only in Brazil and Thailand, is the smelting industry privately owned.

Despite the increased level of participation by the public sector, the overall level of concentration in the global smelting industry has decreased. According to Baldwin (1983), the largest smelting group had a 43 percent market share in 1929, and by 1975, it had decreased to 22 percent. However, the degree of vertical integration between the mines and smelters has increased. This has reduced the supply of ores to many of the independent non-integrated tin smelters, particularly those located in Europe. As a result, some of them have been forced to close down their operations. In summary, given the relatively low levels of barriers to entry, and the current excess capacity, the global smelting industry clearly has a competitive structure.
2.1.5 Secondary tin

As with other metals, a portion of the world consumption of tin comes from secondary or recycled tin. However, data on secondary tin availability and usage is very sketchy and limited, except in the United States, which is the world's largest producer of secondary tin (Bleiwas et al, 1986, p. 5). The consumption of secondary tin in the United States for the period 1965 to 1985 ranged from about 11,000 tonnes to 26,000 tonnes (Carlin, 1985, p. 3 and Robertson, 1982, p. 119). This constituted about 20 to 30 percent of the total tin consumed in the United States during that period.

Secondary tin is of two forms: (a) secondary tin metal in an unwrought form and (b) secondary tin contained in alloys like solder and bronze where it is not separated from the other constituents; it is recycled in the alloys themselves. In the U.S., about 90 percent of the secondary tin produced is of the latter form (U.S. Bureau of Mines, 1985, p. 850).

Secondary tin metal is not inferior in quality to primary tin. Thus, it competes directly with primary tin in the market. Almost all the unalloyed secondary tin metal is obtained from the treatment of tinplate scrap in detinning plants. Only about 10 percent of tin used in tinplate ends up as tin scrap to be recycled. The other 90 percent ends up in garbage dumps in the form of discarded tin cans (Robertson, 1982). Technologies based on magnetic separation are available to separate the ferrous fraction (largely used tin cans) from the rest of the domestic garbage (ITRI, 1982). However, it appears that these
methods are not economically viable at current prices unless there is some form of public subsidy (Robertson, 1982).

In discussing the influence of the price of tin on the supply of secondary tin, Robertson (1982) cited a number of previous studies to conclude that this is an unresolved question. It depends not only on the price of tin, but also on the prices of steel, copper, zinc, lead and other metals with which tin is alloyed. The cost of recovery will also influence the supply of secondary tin. For example, in detinning plants, secondary tin is a byproduct, since the steel in the tinplate scrap is more valuable. The supply of tin from this source, therefore, will be more responsive to changes in the price of steel than to changes in the price of tin. In general, it appears that there is little variation in the total supply of secondary tin (Chhabra et al, 1978, p. 11).

2.2 Demand for tin

Tin is rarely used as a final product. It is mainly used as a protective coating or as an alloy with other metals. Thus, the demand for tin is a derived demand. It is basically an industrial metal consumed in small quantities in a wide range of industries. As such, its consumption is highly concentrated in the more industrialized countries. The following subsection reviews the trends in the consumption of tin. After that, the uses of tin are discussed in some detail.
2.2.1 World consumption of tin

The United States has been the largest consumer of tin throughout this century, though its share of the total world consumption has declined considerably in recent times, as shown in table 2.7. In 1955, the United States consumed about 61,000 tonnes or 42 percent of the total western world consumption; by 1985 the proportion dropped to about 23 percent. The decline in the consumption of tin in the U.K. was even more pronounced. In 1955, the U.K. was the second largest consumer, using about 23,000 tonnes or 16 percent of the reported total. By 1985, its consumption had dropped both in relative and absolute terms, so that it is now barely the fifth largest consumer, accounting for about 6,000 tonnes or less than 4 percent of the western world consumption. In contrast, Japanese consumption of tin increased remarkably during the same period. Japan is now the second largest consuming country, accounting for nearly 32,000 tonnes, which is about 20 percent of the western world consumption. This compares to the less than 7,000 tonnes or 4.5 per cent of world consumption in 1955. The top five consuming nations together accounted for 74.1 percent of the total western world consumption in 1955. By 1985, this concentration had declined to 60.6 percent.

These trends in the consumption pattern mirror the changes that have taken place in those nations' shares of the world industrial output. Japan's share in the world industrial production has risen sharply during this period while the shares of the U.K. and to a lesser extent, of the U.S. have declined. Also, as some of the developing countries
Table 2.7: World consumption of tin, 1955-1985 (1000 tonnes)\(^a\)

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>U.S.A.</td>
<td>60.8</td>
<td>52.4</td>
<td>59.5</td>
<td>53.9</td>
<td>43.6</td>
<td>44.3</td>
<td>37.2</td>
</tr>
<tr>
<td>Japan</td>
<td>6.6</td>
<td>13.1</td>
<td>17.4</td>
<td>24.7</td>
<td>28.1</td>
<td>30.9</td>
<td>31.6</td>
</tr>
<tr>
<td>West Germany</td>
<td>8.3</td>
<td>28.2</td>
<td>11.8</td>
<td>14.1</td>
<td>12.0</td>
<td>14.3</td>
<td>15.7</td>
</tr>
<tr>
<td>France</td>
<td>9.9</td>
<td>11.3</td>
<td>10.3</td>
<td>10.5</td>
<td>10.0</td>
<td>10.1</td>
<td>6.9</td>
</tr>
<tr>
<td>U.K.</td>
<td>22.8</td>
<td>22.1</td>
<td>19.6</td>
<td>17.0</td>
<td>12.2</td>
<td>6.4</td>
<td>6.0</td>
</tr>
<tr>
<td>Italy</td>
<td>3.0</td>
<td>4.6</td>
<td>5.8</td>
<td>7.2</td>
<td>6.3</td>
<td>5.8</td>
<td>5.0</td>
</tr>
<tr>
<td>Brazil</td>
<td>1.3</td>
<td>1.6</td>
<td>2.1</td>
<td>2.5</td>
<td>4.3</td>
<td>5.0</td>
<td>4.6</td>
</tr>
<tr>
<td>Netherlands</td>
<td>2.6</td>
<td>3.1</td>
<td>3.4</td>
<td>5.5</td>
<td>3.6</td>
<td>5.2</td>
<td>4.3</td>
</tr>
<tr>
<td>Canada</td>
<td>4.1</td>
<td>3.9</td>
<td>5.0</td>
<td>4.6</td>
<td>4.3</td>
<td>4.8</td>
<td>3.8</td>
</tr>
<tr>
<td>Others</td>
<td>30.9</td>
<td>29.4</td>
<td>38.1</td>
<td>45.6</td>
<td>48.6</td>
<td>48.3</td>
<td>45.7</td>
</tr>
<tr>
<td>Total</td>
<td>150.2</td>
<td>169.9</td>
<td>173.1</td>
<td>185.5</td>
<td>172.8</td>
<td>175.0</td>
<td>160.8</td>
</tr>
</tbody>
</table>

Notes: \(^a\)The figures given in this table excludes consumption in some centrally planned socialist countries.

have become more industrialized, their consumption of tin has increased. For example, Brazil consumed only about 1,300 tonnes or less than 1 percent of the western world total in 1955. By 1980, however, its consumption had increased to about 5,000 tonnes or 3.1 percent of the western world consumption.

Consumption in the centrally planned socialist countries has not varied very much in the last 20 years, and has ranged between 50 to 60 thousand tonnes. Though China and the U.S.S.R. are major tin producers, as a group, the communist nations have been net importers of tin.

Overall, there has been very little growth in the world consumption of tin in the last sixty years. According to Robertson (1982):
Average consumption in the years 1925-9 was 154,000 tonnes. Fifty years later it had grown by only one-third...... (p. 77).

(In contrast) copper consumption doubled between 1920 and 1929, and increased fourfold between 1929 and 1976. Zinc consumption doubled between 1920 and 1929, and increased nearly three and a half times between 1929 and 1976. Lead consumption doubled between 1920 and 1929, and again between 1930 and 1976. Nickel consumption increased nearly thirteen times between 1930 and 1976 (p. 100).

Robertson and others (Fox, 1974; Williamson, 1985) have argued that the main cause for the stagnation in the consumption of tin is the relatively high price of tin, which has encouraged various substitutes. The substitution of tin by other materials is also encouraged by strategic considerations based on:

.........suspected or even imagined difficulties in the continuity of the supply of tin both in the near and distant futures. In particular, the drive for substitutes is likely to be strong when an important consuming country (e.g. the U.S.A.) possesses no domestic mine resource of tin and when many of the normal outside sources are geographically remote or subject to political tension (Hedges, 1964, p. 44).

However, a study of three tin-using industries indicated that price was not the most important factor that caused substitution.\(^{10}\) Technological change was the most critical factor. Government regulations and changing consumer tastes were also significant factors.

---

\(^{10}\)This study, which is reported in Tilton (1983), described in detail the role of tin in three applications (beverage containers, solder, and tin chemical stabilizers), and investigated the factors that produced the gradual displacement of tin.
Table 2.8: Consumption of tin by use for selected countries

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Tinplate</td>
<td>62600</td>
<td>63400</td>
<td>47900</td>
<td>42900</td>
<td>29800</td>
</tr>
<tr>
<td>(%)</td>
<td>(39.9)</td>
<td>(43.4)</td>
<td>(40.3)</td>
<td>(36.1)</td>
<td>(27.9)</td>
</tr>
<tr>
<td>Solder</td>
<td>34200</td>
<td>35100</td>
<td>28600</td>
<td>30200</td>
<td>33200</td>
</tr>
<tr>
<td>(%)</td>
<td>(21.8)</td>
<td>(24.0)</td>
<td>(24.1)</td>
<td>(25.4)</td>
<td>(31.1)</td>
</tr>
<tr>
<td>Bronze and brass</td>
<td>22600</td>
<td>12300</td>
<td>9300</td>
<td>8600</td>
<td>7000</td>
</tr>
<tr>
<td>(%)</td>
<td>(14.4)</td>
<td>(8.4)</td>
<td>(7.8)</td>
<td>(7.2)</td>
<td>(6.6)</td>
</tr>
<tr>
<td>White metal</td>
<td>11300</td>
<td>12200</td>
<td>10300</td>
<td>8300</td>
<td>5500</td>
</tr>
<tr>
<td>(%)</td>
<td>(7.0)</td>
<td>(8.3)</td>
<td>(8.7)</td>
<td>(7.0)</td>
<td>(5.1)</td>
</tr>
<tr>
<td>Tinning</td>
<td>6800</td>
<td>6900</td>
<td>4800</td>
<td>5800</td>
<td>3900</td>
</tr>
<tr>
<td>(%)</td>
<td>(4.3)</td>
<td>(4.7)</td>
<td>(4.0)</td>
<td>(4.9)</td>
<td>(3.6)</td>
</tr>
<tr>
<td>Other uses</td>
<td>19800</td>
<td>16300</td>
<td>18000</td>
<td>23000</td>
<td>27400</td>
</tr>
<tr>
<td>(%)</td>
<td>(12.6)</td>
<td>(11.2)</td>
<td>(15.1)</td>
<td>(19.4)</td>
<td>(25.7)</td>
</tr>
<tr>
<td>Total</td>
<td>157000</td>
<td>146200</td>
<td>118900</td>
<td>118800</td>
<td>106800</td>
</tr>
<tr>
<td>(%)</td>
<td>(100.0)</td>
<td>(100.0)</td>
<td>(100.0)</td>
<td>(100.0)</td>
<td>(100.0)</td>
</tr>
</tbody>
</table>

Notes: *The countries are U.S.A., Japan, France, West Germany, U.K. and Italy.  
Figures may include some tin used in terneplate.  
Figures include tin used in babbitt and anti-friction metal.  
The main use under this category is for chemicals.  

2.2.2 The patterns of tin usage

As shown in table 2.8, between 1965 and 1985 there has been a decline in the consumption of tin for tinplating, especially in the 1980s. Tin use in bronze and brass also has declined, though most of the decline occurred in the 1960s. On the other hand, the
proportion of the total consumption of tin that is used under the categories of solder and 'other uses' increased during this period.\(^\text{11}\)

Until the early 1980s, the largest use of tin was in making tinplate, which is steel sheet or strip coated with a very thin layer of tin. Tinplate is mostly consumed in the packaging industry, especially, to produce the ubiquitous tin can, which is commonly used as containers for food and beverages. As the last column in table 2.9 indicates, from 1950 to 1980, about 40 percent of the total consumption of tin has been used for tinplating. Since then, the proportion has declined to about one-third of the total.

There has been a continuous decline in the intensity of usage of tin in tinplating during the entire period. Thus in 1985 almost twice as much tinplate was produced using 14 percent less tin than in 1950. This reduction in the intensity of tin usage was largely due to the introduction of the electrolytic process in the 1940s to replace the older hot-dip process. This new technology enabled greater control over the uniformity and thickness of tin coating, leading to great savings in the use of tin. As shown in table 2.9, the average percentage by weight of tin used in tinplate was 1.22 percent in 1945, when a large proportion of tinplate was produced by the hot-dip process. By 1985, when almost all tinplate was produced using the electrolytic process, it had declined to a low of 0.48

\(^{11}\)The figures in table 2.8 are based on the tin consumption patterns in the leading industrial economies in which the electronics and chemical industries are relatively more advanced. Therefore, the distribution of consumption of tin by uses for the whole world will show slightly lower percentages for the categories of solder and 'other uses' (whose main component is tin-based chemicals) and a higher percentage for the tinplate sector. For example, in 1985, 32.5 per cent of the world consumption of tin was used to make tinplate; the comparable figure for the top six industrial economies as shown in table 2.8 was 27.9 percent.
Table 2.9: Tin used in tinplate production, 1945-1985

<table>
<thead>
<tr>
<th>Year</th>
<th>Tinplate produced (1000 tonnes)</th>
<th>Tin used for tinplate (1000 tonnes)</th>
<th>Percentage of tin in tinplate (%)</th>
<th>Percentage of tin used for tinplate production (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1945</td>
<td>2825</td>
<td>34.5</td>
<td>1.22</td>
<td>35.5</td>
</tr>
<tr>
<td>1950</td>
<td>5646</td>
<td>60.2</td>
<td>1.07</td>
<td>39.2</td>
</tr>
<tr>
<td>1955</td>
<td>6877</td>
<td>63.5</td>
<td>0.92</td>
<td>42.3</td>
</tr>
<tr>
<td>1960</td>
<td>9164</td>
<td>72.0</td>
<td>0.79</td>
<td>42.4</td>
</tr>
<tr>
<td>1965</td>
<td>10726</td>
<td>73.3</td>
<td>0.68</td>
<td>42.8</td>
</tr>
<tr>
<td>1970</td>
<td>12403</td>
<td>75.0</td>
<td>0.60</td>
<td>41.8</td>
</tr>
<tr>
<td>1975</td>
<td>11560</td>
<td>67.0</td>
<td>0.58</td>
<td>38.8</td>
</tr>
<tr>
<td>1980</td>
<td>12978</td>
<td>67.9</td>
<td>0.52</td>
<td>38.8</td>
</tr>
<tr>
<td>1985</td>
<td>10869</td>
<td>51.8</td>
<td>0.48</td>
<td>32.5</td>
</tr>
</tbody>
</table>


percent. Tinplating technology is expected to continue improving to enable even thinner coating in the future.

Demand for tinplate became stagnant in the 1970s, and appears to be declining in the 1980s. This is due to the intense competition faced by tinplate in the packaging industry from aluminium, glass, plastic, tin-free steel, paper and other packaging materials. Moreover, the increased availability of frozen, dehydrated and other forms of processed food, due to innovations in the food processing industry, also affected the demand for tinplate. So, both the declining demand for tinplate and the decreasing

---

12 Computing the percentage in terms of weight understates the reduction in the amount of tin used per tin can. Improved technology has enabled the surface area coated by a kilogram of tin to be increased substantially. Thus, a study in the U.S. showed that the tin content of the average tinplate container was reduced by 93 percent between 1950 and 1977 (Tilton, 1983, p. 4).

13 The study on tin usage in the beverage container industry, which is reported in Chapter 2 of Tilton (1983), provides an interesting example of the dynamics of this competition.
intensity of tin usage in tinplate, has continued to reduce tin consumption in the tinplate sector.

The most important non-tinplate use for tin is in soft solder, an alloy of tin and lead. Soft solder accounts for between a quarter and a third of the world consumption of tin. Traditionally, the largest user of soft solder was the motor vehicle industry, where it was employed mainly for soldering radiators. Improvements in technology, coupled with the increased popularity of smaller cars, has reduced the demand for solder in this industry. There has been a similar decline in the demand for solder in the plumbing industry due to the substitution of lead pipes with copper pipes, and later with plastic pipes, which require no solder at all. The decline in the usage of the three-piece cans with soldered side seams in the beverage industry has also caused a drop in the demand for solder.

However, there is one major end-use industry in which there has been a sustained increase in the use of solder, and that has been the electronics industry. The introduction of the printed circuit board enabled the automation of the soldering process using a solder bath. This increased the usage of solder by 5 to 10 times per electronic product (Tilton, 1983, Chapter 4). Moreover, the tin content in the solder had to be increased from an average of 50 percent to 65 percent, in order to get better quality products. With the subsequent miniaturization of electronic products that resulted from innovations in solid state technology, the amount of solder used per joint has shrunk considerably. But this has been more than compensated by the sharp increase in the volume of output of the
electronics industry. In overall terms, the demand for tin in solder is expected to remain stable or increase slowly.

The tin chemicals sector, which is the major component of the category labelled other uses in table 2.8, has enjoyed high growth rates in the last two decades. Tin-based organic compounds are used as fungicides, germicides, insecticides, anti-fouling agents and stabilizers in polyvinyl chloride (PVC). Inorganic tin compounds are used in a wide variety of products ranging from toothpaste to dyes. Bronze and brass have become less important users of tin. Brass is increasingly being substituted with stainless steel or plastics, in its various applications.

In addressing the future prospects of tin, it is very difficult to make definitive statements. Research into substitutes in the industrialized nations is inevitable for strategic and economic reasons. However, tin has a number of unique and desirable properties. In addition, it is an ecologically more attractive material than many of its substitutes (Baldwin, 1983, p. 54). Tin-based chemicals degrade easily when exposed to sunlight and oxygen. Unlike aluminium and plastic, tinplate decomposes as it rusts. But ultimately, the competitive strength of tin can be improved only by more research and development as the following quote illustrates:

On the consumption side, there is a great need for successful end-use research to develop new markets for tin. The tin industry has lagged behind other major metals in research to develop commercially successful new uses. It is possible that properly funded and directed research could result in new applications that would utilize tin's corrosion resistant properties, its
electrical conductivity, its excellent wettability, or its ability to form a variety of complex chemical compounds (U.S. Bureau of Mines, 1985, p. 858).

2.3 International trade and the marketing system

As we have seen in the previous sections, most of the world’s output of tin is from developing nations while most of the leading consuming nations have virtually no tin resources of their own. This has led to a high degree of concentration in exports and imports, which parallels the concentration found in the production and consumption of tin. In this section we will discuss the changing patterns of trade in tin and the marketing system.

2.3.1 Trade patterns in tin

Tables 2.10 and 2.11 show the leading net exporters and importers of tin, respectively, for 1975, 1980 and 1985. Though Malaysia has been the leading exporter of tin throughout this century, its dominance has declined in the last ten years. In 1985 it accounted for just under 28 percent of the world’s exports of tin. Though Singapore does not have any tin resources of its own, it was the second largest net exporter of tin in 1985. Singapore’s exports originate from the tin concentrates that are smuggled from the neighbouring Southeast Asian countries. The rise of Brazil as an exporter of tin is very recent. Though it consumes more tin than most other developing countries, the rapid rise in production has resulted in a large surplus, which is exported. In 1980, Brazil’s exports
Table 2.10: Net exports of tin for selected years

<table>
<thead>
<tr>
<th></th>
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<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Quantity (tonnes)</td>
<td>Percentage of total</td>
<td>Quantity (tonnes)</td>
</tr>
<tr>
<td>Malaysia</td>
<td>58488</td>
<td>35.9</td>
<td>60235</td>
</tr>
<tr>
<td>Singapore</td>
<td>1569</td>
<td>1.0</td>
<td>13428</td>
</tr>
<tr>
<td>Brazil</td>
<td>1795</td>
<td>1.1</td>
<td>902</td>
</tr>
<tr>
<td>Indonesia</td>
<td>18581</td>
<td>11.4</td>
<td>29569</td>
</tr>
<tr>
<td>China</td>
<td>15200</td>
<td>9.3</td>
<td>4200</td>
</tr>
<tr>
<td>Thailand</td>
<td>16661</td>
<td>10.2</td>
<td>33445</td>
</tr>
<tr>
<td>Bolivia</td>
<td>26442</td>
<td>16.2</td>
<td>21762</td>
</tr>
<tr>
<td>Australia</td>
<td>6867</td>
<td>4.2</td>
<td>8845</td>
</tr>
<tr>
<td>Zaire</td>
<td>4961</td>
<td>3.0</td>
<td>2206</td>
</tr>
<tr>
<td>Burma</td>
<td>5234</td>
<td>3.2</td>
<td>2118</td>
</tr>
<tr>
<td>Peru</td>
<td>-0-</td>
<td>-0-</td>
<td>703</td>
</tr>
<tr>
<td>Nigeria</td>
<td>4666</td>
<td>2.9</td>
<td>2719</td>
</tr>
<tr>
<td>Others</td>
<td>2496</td>
<td>1.5</td>
<td>3234</td>
</tr>
<tr>
<td>Total</td>
<td>162960</td>
<td>100.0</td>
<td>183366</td>
</tr>
</tbody>
</table>

Notes: *Net exports are calculated as the sum of exports of tin metal and tin-in-concentrates minus the sum of imports of tin metal and tin-in-concentrates.


were less than 1 percent of the total world exports of tin. Five years later, the proportion had increased to more than 11 percent.

Export figures for China are not very reliable. They are based on the reports provided by importing countries. Notwithstanding this unreliability, it is still clear that there was a sharp increase in China's tin exports from 1980 to 1985. The high price of tin that prevailed until 1985 has been a major cause for this increase. The high price has also encouraged the entry of some non-traditional exporters, like Peru. However, there has been declines in exports from some other countries for different reasons. The decline in the exports of Malaysia, Indonesia and Thailand are partly due to the export controls
### Table 2.11: Net imports of tin for selected years

<table>
<thead>
<tr>
<th></th>
<th>1975</th>
<th></th>
<th>1980</th>
<th></th>
<th>1985</th>
<th></th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Quantity</td>
<td>Percentage of total</td>
<td>Quantity</td>
<td>Percentage of total</td>
<td>Quantity</td>
<td>Percentage of total</td>
</tr>
<tr>
<td></td>
<td>(tonnes)</td>
<td></td>
<td>(tonnes)</td>
<td></td>
<td>(tonnes)</td>
<td></td>
</tr>
<tr>
<td>U.S.A.</td>
<td>47185</td>
<td>29.1</td>
<td>42527</td>
<td>25.5</td>
<td>32591</td>
<td>24.2</td>
</tr>
<tr>
<td>Japan</td>
<td>21748</td>
<td>13.4</td>
<td>31027</td>
<td>18.6</td>
<td>28226</td>
<td>21.0</td>
</tr>
<tr>
<td>W. Germany</td>
<td>13979</td>
<td>8.6</td>
<td>16068</td>
<td>9.6</td>
<td>16918</td>
<td>12.6</td>
</tr>
<tr>
<td>U.S.S.R</td>
<td>10300</td>
<td>6.4</td>
<td>15552</td>
<td>9.3</td>
<td>13521</td>
<td>10.0</td>
</tr>
<tr>
<td>Netherlands</td>
<td>5296</td>
<td>3.3</td>
<td>5586</td>
<td>3.4</td>
<td>7504</td>
<td>5.6</td>
</tr>
<tr>
<td>France</td>
<td>9660</td>
<td>5.9</td>
<td>10112</td>
<td>6.1</td>
<td>6301</td>
<td>4.7</td>
</tr>
<tr>
<td>Italy</td>
<td>5229</td>
<td>3.2</td>
<td>6299</td>
<td>3.8</td>
<td>5007</td>
<td>3.7</td>
</tr>
<tr>
<td>Canada</td>
<td>4168</td>
<td>2.6</td>
<td>4283</td>
<td>2.6</td>
<td>3491</td>
<td>2.6</td>
</tr>
<tr>
<td>S. Korea</td>
<td>821</td>
<td>0.5</td>
<td>1309</td>
<td>0.8</td>
<td>3146</td>
<td>2.3</td>
</tr>
<tr>
<td>Poland</td>
<td>4510</td>
<td>2.8</td>
<td>3309</td>
<td>2.0</td>
<td>3029</td>
<td>2.3</td>
</tr>
<tr>
<td>Spain</td>
<td>2521</td>
<td>1.6</td>
<td>2697</td>
<td>1.6</td>
<td>2848</td>
<td>2.1</td>
</tr>
<tr>
<td>U.K.*</td>
<td>8751</td>
<td>5.4</td>
<td>4980</td>
<td>3.0</td>
<td>-0-</td>
<td>-0-</td>
</tr>
<tr>
<td>Others</td>
<td>28107</td>
<td>17.3</td>
<td>23054</td>
<td>13.8</td>
<td>12150</td>
<td>9.0</td>
</tr>
<tr>
<td>Total</td>
<td>162275</td>
<td>100.0</td>
<td>166803</td>
<td>100.0</td>
<td>134732</td>
<td>100.0</td>
</tr>
</tbody>
</table>

**Notes:**  
*Net imports are calculated as the sum of imports of tin metal and tin-in-concentrates minus the sum of exports of tin metal and tin-in-concentrates.*  
*The U.K. became a net exporter of tin in 1985.*


imposed by the ITC. The reduction in the exports of Bolivia, Nigeria and Zaire appears to be due to internal production problems.

The United States has been the leading importer of tin since the early part of this century. Among the top seven importers, shown in table 2.11, only the Soviet Union has sizeable tin resources of its own. However, the U.S.S.R. does not produce enough to satisfy its needs, and it imports a significant amount of tin. Normally, the U.K. is a significant net importer of tin. However, in 1985 the United Kingdom became a net
exporter of tin for the first time this century! This reversal is due to a combination of the decreasing consumption of tin in the U.K. and the revival of the country's tin mining industry. The only developing country among the top ten net importers of tin is South Korea, whose imports in 1985 were nearly four times those in 1975. This reflects the rapid growth in the industrial output of that nation.

2.3.2 The marketing system

Prior to October 1985, the three most important markets where tin was traded were the London Metal Exchange (LME), the Kuala Lumpur Tin Market (KLTM) and the New York market. Trading was suspended in October 1985 on all the three markets, following the announcement by the ITC that its buffer stock manager had run out of money, leaving debts of around £900 million. Trading was resumed on the KLTM and the New York market in early 1986 and on the on the LME in June 1989.

The London Metal Exchange. The LME is an organized exchange that facilitates trading in the main non-ferrous metals. In fact, the contract in tin was one of the LME's two original contracts with over a century of trading behind it. The LME dealt in both physical tin contracts and forward tin contracts. The LME's principal use was for hedging and speculation. Actual metal transactions were less than 15 percent of the total trade on the exchange (Robertson, 1982, p. 129). Prices on the LME tended to fluctuate more than the

14 Its net exports in 1985 was 313 tonnes which was less than 0.2 percent of the total world exports.
prices on the other two markets, due in part to these speculative activities. Compared to the trading in other non-ferrous metals, trading in tin is thinner and hence the market is more susceptible to large fluctuations; it also makes it easier to corner the market. Trading in tin contracts was suspended in October 1985. Meanwhile, a grey market developed in Europe. The LME resumed trading in tin contracts in June 1989. It now operates on a clearing house system, unlike the old system in which the traders themselves acted as principals and there was no automatic enforcement of margin calls.\footnote{Gemmil (1985) argues that if the LME had used a clearing house, tin trading need not have been suspended following the October 1985 crisis.}

The Kuala Lumpur Tin Market. The KLTM is an important market in terms of its influence on global tin trading and distribution. A large proportion of the trade in tin concentrates and metal of Malaysia, Thailand, Indonesia, Australia and also of Bolivia, is based on the price of tin quoted at the KLTM. Since 1972, the ITC’s reference prices have been stated in terms of the KLTM prices (Baldwin, 1983, p. 192).

The KLTM officially started operating only on 1 October, 1984, when it replaced the long established Penang tin market. The KLTM operates on an open outcry system in which "daily trading will begin with a series of price tries by a call chairman with bids and offers then balanced to give the daily price fix" \textit{(Mining Journal, 21 September 1984, p. 197)}. Trading was initially limited to one tonne lots of high grade "fresh tin" (i.e. tin not previously traded) of Malaysian origin. Since January 1987, tin from Thailand and
Figure 2.1: Price of tin on the London Metal Exchange, 1950-85
Figure 2.2: Price of tin on the Kuala Lumpur Tin Market, 1950-85

TIN PRICE ON THE KLTM
1950 to 1985
Indonesia has also been traded on the KLTM, and the restriction on "fresh tin" has been removed (Malaysian Business, February, 1987). The KLTM is a physical market, and hence provides no facilities for hedging or speculating. Forward trading in tin began in the Kuala Lumpur Commodity Exchange in October 1987.

The New York Metal Market. Though it is the least important of the three markets, the significance of the New York market lies in the fact that it acts as the purchasing point for the United States, which is the largest consumer in the world. It is not an organized exchange like the LME and the KLTM. The New York tin price is provided by the tin editor of the American Metal Market on the basis of prices quoted to him or her by the major New York dealers.\(^\text{16}\)

After allowing for freight charges, insurance and exchange rates, the prices on the three markets have generally been equivalent. Figures 2.1 and 2.2 show the average annual tin prices on the LME and the KLTM, respectively, from 1950 to 1985. The divergence between the two prices is mainly due to changes in exchange rates.

\(^{16}\text{A more detailed account of this procedure can be found in Baldwin (1983, p. 205).}\)
Although some form of producer pricing\textsuperscript{17} is used for almost all metals, tin is an important exception. The main reason for this is the absence of vertical integration between producers, smelters and the users of tin. For example, if the major steel companies which produce tinplate were to be vertically integrated with tin mining and smelting companies, some form of producer pricing may have emerged. The absence of producer pricing does not imply that tin prices have always been determined in a free and competitive market environment. Since the 1920s, there have been many interventions in the tin market which were politically motivated. Since 1950, these include the actions of the ITC and the United States government, which has a large strategic stockpile of tin. Thus, the behaviour of tin prices cannot be explained without an understanding of these political interventions which are discussed in the next section.

2.4 The international tin agreements

When compared to other agricultural and mineral commodities, world trade in tin is relatively unimportant. Its distinctiveness is due to the long history of market interventions arising from international arrangements between governments to control its

\textsuperscript{17}The major firms involved in the production of non-ferrous metals sold a large portion of their output directly to consumers on long term contracts where the prices were fixed for the duration of the contract. Such prices are known as producer prices. Dealer prices or spot market prices are the basis for dealer transactions that call for current delivery of a fixed amount at a specified price. In the 1980s, producer pricing has become less important (MacAvoy, 1988).
output and price.\textsuperscript{18} The first phase of these international arrangements covered the interwar period, and only the tin producing nations were involved. In contrast, both the major producing and consuming countries were parties to the tin agreements in the second phase, which lasted from 1956 to 1985. Since the focus of this study is on the postwar international tin industry, only the second phase will be covered in this section.\textsuperscript{19}

When the war ended, the tin market was restored to normalcy quite rapidly and all restrictions on the use of tin were lifted by 1949. Tin mines in Southeast Asia were rehabilitated quickly and by 1948 supply exceeded commercial consumption. Given the changed post-war geopolitical atmosphere in which the United States was the dominant economic and military power, there was no question of reverting to the pre-war producer agreements to control the output of tin. So an International Tin Study Group (ITSG) made up of members from major tin producing and consuming countries was convened in a meeting held in April, 1947. It was given the task of drafting proposals for the establishment of an international tin organization which was to be in accordance with the principles of the Havana Charter that we referred to in section 1.1.2. After lengthy negotiations, numerous draft proposals and two international tin conferences convened by

\textsuperscript{18} The most comprehensive account of the history of international tin agreements can be found in Fox (1974). Knorr (1945) focuses on the economics of tin control during the inter-war years. Another detailed account covering the period up to the mid-1960s is provided by Yip (1969), though his emphasis is on the Malaysian tin industry.

\textsuperscript{19} Appendix 3 contains an account of the international tin control schemes of the interwar period. These arrangements had much influence on the evolution of the postwar ITAs.
the United Nations, an agreement was reached in 1953 and came into effect on 1 July 1956.\textsuperscript{20}

A major factor for the nine year delay between the formation of the ITSG in 1947 and the implementation of the tin agreement in 1956 was the purchase of tin by the United States for its strategic stockpile. Tin is one of the metals for which the United States depends completely on imports. Though the idea of a strategic stockpile of tin originated in the 1930s, it was only with the beginning of the second World War that the United States began buying tin for its stockpile. Its objective was to have a large enough reserve of tin to meet war time demand even if the war spread to Southeast Asia and tin supply from there was disrupted. Stockpile purchases were continued after the war due to the onset of the cold war with the Soviet Union and political turmoil in the major tin producing countries. These purchases absorbed the excess supply from 1948 and in fact encouraged a rapid expansion of production in the early postwar years. When the Korean War began in 1950, there was a general boom in commodity prices. In particular, the price of tin soared with the increased demand for stockpile purchases. By the time the U.S. ended its stockpile purchases in 1955, it had far too much tin. As Fox (1974) stated:

Neither party, when stockpiling ceased in 1955 and the U.S. was left sitting on top of around 350,000 tons of tin (the equivalent of over two years' total world production or of seven years of U.S. annual consumption), had yet seriously considered what would happen if the absurdity of these figures were to be fully realised in the U.S.A., and if any part of that gigantic holding were to be released, however gently, on the world market (p. 242).

\textsuperscript{20}See Fox (1974, Chap. 10) for a comprehensive account of the negotiations. He was the Secretary-General of the tin study group from 1948 to 1956 and the Secretary of the International Tin Council from 1956 to 1971.
The disposal of this stockpile has been a constant source of friction between the governments of the tin producing countries and the U.S. administration since then.

2.4.1 The First International Tin Agreement

The objectives of the first International Tin Agreement (ITA) were as follows:
(a) to prevent or alleviate widespread unemployment or underemployment and other serious difficulties which are likely to result from maladjustment between the supply of and the demand for tin;
(b) to prevent excessive fluctuations in the price of tin and to achieve a reasonable degree of stability of price on a basis which will secure long term equilibrium between supply and demand;
(c) to ensure adequate supplies of tin at reasonable prices at all times; and
(d) to provide a framework for the consideration and development of measures to promote the progressively more economic production of tin while protecting tin deposits from unnecessary waste or premature abandonment.

The governing body of the ITA was the International Tin Council (ITC) in which the tin producing and consuming countries that signed the agreement each as a group had 1000 votes. Each producing member received five initial votes; the remainder was to be divided among the producing members as nearly as possible in proportion to their individual percentages of production during the calendar years 1950 to 1952. This
distribution was changed annually and when there were changes in membership. Each consuming member also received five initial votes and an additional number reallocated each year on the basis of the mean consumption during the preceding three years. All important decisions required a distributed simple majority for approval.

Tin prices were to be stabilized within an initial range of £640 to £880 per long ton\textsuperscript{21} by using a buffer stock and export restrictions. The agreement provided for the council to revise the price range, if necessary. During the five years the first ITA was in effect there was only one change. In March 1957, the floor price was raised to £730 per ton. The ceiling price remained unchanged at £880 per ton. The buffer stock of 25,000 tons was to be financed entirely by the producing members. For the purpose of buffer stock operations, the price range was divided into three sectors. When the price is in the upper sector, set initially at £800 to £880 per ton, the buffer stock manager \textit{may} sell tin from the buffer stock to prevent the market price from rising too steeply. However, if the ceiling price is exceeded, he \textit{must} sell tin until either the price falls below the ceiling or the stock is exhausted. He should neither buy nor sell tin when the price is in the middle sector (£720-800 per ton). When the price is in the lower sector (£640-720 per ton), the buffer stock manager \textit{may} buy tin to prevent the market price from falling too steeply. Finally, when the price is equal to or below the floor price, the manager \textit{must} buy tin until either the price rises above that level or he runs out of funds. In addition to the buffer

\textsuperscript{21}Until the end of 1969, tin prices in the London Metal Exchange were quoted in £ per long ton. From the beginning of 1970, LME switched to the metric ton or tonne. In this and following chapters, a tonne refers to a metric ton and a ton refers to a long ton.
stock, the ITC could impose export controls on producing members if at least 10,000 tons of tin had accumulated in the buffer stock.

When the agreement came into force in July 1956, all the major non-communist tin producing countries were represented in the ITC. The consuming members in the ITC, however, represented less than 40 percent of the consumption of tin in the non-communist world. The most important non-participant was the United States which was the world's largest consumer of tin. The United States government initially supported the agreement at the 1953 international tin conference, though it was done more for political rather than economic reasons. Communist insurgency in Malaysia was at its highest levels during the early 1950s. It was thought that stability in the prices of its two major export commodities, tin and rubber, would give a measure of economic stability to the country and thus help in overcoming the political problems associated with communist terrorism in Malaysia. However, due to pressure from its tin using industries, the United States declared that it would not join the agreement but did not object to other countries joining the first ITA. It also confirmed that disposals from its stockpile would take place only at the president's direction. Most members of the ITC were quite pleased with this United States attitude of 'benevolent neutrality,' as it was known then. Besides the United States, the other major consuming countries which did not join the first ITA were West Germany, Japan and the Soviet Union.
The only serious problem encountered by the first ITA came from the unexpectedly large exports of tin from the Soviet Union in 1957 and 1958 amounting to 18,011 tons and 21,948 tons, respectively. In contrast, it exported only 3,248 tons of tin in 1956. As a result, the market price of tin was depressed and the ITC acted by purchasing tin for the buffer stock as well as imposing export controls for eleven quarters beginning in December 1957. The floor price was breached once in September 1958, when the buffer stock manager ran out of funds. Fortunately, after diplomatic representation from some ITC members (India, Indonesia, Malaysia and the United Kingdom), tin exports from the Soviet Union tapered off from 1959 and the price of tin recovered. Though export controls were removed in September 1960, tin production did not recover completely due to technical and political problems, especially in Bolivia, Indonesia and Zaire. So by the time the first ITA came to an end in June 1961, the situation had changed from one of surplus to one of tin shortage with the market price of tin remaining above the ITC ceiling price.

2.4.2 The Second International Tin Agreement

The second ITA, the terms of which were negotiated at an international tin conference convened by the United Nations in New York during May 1960, came into effect on 1 July 1961. There were very few changes from the first ITA. In the face of consuming countries’ continued unwillingness to share in the financing of the buffer stock, producing members were able to argue successfully for a reduction in the size of the buffer stock from 25,000 to 20,000 tons. However, this reduction was offset to some extent by a
new provision which allowed the buffer stock manager to increase his resources by borrowing funds on the security of the tin held in the buffer stock. The minimum quantity of tin that had to be in the buffer stock before export controls could be introduced was reduced to 5,000 tons. The voting procedure was also changed so that it now required a distributed two-thirds majority in the council to approve important decisions. The only major change in membership resulted from Japan's decision to join the second ITA as a consuming member.

During most of the five years during which the second ITA was in effect, consumption of tin persistently exceeded mine production of tin which led to lower inventories. In response to this shortage and the ensuing increase in the market price, the ITC price range was revised upwards three times: in January 1962 to £790-965 per ton, in December 1963 to £850-1,000 per ton, and finally in November 1964 to £1,000-1,200 per ton. The shortage was alleviated to some extent by sales from the United States strategic stockpile beginning from 1962. In the four-year period of 1963 to 1966, total disposals amounted to nearly 80,000 tons which was equivalent to about 12 percent of the non-communist world's tin consumption during the same period. For much of the life of the second ITA, the ITC could do very little to keep the market price effectively below the ceiling since it did not have sufficient metal in its buffer stock.
2.4.3 The Third International Tin Agreement

An international tin conference was convened in March 1965 at New York by the then newly formed UNCTAD for the purpose of negotiating a third tin agreement. After lengthy negotiations, the preamble to the agreement was completely rewritten to reflect the aspirations of the developing countries which viewed international commodity agreements as a means of ensuring not only stable but increased export earnings. Nevertheless, as Fox (1974) put it "the third agreement required little adaptation in its objectives, and no change in its machinery, to accommodate the new wind from UNCTAD" (p. 355). The sponsorship of the third ITA by UNCTAD also made it acceptable for some Eastern bloc countries such as Czechoslovakia, Poland, Hungary and Yugoslavia, who joined as consuming members.

The third ITA came into force on 1 July 1966 and at its first meeting held in the same month, the ITC approved an increase in the price range to £1,100-1,400 per ton. However, the improved supply situation coupled with continued United States stockpile sales resulted in a steady decline in the price of tin throughout 1966. Tin producers were unhappy with the United States over its tin sales. In October 1966, an ITC delegation met with U.S. officials in Washington and obtained an assurance from the United States that it would moderate its tin sales programme so as not to undermine the buffer stock operations of the ITC. According to Fox (1974), the United States agreed to curb its stockpile sales mainly for political reasons:
The U.S.A. was involved in the internal struggle for the control of the raw materials of Congo-Zaire; there had started a parallel struggle in Indonesia after the overthrow of the Left there under Sukarno; Bolivia seemed wide open to subversion. Above all, there was the war in Vietnam for which the Thai airfields were valuable. Much public opinion within the U.S. had shifted to oppose any further running down of strategic stocks. In such an atmosphere the few million dollars immediately involved in pressing on with a tin disposals programme unpopular in very sensitive international areas was of no importance (p. 348).

Sales from the stockpile dropped off sharply in 1967 and 1968. On 1 July 1968, commercial sales from the stockpile were suspended and did not resume until 1973.

In the wake of the November 1967 devaluation of the pound sterling, the price range was changed to £1,280-1,630 per long ton. To counter declining tin prices, mild export controls representing a restriction of only 4 percent were imposed from October 1968 to December 1969 by which time the market price had breached the ITC ceiling once again. The tin market remained steady through the first few months of 1970. In October 1970 the price range was increased again to £1,350-1,650 per tonne. By the time the third ITA came to an end in June 1971, the market had become weaker and the buffer stock manager had to step in buy tin to keep the price within the ITC range.

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22 With effect from January 1970, tin prices in the London Metal Exchange were quoted in £ per metric ton or tonne (1 tonne = 1000 kg = 0.984206 long ton).
2.4.4 The Fourth International Tin Agreement

The provisions in the fourth ITA, which were negotiated in 1970, remained essentially unaltered except for some changes which provided greater flexibility to the buffer stock manager. As for membership, the Soviet Union and West Germany joined as consuming members while Australia’s membership category was changed from that of a consumer to a producer. However, ITC members were unable to convince Brazil, which was becoming an increasingly important tin producer, to join the agreement. When the fourth ITA came into effect on 1 July 1971, the buffer stock manager continued with his price support operations and by the end of 1972 the buffer stock had more than 12,000 tonnes of tin. Meanwhile, an important precedent was set when two consuming members, France and the Netherlands, agreed to make voluntary contributions to the buffer stock in proportion to their votes in the ITC.

Another significant event that occurred in the life of the fourth ITA was the decision by the ITC to use the Penang market price as its reference price with effect from July 1972. A major reason for this switch was the instability of the pound sterling in the early 1970s which meant that tin prices at the LME were heavily influenced by currency movements. In contrast, the Malaysian ringgit was a relatively more stable currency. Moreover, with the reduced output from European smelters, the volume of physical trading in the LME had declined considerably. The Penang market, on the other hand, was strictly a physical market. According to Fox (1974), more than half the imports of the
United States and three-quarters of the Japanese intake of tin in 1972 was purchased in the Penang market. Thus, the ITC price range now became M$9.64 - $11.87 per kilogramme.\(^{23}\)

When the price of tin weakened in late 1972, export controls were introduced for three quarters beginning in January 1973. Towards the end of that year, tin and other commodities were caught up in the price boom that followed the quadrupling of the price of petroleum. So export controls were removed and heavy sales from the buffer stock occurred. To dampen the price rise, the United States resumed commercial sales from its strategic stockpile in June 1973; by the end of 1974, nearly 44,000 tonnes had been disposed of. Even then, tin prices remained high and the ITC had to revise its price range upwards three times by January 1975, when it was set at M$14.88 - $18.19 per kg. However, when prices fell following the 1975 economic recession, buffer stock purchases were resumed and export controls were imposed in April 1975. By early 1976 prices recovered and before the fourth ITA expired in June of that year, two more upward revisions of the price range were approved by the ITC.

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\(^{23}\)Initially, the price of tin in the Penang market was quoted in M$ per picul, the picul being a domestic unit of weight (1 picul = 60.479 kg = 133.33 lb). So the official ITC price range was M$583 - $718 per picul. It is only from January 1981, when Malaysia switched to the metric system, that the price has been quoted in M$ per kg. However, to be consistent, the metric price is used throughout this section.
2.4.5 The Fifth International Tin Agreement

In May 1975 an international tin conference was convened at Geneva by UNCTAD to negotiate the renewal of the tin agreement. The negotiations were influenced by two events. One was the announcement by the United States administration that it planned to join the fifth ITA subject to the approval of the U.S. senate. The other was the adoption of the resolution calling for the establishment of a New International Economic Order (NIEO) by the U.N. General Assembly in April 1974, over the opposition of the United States. The most divisive issue in the course of the talks at Geneva was the question of buffer stock financing. The tin producers, led by Bolivia, insisted that consumer members must share equally in the cost of financing the buffer stock. The consuming countries, led by the United States and West Germany, refused to agree to mandatory contributions. However, Belgium, Canada, Denmark, France, Japan, the Netherlands, Norway and the United Kingdom, eventually made voluntary cash contributions to the buffer stock. The terms of the fifth ITA were substantially the same as those of the fourth ITA, though the preamble had been changed to express support for the NIEO declaration. The only major change in membership was, of course, the accession of the United States as a consuming member.

The fifth ITA came into force on 1 July 1976. Demand for tin was high throughout the late 1970s, while the supply of tin was unable to keep pace mainly because output from some major tin producers like Bolivia and Malaysia was either stagnating or falling due
to having to mine ores of declining quality. Therefore, the price of tin increased sharply during the first four years of the fifth ITA. For much of this period the market price was above the ITC ceiling price, even though the ITC price range was revised upwards five times. Each time the producers, led by Bolivia, requested for a price revision, citing higher market prices and increased production costs, the consuming countries, led by the United States, would oppose the move arguing that the production costs were high because of inefficient operations and the high incidence of taxation on the tin industry, particularly in Bolivia. Thus they were able to restrict the price range changes to levels at which the ceiling was almost always below the market price. The conflict over the price range between the consuming and producing members in the council became increasingly bitter.

As for the buffer stock, it was exhausted in January 1977 and remained inactive until April 1981.

In the second half of 1980, prices started declining and were well within the ITC price range. Meanwhile the negotiations for the sixth ITA, which began in Geneva in April 1980, turned out to be much more protracted and acrimonious than expected. So in January 1981, the ITC decided to extend the fifth ITA for an additional year till June 1982. In April 1981 the buffer stock manager resumed buying tin in an effort to stop the slide in the price of tin. Meanwhile, the United States government began to increase its rate of disposal from its tin stockpile throughout 1981. This annoyed the major tin producers, who protested strongly to the United States claiming that it was not honouring
its October 1966 commitment to the ITC not to sell tin if such sales interfered with the buffer stock operations of the ITC.

During the second half of 1981, tin trading was dominated by a "mystery buyer" whose purchases of nearly 50,000 tonnes of tin at the LME pushed the price of tin from about £6,500 per tonne in July 1981 to about £9,000 in February 1982. The mystery buyer was later identified as a group financed by the Malaysian government. The motives of this group have been unclear. It could have been an attempt to influence the voting at the October 1981 ITC meeting which was considering a request from producing members for a 28 percent increase in the price range. An increase of only 6.85 percent was approved; the delegates from the consuming nations justified the smaller increase by arguing that the ITC ought not to establish a floor price that would permit the group to sell its tin holdings at a profit. If the aim of the operation had been to make a speculative profit by cornering the market, it was not successful either. In late February 1982, when it appeared that the group would succeed in cornering the market, the LME committee, whose members had speculated against this group and were facing potentially huge losses, changed the rules to limit the losses of its members. As a result the buying operation collapsed and the price of tin fell sharply in a matter of few days in both the LME and the Penang tin market. The ITC buffer stock manager had to step in to support the price of tin and by June 1982, when the fifth ITA expired, he had acquired nearly 50,000 tonnes of metal. As an

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24 See the 1983 Mining Annual Review, Baldwin (1983) and Williamson (1985) for more details about this operation and its aftermath.
additional measure, the ITC imposed a 11 percent export cutback for the second quarter in April 1982.

2.4.6 The Sixth International Tin Agreement

Negotiations for the sixth ITA turned out to be much more protracted than those for the previous ITAs. There were four separate bargaining sessions before agreement was reached on the terms of the sixth ITA. The initial position of the producers was that the buffer stock should be no more than 30,000 tonnes and must be financed equally by producing and consuming members. They also wanted to retain the provisions on export controls. Most of the consuming countries wanted to continue with the provisions of the fifth ITA. The United States, however, made some radical proposals. It wanted the ITC to abolish export controls and, in lieu of them, to increase the buffer stock to about 70,000 tonnes; the buffer stock was to be financed equally by consumers and producers. The final agreement provided for a buffer stock of 30,000 tonnes, equally funded by producer and consumer members, plus another 20,000 tonnes which would be financed from borrowing on the security of the initial 30,000 tonnes. Export controls would be imposed only when the buffer stock has accumulated 35,000 tonnes. However, neither the United States nor Bolivia were satisfied with these terms; as a result, both did not join the sixth ITA.

When the sixth ITA came into force on 1 July 1982, the export cutback was increased to 36 percent on the assessed production basis of the producing members; a year
later it was increased to 40 percent. In spite of the severity of export controls, the world output of tin did not decrease as much as was expected because of the increased supply from three sources: non-ITC members, especially Brazil; consuming members of the ITC, like the United Kingdom, who were not bound by the ITC export control provisions; and tin smugglers who smuggled tin from Malaysia, Thailand and Indonesia to evade export taxes and export controls. This put great pressure on the ITC's buffer stock manager who was rapidly using up all his borrowing capacity to defend the ITC floor price. The price of tin at the Penang tin market\textsuperscript{25} remained at or near the floor level of the ITC price range from March 1982 to October 1985.

However, currency movements during the early 1980s came to the rescue of the buffer stock manager.\textsuperscript{26} In examining how the currency factor affected the ITC operations, it has to be kept in mind that the ITC's head office was in London and its financing was in sterling while it had to defend the floor price denominated in Malaysian dollar, which is closely linked to the U.S. dollar. So, when the U.S. dollar strengthened during the early 1980's, the sterling price of tin rose, while the Malaysian price stayed almost unchanged at or near the floor price. Consumers in industrial countries, whose currency had depreciated against the U.S. dollar, were paying more in their currency for the tin they imported. Williamson (1985, p. 14) argues that this "accelerated the decline in tin

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\textsuperscript{25}As we saw in section 2.3.2, the Penang tin market was later replaced by the Kuala Lumpur Tin Market (KLTM) on 1 October 1984.

\textsuperscript{26}For more details, see Williamson (1985) from which this account is adapted.
consumption and meant that when the recession ended, unlike other base metals offtake, tin demand did not increase significantly."

The currency movement helped the buffer stock manager to increase his borrowing capacity by using the rising value (as measured in pounds sterling) of his tin inventory. As Gemmil (1985) pointed out, in addition to loans from banks, the buffer stock manager also used forward trading for price support operations:

A forward contract is a substitute for holding stock. By making a forward contract, the buffer stock manager is inducing a trader to buy and hold the cash metal to deliver in three months’ time, rather than holding the metal himself. As the contango (three month premium) is slightly less than the cost of holding a stock of metal, this looks like a cheap way of inducing stockholding. The real attraction to the tin Buffer Stock Manager, however, was that such contracting is done on credit and nobody knows its total size. He had used up his bank borrowing, so he needed credit from 'the trade' and forward contracts provided that in a way which allowed the aggregate long position to be hidden from view (p. 31).

Thus he was able to operate in the market until the U.S. dollar peaked against the pound sterling in early 1985. In the following few months, the U.S. dollar/sterling exchange rate moved from $1.05 per £ to $1.40. This led to a concomitant decline in the LME tin price. On 7 March 1985, the LME cash tin price was £10,195 per tonne. By 21 October 1985, it had declined to £8,570 per tonne.

This had two consequences on the position of the buffer stock manager. Firstly, as the underlying value of his collateral (i.e. his tin stocks) with the banks declined, his bankers were demanding additional collateral. Secondly, when his forward trade matured, he incurred losses on them, thus further eroding his financial resources. Though he asked
for more resources from the members of the ITC, it was not forthcoming. Many of the LME traders, sensing that the buffer stock manager was running out of money, started speculating against him by selling tin forward without hedging their sales. They were almost caught in a squeeze in June 1985, but again as in 1982, the LME committee came to their rescue by imposing a loss limit of £90 per tonne per day.\textsuperscript{27} This invited further speculation and by late October 1985, the buffer stock manager had to abandon his price support operations. On 23 October 1985, he informed the LME committee that he had run out of funds and that he would be unable to honour his forward purchases. Trading was suspended at all the three principal markets for tin: the LME, the KLTM and the New York market.

Since then, many attempts have been made to resolve the problem. The ITC had about 60,000 tonnes of physical tin, which had all been pledged to the banks. In addition, the ITC's buffer stock manager was responsible for another 50,000 tonnes of forward purchases of tin. After repeated negotiations among ITC members as well as between the ITC and the banks and brokers, no agreement was reached on how to handle the liabilities of the ITC. The creditors went to the courts filing suits against the ITC. But as we shall see in chapter 7, the matter was finally settled out of court in March 1990. As for the operations of the ITC itself, export controls ceased in 1986; the life of the sixth ITA was extended for another two years with its function limited to collecting statistics and to

\textsuperscript{27}This move by the LME committee was bitterly criticised by buffer stock manager and many producing members of the ITC because it limited the downside risk of losses for the LME members, while their potential gains were practically unlimited.
continue defending itself from the ongoing court actions against it. The ITC ceased all its operations in 1988 and was dissolved in early 1990 after the final settlement. However, for all intent and purpose, the post-war attempt at tin control came to an effective end in 1985.
In the last two decades, econometric modelling of primary commodities has become very widespread. One researcher cited a bibliography containing about 200 econometric models dealing with just non-ferrous metals (Wagenhals, 1984a). The models have been used for short and long term forecasting as well as for policy simulations which covered a wide variety of issues such as producer strategies, impact of primary commodities on local and global economies, price stabilization schemes and environmental regulations. There are a number of excellent references that deal with econometric modelling of primary commodities (Adams and Behrman, 1978; Ghosh et al 1987; Labys, 1973; and Labys and Pollak, 1984). Therefore, this review will concentrate on mineral market models only. We will first look briefly at the theory underlying econometric modelling of mineral markets and then discuss some of the better known models.

3.1 Mineral market models: theory

Econometric modelling of a mineral market basically consists of mathematically expressing a set of market relationships pertaining to the demand, supply and inventory behaviour of the mineral as well as their roles in determining its price.\(^1\) The basic model assumes competitive factor and product markets, an assumption that is generally valid for

\(^1\)The discussion in this section is based on the references cited in the introduction to this chapter, particularly on Ghosh et al (1987).
most primary commodities at least in the absence of coordinated government actions. If producers take product and factor prices as given and maximize their profits subject to the available technology, the supply function is given by

$$QS_t = f(P_t, C_t, T, Z)$$

where $QS_t$ is the production of mineral in the current period $t$, $P_t$ is the price of the mineral, $C_t$ is the price of factor inputs, $T$ is the technology available and $Z$ represents exogenous policy variables influencing supply, such as production quotas or strikes.

In the mining industry, the supply process responds rather slowly to changes in variables like prices; this necessitates lagging these variables in the econometric model. The slowness can be due to the long gestation period required for the installation of additional capacities, to the sluggish diffusion of new technologies and possibly to managerial rigidities (Wagenhals, 1984a, p.78).

There are two sources of demand for minerals: demand for consumption and demand for inventory. Consumption demand for most minerals is a derived demand since the minerals are rarely consumed directly by the ultimate user. A mineral usually goes through a number of manufacturing processes where it is combined with other inputs to produce another intermediate or final good. Thus the consumption of a mineral will depend not only on its price, but also on the prices of its substitutes and complements as well as on the output of the mineral-using goods. In addition, technological and institutional changes influence the consumption of a mineral, and so they have to be taken
into account. Thus, a typical implied consumption demand function of an intermediate industrial mineral can be expressed as follows:

$$Q_D_t = f(P_t, P^*_t, Y_t, T, Z)$$

where $Q_D_t$ is the consumption of the mineral during the current period, $P^*_t$ is the price of substitutes and complements, $Y_t$ is the output of mineral-using goods and $Z$ represents exogenous events that affect the consumption of the mineral. As in the case of the supply function, lagged prices are used because the response to price variations may be slow due to technological constraints.

For most minerals, production is rarely equal to consumption in a particular time period. Inventories absorb the difference between production and consumption. Inventory demand and supply play an important role in the price determining mechanism. In general the supply of inventory is given by the identity:

$$I_t = I_{t-1} + QS_t - QD_t$$

where $I_t$ is the mineral inventory at the end of the current period. In price stabilization studies, publicly held buffer stocks can be introduced into the model by altering the identity as follows:

$$I_t = I_{t-1} + QS_t - QD_t - BS_t$$

where $BS_t$ is the increase in publicly held buffer stocks. Mineral inventories are held by producers, consumers and intermediaries. As a result, it is often difficult to obtain accurate inventory data on a reliable and consistent basis.
The final relationship explains the price adjustment mechanism which is given by the function:

$$P_t = f(I_t, QD_t, Z)$$

where $Z$ represents other relevant variables such as interest rate, inflation rate and exogenous policy changes. Other variations of price adjustment mechanism have been discussed in the literature (Hwa, 1979). In summary, the standard model of a competitive mineral market is made up of four basic components:

a) a supply equation;

b) a consumption or a demand equation;

b) an identity explaining inventory changes; and

d) a price adjustment equation.

In studies of mineral markets, this basic model is often extended and modified to suit the unique features of a particular mineral market. One extension that needs to be considered is the level of aggregation that is required in the supply and demand functions. Demand functions can be disaggregated by end uses, and both supply and demand functions can be disaggregated by geographical regions. Data availability usually restricts the degree of disaggregation in a model.

When the assumption of competitive markets does not hold, the basic model has to be modified to account for the presence of monopoly power among the suppliers. Often, we observe a single dominant producer or a small group of like-minded dominant producers, and another more diverse group of small "fringe" or "second-tier" producers. In such cases, the dominant producer will adjust its supply to maintain the desired price,
while the fringe producers behave as price takers. The petroleum industry is an example of this situation; OPEC behaves as the monopoly producer and regulates its output to maintain the price at a level it is comfortable with. Other oil producing countries act as fringe producers and are price takers in the crude petroleum market. However, market structures can change over a period of time from being competitive to monopolistic or vice-versa. Such regime changes often make it more difficult to model the market.

Another factor that has to be taken into account is that minerals are exhaustible natural resources which are available in finite, though uncertain, quantities. So, unlike produced goods, if a larger quantity of a certain mineral is consumed in the current period, less will be available in future periods. In competitive markets, the profit maximizing output of a produced good occurs when its marginal cost and price are equal. In contrast, the profit maximizing output of an exhaustible resource occurs when the price is equal to the marginal (extraction) cost plus the marginal rent. The latter measures the opportunity cost of depleting the stock of resource; i.e., it is the present value of all future sacrifices associated with the use of the resource. Assuming a world of certainty and constant extraction cost, Hotelling (1931) showed that over a time interval during which a producer freely chooses a positive production level, his marginal rent must be rising at the rate of interest. Hence, the higher the rate of interest, the greater will be the current rate of depletion of the resource. In recent years, this basic model has been extended and applied in a wide variety of circumstances, giving rise to a very substantial literature (Hartwick and Olewiler, 1986).
Despite the advances in the theory of exhaustible resources, most empirical studies involving econometric modelling of mineral markets ignore the exhaustible nature of minerals.\(^2\) The main justification for this omission is that, in practice, marginal rents are close to zero in most mineral markets. The size of Hotelling's rent depends on the value of the exhaustible resource and the scarcity of the remaining stock. If the reserves of an exhaustible resource are large, or is easily substituted for, especially by a produced good which is not exhaustible, then its marginal scarcity rent will be close to zero.

Newbery (1984) states that with the exception of oil, and perhaps diamonds, "most metals, minerals and coal appear to have cost dominated prices...." (p. 520). In his study of the international copper market, Wagenhals (1984b) found that the planning horizon of most copper exporters was less than 25 years, which is small compared to the availability of copper as measured by the reserve/consumption ratio (i.e., the number of years at which the current rate of consumption can be enjoyed before exhaustion). For most minerals, technological improvements in exploration as well as increased exploration activities have resulted in new deposits being discovered, thus increasing the reserve/consumption ratio. For example, the known reserves of tin increased substantially in the last two decades with the discovery of large, rich new deposits in Brazil. In addition, advances in mining technology have enabled the exploitation of low grade deposits that had previously been considered uneconomic. The stock of resources can also be extended by recycling. Given

\(^2\)An exception is the recent work by Radetzki and Labys (1988) which introduces a theoretical model which attempts to integrate a standard econometric commodity model with the rational extraction model derived from Hotelling's seminal analysis.
these factors, it is not surprising that the question of resource depletion is ignored in most econometric models of mineral markets.

3.2 Review of some econometric mineral market models

One of the most significant studies in the econometric modelling of mineral markets is the work done by Fisher, Cootner and Baily (1972) on the world copper industry. Though their model is relatively small, it "has had an impact on future copper market modelling which cannot be overestimated" (Wagenhals, 1984b, p. 76). Their econometric model was a standard market model with some additional features. First, the two price system that prevailed in the copper industry was explicitly incorporated in the model. Under this system, most of the copper in the North American market was dealt with at the U.S. producer price while the London Metal Exchange (LME) price was used in the rest of the world. The U.S. producer price was administered by the major U.S. copper producers and was based on what "they believe to be a sustainable (and profitable) long run level of copper prices, taking into account their own resulting supply decisions" (Fisher et al, 1972). McNicol (1975) provides a detailed account of the two price system. The two markets were not entirely independent of one another. Any large sustained difference between the two prices acted as a signal to the U.S. producers indicating that the U.S. market was probably out of long run equilibrium and they usually adjusted their price accordingly.
Another feature in their model was the relative disaggregation in the supply and demand equations. Separate supply equations were estimated for the United States, Canada, Chile and the rest of the world. Similarly, different demand equations were estimated for each of the three principal copper consuming regions. Lags were introduced in the model to make it dynamic, thus taking into account of the delays incurred before supply and demand adjust to changes in prices.

The model was used to forecast supply, demand and prices for the period 1969-1975. It was also used for two policy simulations. The first case examined the effect of a 10 percent increase in Chilean production every year of 1969 to 1975 on the price of copper and on Chilean revenue. The second simulation looked into the impact of a discovery of a large new source of supply on the price of copper.

An early example of an econometric model which explicitly incorporates monopolistic behaviour is the cobalt market model by Burrows (1971). Zaire produced more than 60 percent of the non-socialist world output of cobalt. So Zaire was modelled as a dominant monopolist who selects a profit maximizing price and output, taking supply from the other producers and total demand as given. Stockpile sales and purchases by the General Service Administration (GSA), a U.S. government agency, were included in the model. However, the model did not take into account of the intertemporal aspects of profit maximization as well as the exhaustibility of cobalt.
Pindyck (1978a) included these two factors in an interesting study that examined the possibility of owners of exhaustible resources obtaining significant monopoly profits through cartelization. His basic model assumed a monopolist with a competitive fringe. The total demand for the resource, $TD_t$, was given by

$$TD_t = f_t(P_t, Y_t, TD_{t-1})$$

where $P_t$ is real price and $Y_t$ is the measure of aggregate income or product. The net demand facing the cartel is

$$D_t = TD_t - S_t$$

where $S_t$ is the supply function for the competitive fringe, and is given by

$$S_t = f_s(P_t, S_{t-1})(1 + \alpha)^{CS_t/S^*}$$

with

$$CS_t = CS_{t-1} + S_t$$

where $CS$ is the cumulative production, $S^*$ is average annual competitive production and $\alpha$ is a parameter that determines the rate of depletion. An identity is required to keep track of cartel resources, $R$, and is given by

$$R_t = R_{t-1} - D_t.$$ 

The objective function that will maximize the sum of discounted profits of the cartel is given by

$$\max W_t = \sum_{i=1}^{N} \frac{1}{(1 + \delta)^i}(P_t - m/R_t)D_t$$

where $m/R_t$ is average production cost, $\delta$ is the discount rate and $N$ is chosen to be large enough (40-60 years) to approximate the infinite horizon problem.
He applied this model with suitable variations to bauxite, petroleum and copper and showed that significant monopoly profits can be obtained through cartelization in the cases of petroleum and bauxite, whereas it was not possible in the case of copper. The main factors that influence the size of the monopoly profits seem to be the market share and the speed of adjustments in supply and demand:

OPEC and IBA (International Bauxite Association) account for around two-thirds of non-Communist world petroleum and bauxite production, while CIPEC (International Council of Copper Exporting Countries) accounts for only one-third of copper production. Demand and competitive supply of petroleum and bauxite adjust only slowly to changes in price, allowing large short term gains to a cartel, while secondary copper supply responds quickly to price changes (Pindyck, 1978a, p. 249).

A recent book by Ghosh, Gilbert and Hughes Hallet (1987) provides an excellent treatment of modelling the international copper market for the purpose of examining price stabilization issues. They estimated a quarterly model of the world copper industry which was used to analyze intervention policies and their welfare consequences. Different buffer stock intervention strategies were evaluated in relation to competing objectives such as price stabilization, revenue stabilization and resource transfer.

3.3 Econometric models of the tin market

The study of the tin market by Desai (1966) was one of the earliest attempts at mineral market modelling with the aim of analyzing price stabilization issues. His model had a simple recursive structure which can be represented as follows:
\[ D_t = D(Y_t) \]
\[ S_t = S(S_{t-1}) \]
\[ P_t = P(I_{t-1}/D_t) \]
\[ I_t = I_{t-1} + S_t - D_t \]

The model, based on annual data from 1948 to 1961, was disaggregated on the demand side by geographical regions and end uses.

Total tin consumption was divided into three regions: the United States, Canada and West European countries, and the rest of the world. For the United States, the demand for tin used in tinplate was estimated separately from the demand for tin consumed for non-tinplate uses. Tin used for tinplate was treated as a function of the quantity of tinplate produced and the technological change represented by the declining tin content of tinplate. The output of tinplate was estimated as a function of the output of manufactured food, which in turn was a function of consumer expenditure on food. The demand for tin in non-tinplate uses in the United States was estimated as a function of a composite index, which represented the industrial production of other tin-using industries, and a time trend to capture the technical substitution against tin. The composite index was based on defence expenditure and gross domestic private investments. He also had a sub-system of equations that accounted for the consumption of secondary tin in the United States.
Similar equations were estimated for the Canada and West European region, though the equation for secondary tin was excluded because it was deemed not important enough in that region. For the ROW region, tin consumption was estimated as a function of a single upward time trend. On the supply side, the world output was estimated as a function of the output lagged by a year and the absence or otherwise of ITC export controls.

Simulation techniques were then applied to the model to evaluate different policy options that an international body like the ITC can pursue to stabilize tin prices and producers' revenues. From the simulations, the study concluded that a combination of output control and a relatively large buffer stock of 35,000 long tons was sufficient to stabilize tin prices and increase producers' revenues.

The main drawback to this model was the absence of tin price as an explanatory variable in either the supply or demand equations. Banks (1972), in commenting on Desai's paper, showed that it was possible to obtain a price effect on total U.S. tin consumption. In his reply, Desai (1972), while accepting Banks' point about the neglect of prices in his original model, stated that at the level of disaggregation and for the time period he employed, he "had tried several relative price variables in the demand and supply equations and was led to reject them because these invariably had nonsignificant coefficients" (p. 753). Another weakness in the model is that in contrast to the high level of disaggregation on the demand side, the total world supply of primary tin was estimated
by a single equation. Thus, it was not possible to observe whether the supply and revenues of the various tin producing countries responded differently to changes in buffer stock sizes and export controls.

A model of the world tin market which overcomes both these objections is the one developed at the World Bank by Chhabra, Grilli and Pollak (1978). This is a disaggregated supply/demand model with a market clearing equation for prices. Individual supply equations were estimated for 8 countries or regions: Malaysia, Indonesia, Thailand, Bolivia, Nigeria, Zaire, the developed countries and the rest of the world (ROW). Supply of secondary tin was ignored in the model due to an absence of consistent and reliable data in most countries except in the United States. Supply equations were based on two major assumptions. Firstly, tin producers were assumed to adjust their output in response to changes in market prices and mining costs. To capture this response, they used the LME price deflated by a mining cost index constructed on the basis of the ITC’s cost surveys for 1973-75. The prices were lagged to take into account the dynamic nature of the model. Dummy variables were used to account for the fact that tin producers in the ITC had to adjust to export controls. Though it was recognized that other factors including government policy and taxation influenced the supply of tin, they were not incorporated because of an absence of consistent and reliable data.

Demand was disaggregated into 6 countries or regions: the United States, Western Europe, Japan, South Africa, other developed countries and rest of the world. In the first
three cases, there was a further division of demand from tinplate and non-tinplate uses. Consumption of tin for use in tinplate was estimated as a function of the production of tinplate, tin prices, prices of complements and substitutes, and technological factors such as the evolution of electrolytic tinplating. Demand for non-tinplate uses was estimated as a function of industrial production and prices of tin and its substitutes. The prices were suitably lagged to account for the institutional and technological rigidities that prevent an immediate adjustment of the demand for tin to changes in prices or demand for final products.

An inventory identity took care of the difference between production and consumption. The price equation was given as follows:

\[ P_t = f(P_{t-1}, (I_t/C_t), WPI_t, D_{74}) \]

where \( P_t \) is the nominal price of tin in period \( t \), \( I_t \) is ending inventory, \( C_t \) is total consumption of tin, \( WPI_t \) is the United States wholesale price index which captured increases in the nominal price that arise from general inflationary conditions; and \( D_{74} \) is a dummy variable to account for the speculation in commodity prices during 1974. The model was then used to forecast tin prices under different scenarios as well as to perform historical simulations involving the ITC buffer stocks.

A major weakness in the World Bank model is that it does not take into account the differences in the intensity of export controls. They use a single dummy variable which has a value of 1 in the years of export control and 0 otherwise. Surely, the impact of the
severe export controls in 1958 and 1959 is not going to be the same order of magnitude as the impact of the milder export controls in 1969 and 1973. In addition to this, Baldwin (1983) also questions the price deflator used in the World Bank model:

...(it) used cost surveys done by the ITC for 1973-75 to weight the costs of fuel, capital and labour in order to construct indices that were applied to time-series regressions running from 1955 to 1975. Chhabra, Grilli, and Pollak thus incorporated a refinement that captured an important structural feature for their model, but at the cost of making a very dubious assumption that the mix of productive inputs was fixed at 1973-75 proportions despite changes in relative factor costs and technology over the 1955-75-period (p. 107).

3.4 A new econometric model

In the next two chapters we will specify and estimate a new econometric model of tin. The model builds upon the tin models that were reviewed in the last section, and in particular, upon the World Bank model. Model specification is influenced heavily by the purpose for which the model is being constructed. In this study, the model is going to be used for historical simulations to evaluate the impact of the international tin agreements (ITAs) on the tin industry. Given this objective, it is necessary that the model represents historical behaviour as accurately as possible.

Our model is a substantial improvement over the World Bank model in a number of ways. Firstly, the World Bank model is based on 21 years of data (i.e. 1955-75) whereas ours is based on 32 years (1954-1985). In the latest 10 year period from 1975 to 1985, there have been major changes in the industry. For example, the New Economic Policy
introduced by the Malaysian government appears to have an impact on the tin industry in the 1970s and 1980s. Nigeria and Zaire have not recovered from their internal problems. There have been major discoveries of new tin deposits in Brazil. The Indonesian tin industry appears to have completely recovered from the problems encountered during the Sukarno regime. And of course, the severe ITC export controls from 1982 to 1985 also has affected the industry. Our model will attempt to capture these changes.

Our model takes into account institutional and political realities in a more comprehensive manner. For example, unlike the World Bank model, we have used a separate dummy variables to represent the different periods in which there were ITC export controls thus taking into account of their intensity. We have paid more attention to the political problems in the individual countries. We have used new variables to capture these exogenous policy changes.

Since the focus of our study is more on the impact of the ITAs on the producers’ supply functions, we have constructed a model which is sufficiently disaggregated at the production level. In the case of consumption, we have disaggregated only at the geographical level and not at the end-user levels. In fact, for the simulation exercises in chapter 6, we will be using a single aggregated consumption function to reduce the complexity of the simulation model.
4. SUPPLY FUNCTIONS FOR PRIMARY TIN

In this chapter, supply schedules will be estimated for the tin producing countries. In the first section, a general supply function for primary tin will be specified. Then in section 4.2, the general model will be used to estimate supply functions for the main tin producing countries or regions. In the subsequent sections, we will discuss the supply function for each country or region in some detail and alter the general model to take into account local political and institutional effects on tin production. In the final section, both the short and long run elasticities of supply are presented and discussed.

4.1 Specification of a supply function for tin

As we saw in chapter 3, though tin is an exhaustible resource, we can assume current profit maximization in deriving the supply schedules because of the relatively large reserves of tin. This assumption has been used in many previous studies of mineral industries, some of which were reviewed in the last chapter. In the most general form, the supply of tin can be expressed as:

\[
QS_t = f(P_t, W_t, Z_t)
\]

where

- \( QS \) = the mine production of tin;
- \( P \) = the price of tin;
- \( W \) = an index representing factor prices; and
- \( Z \) = variable(s) representing policy changes.
Production, however, may not respond immediately due to the various lags involved in the process of adjustment to changes in price. It takes a few years to bring about changes in the capacity of tin mines, especially where dredging or underground mining technology is used. Such expansion of capacity is quite capital-intensive, and once the expansion has taken place, it may be very costly to close down an operation. So mining firms have to be convinced of a long-term rising price trend or at least some price stability before they proceed with expanding the capacity of mines. This is even more relevant for exploration and development of new tin resources, where the time required from the moment a decision to develop a new mine is made till production begins, can easily be between 7 to 10 years. For these technological and institutional reasons, a suitable distributed lag structure has to be incorporated into the supply function given in (4.1.1).

The most appropriate lag structure in situations of technical and institutional rigidities or inertia is the stock adjustment or partial adjustment model (Gujarati, 1978, p. 265 and Pindyck and Rubinfeld, 1981, p. 235). Using this model, which was first postulated by Nerlove (1958), we can assume that the desired level of tin supply, \( QS^*_t \), is dependent on the current level of tin price, \( P_t \), and if we further assume that the supply function is linear, we get:

\[
(4.1.2) \quad QS^*_t = \alpha + \beta P_t + u_t
\]

where \( u_t \) is a random error component. The actual supply, \( QS_t \), will not adjust completely to \( P_t \) in one period for the reasons given in the previous paragraph. So a partial adjustment process is assumed and is specified as:
(4.1.3) \[ QS_t - QS_{t-1} = \delta(QS^*_t - QS_{t-1}) \]

where \( 0 \leq \delta \leq 1; \)

i.e. the actual change in supply in the current period is only a fraction \( \delta \) of the difference between the desired level of supply, \( QS^*_t \), and the previous year's actual level of production, \( QS_{t-1} \). The closer \( \delta \) is to 1, the more completely the gap is closed in one year. Substituting (4.1.2) into (4.1.3) and rearranging terms, we get:

(4.1.4) \[ QS_t = (1-\delta)QS_{t-1} + \delta \alpha + \delta \beta P_t + \delta u_t. \]

If the real price of tin, \( RP \), is defined as the nominal price, \( P \), deflated by \( W \), an index representing factor prices, and if we incorporate the partial adjustment mechanism discussed above into the supply function specified in (4.1.1), we get:

(4.1.5) \[ QS_t = f(QS_{t-1}, RP, Z). \]

At a theoretical level, if the current price is used as an explanatory variable, then price and quantity supplied have to be determined simultaneously. This introduces a problem of simultaneity bias in the estimation of the disaggregated tin supply functions. One way to overcome the simultaneity bias problem is to use lagged price as an explanatory variable. Of course in order for this to be reasonable, we must have some theoretical reasons for believing that the use of lagged price is appropriate. In this situation it is reasonable to suggest that using lagged prices is acceptable because output decisions are made before current prices are revealed. This may be the reason why in the
actual estimation of the supply functions, the equations with lagged prices gave a better fit than the corresponding equations using the current price.

In addition to the lagged output and price, a country's supply of tin is influenced by political and institutional factors. The export controls imposed by the International Tin Council affected the supply of tin from member countries of the ITC. Political factors that are specific to individual tin producing countries also influence the supply of tin from these countries. We have already discussed the impact of these political factors in chapter 2, when the structure of the tin mining industry in the major tin producing countries was examined in detail. In this chapter we will attempt to incorporate these factors in a systematic way in our model. Indeed this is one of the major improvements of this model over earlier econometric models of the tin industry.

Since export controls affected all the ITC producer members, dummy variables are used in the general model to capture the impact of the export controls on tin supply. The rest of this section explains in detail the use of these dummy variables. After the supply functions are estimated using the general model, the country specific policy variables are incorporated in the supply functions when we examine each country's supply function in detail in sections 4.3 to 4.9.

Since there is no a priori hypothesis concerning the functional form of equation (4.1.5), we assume a linear form and obtain the following supply schedule:
\[ QS_{x_t} = \beta_0 + \beta_1 QS_{x,t-1} + \beta_2 RP_{t-1} + \beta_3 Dn + \epsilon_t \]

where $QS_x$ = the mine production of tin in country or region $x$; 
$RP$ = the real price of tin; 
$Dn$ = dummy representing export control in year $n$; and 
$\epsilon_t$ = random error term.

Dummy variables are used to represent the export controls that were imposed by the ITC on its producing members. Earlier studies have used a single dummy variable to represent export control years without taking into account the degree of severity of export controls. In contrast, a separate dummy is used for each year there was a significant change in export control levels to account for the change in the degree of severity of the export controls from year to year. It is useful at this point to briefly review export control periods. Between the beginning of the international tin agreement in July 1956 and its collapse in October 1985, there were five periods of export controls as shown in table 4.1.

Recall from chapter 3 that the first set of export controls resulted from the sharp increase in the sale of tin from the U.S.S.R., which caused tin prices to fall close to the floor price set by the ITC. The controls were severe involving an average of 28 percent reduction in exports in 1958. This continued in 1959. In 1960 the export controls were eased somewhat. To represent these changes in export controls, we have added two dummy variables, $D58$ and $D60$, to the general model. $D58$ and $D60$ have a value of 1 in 1958 and 1960, respectively, and 0 in other years.
Table 4.1: Export control periods, 1956 - 1985

<table>
<thead>
<tr>
<th>Period</th>
<th>Date</th>
<th>Percentage cutback in exports</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>15 Dec 1957 - 30 Sep 1960</td>
<td>28%</td>
</tr>
<tr>
<td>2</td>
<td>19 Sep 1968 - 31 Dec 1969</td>
<td>4%</td>
</tr>
<tr>
<td>3</td>
<td>19 Jan 1973 - 30 Sep 1973</td>
<td>0%</td>
</tr>
<tr>
<td>4</td>
<td>18 Apr 1975 - 30 Jun 1976</td>
<td>18%</td>
</tr>
<tr>
<td>5</td>
<td>27 Apr 1982 - 31 Dec 1983</td>
<td>36%</td>
</tr>
</tbody>
</table>

The second and third export control periods were very mild. The 1968/69 export levels involved a reduction of less than 4 percent of the most recent uncontrolled exports. In 1973, ITC member countries were requested not to exceed the previous year’s export levels. According to Baldwin (1983), "some producers did not meet their quotas, and the effects of controls were generally viewed as negligible" (p. 90). So in our general model, we have not included any dummies for these two periods.

The fourth period of export control began in response to the world recession of 1975. An 18 percent cutback of exports was implemented beginning in April 1975. However, by the first quarter of 1976, export controls were effectively over. So we have incorporated the dummy variable, D75, to represent this.

When the fifth and final period of export control began on 27 April 1982, total exports allowed for the ITC member countries amounted to 25,400 tonnes per quarter. However, during 1983 it was lowered to 22,000 tonnes per quarter. So we have used D82 to represent the introduction of export quotas and D83 to represent the tightening of the
quotas. There were no more changes in the export quotas till the tin agreement collapsed in October 1985. We have used the dummy, D85, to capture the supply shock that may have arisen due to the collapse of the tin agreement.

When all the above dummy variables are incorporated in the model given in (4.1.6), we get:

\[ QSx_t = \beta_0 + \beta_1 QSx_{t-1} + \beta_2 RP_{t-1} + \beta_3 D58 + \beta_4 D60 + \beta_5 D75 + \beta_6 D82 + \beta_7 D83 + \beta_8 D85 + \epsilon_t \]

In this model, \( \beta_1 \) (which is equal to \( 1 - \delta \), where \( \delta \) is the coefficient of adjustment) should be positive and have a value between 0 and 1. The price coefficient, \( \beta_2 \), should also be positive. All the export control coefficients should be negative except for D60. In 1960, the export controls were eased and thus \( \beta_4 \) should be positive. To summarize, we expect:

\[ \beta_1, \beta_2 \text{ and } \beta_4 > 0 \]

and

\[ \beta_3, \beta_5, \beta_6, \beta_7 \text{ and } \beta_8 < 0. \]

This model was used to estimate the supply schedules for the different countries and regions.

4.2 Estimation of the supply equations

Supply equations based on (4.1.7) were estimated using the ordinary least square (OLS) procedure for the ITC member countries, Australia (AU), Bolivia (BO), Indonesia (IN), Malaysia (MA), Thailand (TH) and Zaire and Nigeria (ZN) as well as for the non-
ITC members (NC). Unless otherwise noted, the SHAZAM econometrics computer program was used for all estimations in this and subsequent chapters. In the next subsection, some issues concerning the statistical methodology used in the estimation of this econometric model will be discussed. After that, summary statistics of the data used in the regressions are provided. Finally, the regression results for the general model will be analyzed.

### 4.2.1 Some remarks on methodology

In regression estimates, one has to make a choice among competing models that may explain the data. The criteria that is used in this study follow the guidelines in Johnston (1984, pp. 504-509). He suggests that the following four aspects of specification are important:

1. Residual variance (or statistical fit) as measured by the $R^2$ and the standard error of estimate (SEE).

2. Signs and precision of specific coefficients as indicated by the $t$ statistic for each coefficient.

3. Well behaved disturbances, i.e. we prefer a model which has a homoscedastic non-autocorrelated disturbance term.

The SHAZAM econometric computer programme provides a complete set of diagnostics to test the above assumptions of the classical linear model. For example, we used the sequential Chow test to examine the stability of the relationships. Similarly, the Durbin-Watson and Durbin's $h$ statistic provide a measure of the presence of serial correlation in the specifications. The SHAZAM package has also tests to check for normality of residuals and for the presence of heteroscedasticity.

In addition to the four criteria tested above, parsimony in the number of the variables was also used as a guide for selection of the best model. In selecting between different specifications, if all the criteria above indicate a preference for one of the alternate model, then the decision is relatively straightforward. In practice, one model may have a higher $R^2$, but disturbances which are autocorrelated, while the reverse may be true in another model. In such a case, "the choice between specifications has to rest on the relative importance of various factors to the decision maker" (Johnston, 1984, p. 509). In our case we have placed more importance on criterion (3) and (4), i.e., on the presence of well behaved disturbances and on the stability of relationships.

In the general model that was specified in section 4.1, we have included dummy variables to represent export controls. In sections 4.3 to 4.9, where we discuss each individual country's supply function, we will include political and institutional factors that affect the output of tin in the specification of the supply function. Here there is a more fundamental problem of specification search. What are the political factors that ought to
be included and which are to be excluded? In general, I have used two approaches to solve this problem. Firstly, I rely on the institutional knowledge that I have gathered from trade and industry publications during the course of my research, as well as from interviews with individuals associated with the tin industry. A second approach is what Leamer (1978)\(^1\) classifies as a postdata model construction (p. 6, p. 11-12 and chapter 9). Basically, we examine the residual plots and the diagnostics from the general model and check to see whether political factors can explain for anomalies in the data. Where they do, the political factors are included in the model. If they do not explain these anomalies, then the model is left unchanged.

4.2.2 Data

For all countries except Bolivia we used annual data for the period of 1954 to 1985 (32 observations). In the case of Bolivia, due to the effect of the 1953 revolution, the 1954 data was omitted, resulting in 31 observations. A list of the variables used and the source of the data is provided in appendix 4. The mining output of tin, QSx,\(_t\), for country or region x in period t, was obtained from various issues of *Tin Statistics* published by the International Tin Council. All output is given in metric tonnes. The real price of tin (RPLUS) was obtained by converting the LME spot tin price to U.S. dollars and deflating it by the U.S. wholesale price index. It is expressed in 1980 U.S. dollars per tonne. We

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\(^1\)Leamer (1978) is an excellent exposition of specification searches which provides useful insights to the search process.
Summary statistics for the quantity and price variables are given in table 4.2. During the 1954 - 1985 period, the biggest tin producer was Malaysia whose average output of 60794 tonnes was more than twice that of Bolivia, the second largest tin producer. When it comes to variation of output as measured by the coefficient of variation (CV) (which is the standard deviation expressed as a proportion of the mean), both Malaysia and Bolivia have the least variability. The non-ITC countries have the highest CV. This is in large part due to the sharp increase in tin production from Brazil since the late 1970s. Australian output, too, has a large CV due to the development of new tin mines in the 1970s. The production trends in the various countries are discussed in greater detail when
time series plots of output and the regression estimates for each country are discussed later in this chapter.

4.2.3 Results of the estimates for the general model

Table 4.3 presents the results of the estimates of supply equations based on the general model given by (4.1.7). Export control dummy variables were not used for NC, since the non-ITC tin producing countries were not subject to export controls. Australia became a producing member only after 1970; so, export control dummies were used only after that for Australia. Bolivia ceased to be an ITC member from 1982. So the dummy variables D82, D83 and D85 were omitted for Bolivia.

In general, $\beta_1$, the regression coefficient of the lagged output term, $Q_{S,t-1}$, was significant and had the right sign in all the seven equations. However, for Zaire and Nigeria (ZN) and the non-ITC countries (NC), the coefficients exceeded one. As we saw in equation (4.1.3), $\beta_1 = 1-\delta$, where $\delta$ is the coefficient of adjustment and $0<\delta<1$. This implies that the specification of the supply function for ZN and NC may have to be reviewed. Of the remaining five countries, the value of $\beta_1$ was highest for Australia at 0.9799 and the lowest for Thailand at 0.5708. It is possible to conclude from this that Australian production has the highest level of institutional and/or technological rigidities while Thailand has the lowest.
Table 4.3: Regression estimates of supply equations based on the general model

<table>
<thead>
<tr>
<th>Independent Variables</th>
<th>Malaysia</th>
<th>Bolivia</th>
<th>Indonesia</th>
<th>Country (x)</th>
<th>Australia</th>
<th>Zaire/Nig.</th>
<th>Non-ITC</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\beta_0$: Constant</td>
<td>5067.1</td>
<td>5419.5</td>
<td>-1488.7</td>
<td>1244.3</td>
<td>234.4</td>
<td>-2309.9</td>
<td>-1085.1</td>
</tr>
<tr>
<td></td>
<td>(1.20)</td>
<td>(1.84)</td>
<td>(-0.78)</td>
<td>(1.43)</td>
<td>(0.48)</td>
<td>(-1.39)</td>
<td>(-0.84)</td>
</tr>
<tr>
<td>$\beta_1$:QSx,3</td>
<td>0.9415</td>
<td>0.8693</td>
<td>0.9195</td>
<td>0.5708</td>
<td>0.9799</td>
<td>1.0726</td>
<td>1.1726</td>
</tr>
<tr>
<td></td>
<td>(15.2)</td>
<td>(7.56)</td>
<td>(13.6)</td>
<td>(6.74)</td>
<td>(14.7)</td>
<td>(17.8)</td>
<td>(21.6)</td>
</tr>
<tr>
<td>$\beta_2$:RPLUS,01</td>
<td>-0.0909</td>
<td>-0.1936</td>
<td>0.3549</td>
<td>0.8548</td>
<td>0.0300</td>
<td>0.0910</td>
<td>-0.0899</td>
</tr>
<tr>
<td></td>
<td>(-0.54)</td>
<td>(-1.35)</td>
<td>(2.61)</td>
<td>(5.08)</td>
<td>(0.39)</td>
<td>(0.97)</td>
<td>(-0.54)</td>
</tr>
<tr>
<td>$\beta_3$:D58</td>
<td>-22166</td>
<td>-10799</td>
<td>-2962.5</td>
<td>-6359.8</td>
<td>-6134.3</td>
<td>-6134.3</td>
<td>-6134.3</td>
</tr>
<tr>
<td></td>
<td>(-7.25)</td>
<td>(-4.42)</td>
<td>(-1.21)</td>
<td>(-4.27)</td>
<td>(-6.62)</td>
<td>(-6.62)</td>
<td>(-6.62)</td>
</tr>
<tr>
<td>$\beta_4$:D60</td>
<td>12410</td>
<td>-4716.7</td>
<td>2071.3</td>
<td>157.1</td>
<td>2863.4</td>
<td>2863.4</td>
<td>2863.4</td>
</tr>
<tr>
<td></td>
<td>(3.64)</td>
<td>(-1.95)</td>
<td>(0.86)</td>
<td>(0.10)</td>
<td>(3.12)</td>
<td>(3.12)</td>
<td>(3.12)</td>
</tr>
<tr>
<td>$\beta_5$:D75</td>
<td>-3588.8</td>
<td>2982.0</td>
<td>-1606.8</td>
<td>-8187.0</td>
<td>-1606.3</td>
<td>-628.2</td>
<td>-628.2</td>
</tr>
<tr>
<td></td>
<td>(-1.16)</td>
<td>(1.23)</td>
<td>(-0.66)</td>
<td>(-5.16)</td>
<td>(-1.82)</td>
<td>(-0.69)</td>
<td>(-0.69)</td>
</tr>
<tr>
<td>$\beta_6$:D82</td>
<td>-79*Xx.2</td>
<td>-1814.5</td>
<td>-4259.2</td>
<td>-680.2</td>
<td>31.6</td>
<td>31.6</td>
<td>31.6</td>
</tr>
<tr>
<td></td>
<td>(-2.60)</td>
<td>(-0.72)</td>
<td>(-2.71)</td>
<td>(-0.76)</td>
<td>(0.03)</td>
<td>(0.03)</td>
<td>(0.03)</td>
</tr>
<tr>
<td>$\beta_7$:D83</td>
<td>-11934</td>
<td>-7111.4</td>
<td>-6074.5</td>
<td>-3362.7</td>
<td>545.0</td>
<td>545.0</td>
<td>545.0</td>
</tr>
<tr>
<td></td>
<td>(-3.87)</td>
<td>(-2.87)</td>
<td>(-4.05)</td>
<td>(-3.70)</td>
<td>(0.56)</td>
<td>(0.56)</td>
<td>(0.56)</td>
</tr>
<tr>
<td>$\beta_8$:D85</td>
<td>-6105.2</td>
<td>-1882.0</td>
<td>-6075.7</td>
<td>-1382.6</td>
<td>676.8</td>
<td>676.8</td>
<td>676.8</td>
</tr>
<tr>
<td></td>
<td>(-1.85)</td>
<td>(-0.79)</td>
<td>(-4.16)</td>
<td>(-1.61)</td>
<td>(0.67)</td>
<td>(0.67)</td>
<td>(0.67)</td>
</tr>
</tbody>
</table>

N (obs.) 32  31  32  32  32  32  32
R² 0.9330 0.7301 0.8786 0.9555 0.9550 0.9785 0.9616
SEE 2935.1 2318.9 2320.8 1431.1 840.9 861.8 2386.9
DW 1.57 1.46 1.98 1.23 1.98 2.06 2.65
Durbin's h 1.10 1.62 -0.35 2.05 0.055 -0.18 -2.02

Notes: 1. The dependent variable is QSx,
2. The figures in parenthesis are asymptotic t-values.
3. The $R^2$ given in this table is adjusted $R^2$. 
As for $\beta_2$, the coefficient of the price variable, $RPLUS_{t-1}$, only Thailand and Indonesia have statistically significant coefficients. Thailand has a higher coefficient indicating that its production is more responsive to price changes. Price effects were insignificant for the remaining five countries and in two cases, i.e. Malaysia and Bolivia, the signs were opposite to what was expected.

The 1958 export control seems to have had significant impact on the mining output of tin in all the ITC member countries. However, the easing of export restrictions in 1960 did not show up clearly in the coefficients ($\beta_4$) of the D60 dummy variable. In the case of Bolivia, the coefficient was negative implying that its output declined even when export controls were being eased. As we shall see later, this was because its industry was facing difficulties during this period (Fox, 1974, p. 304). In general export control dummy variables had the right signs and were significant in most of the export control years for Malaysia and Thailand indicating that the controls were binding on the production capacity of these two countries. For other ITC member countries, it was significant only in one or two export control periods.

The adjusted $R^2$ was more than 0.93 in five of the seven equations. The high values of $R^2$ are not surprising given that one of the regressors is the lagged dependent variable. The presence of the lagged dependent variable also affects the reliability of the Durbin-Watson statistic. In such cases Durbin's $h$-statistic is a better indicator in detecting autocorrelation (Johnston, 1984, p. 318). This statistic is distributed normally with zero
mean and unit variance. So if $h > 1.645$, we can reject the null hypothesis at the 5 percent level of significance in favour of the hypothesis of a positive first-order autocorrelation. Similarly, if $h < -1.645$, the null hypothesis can be rejected in favour of the hypothesis of a negative autocorrelation. The Durbin's $h$-statistic in table 4.3 indicates the presence of a positive first-order autocorrelation for Thailand and negative first-order autocorrelation for the non-ITC countries.

In section 4.1, when we discussed the inclusion of policy variables in the model, we distinguished between two sets of policy variables. The first concerned the export controls. The effect of export controls have been accounted for in the general model by the inclusion of dummy variables. The second set of policy variables are country specific. In some countries (e.g. Zaire) internal political strife has affected tin production. In other countries (e.g. Malaysia) specific policies have influenced the output of tin. In the next seven sections, we will include these country specific factors in the equations for each country to come up with better estimates that can be used for the simulation exercises in chapter 6.
4.3 Mine production of tin for Malaysia

The estimated equation for Malaysia based on the general model as shown in table 4.3 is:

\[(4.3.1) \quad QSMA_t = 5067.1 + 0.9415 \cdot QSMA_{t-1} - 0.0909 \cdot RPLUS_{t-1} \]

\[-22166 \cdot D58 + 12410 \cdot D60 - 3588.8 \cdot D75 \]
\[-7957.2 \cdot D82 - 11934 \cdot D83 - 6105.2 \cdot D85 \]

Adj. \(R^2 = 0.9330 \quad SEE = 2935.1 \quad D.W. = 1.57 \]
Period: 1954-1985 \(N = 32\) obs. Durbin's h = 1.10

It is clear that the price variable has the wrong sign and is not significant either.

Given that the Malaysian tin industry has been operated largely by the private sector, such a result indicates problems in the specification of the model. Figure 4.1 is a plot of the Malaysian mine production of tin (QSMA) and the real price of tin (RPLUS). The production trend can be divided into three phases. From 1950 to 1972, tin production appears to have been on the increase more or less in line with the increasing real price of the metal. From 1972 till the early 1980s, tin production declined even as the real price of tin was on the increase. From 1982, production continued declining, but this time in conjunction with declining real price of tin. This decline was in large part due to export controls imposed by the ITC since 1982. It is the decline in the second phase, i.e. from 1972 to 1981 which requires a closer examination.
Figure 4.1: Real price and mine production of tin, Malaysia, 1950-1988

![Graph showing real price and mine production of tin in Malaysia from 1950 to 1988.](image-url)
As was discussed in chapter 2, the Malaysian tin industry was affected by the New Economic Policy (NEP) introduced by the government in 1971. The aim of this policy was to promote the participation of the indigenous Malay community in the modern sector of the economy. The tin industry, which was dominated by foreign (mainly British) and Chinese Malaysian interests, was one of the targets of the NEP. So beginning from the early 1970s, both the federal and state governments through a number of government owned corporations started buying over some of the larger foreign owned tin mining companies (Baldwin, 1983 and Thoburn, 1981). The local Chinese who owned smaller mines began to have difficulties in obtaining new land for mining and in getting extensions to existing mining leases. Therefore, investment into exploration and development of new mines dropped during this period. Baldwin (1983) cites another reason:

"Malaysia reported declining output from 1972 through 1977, but it is widely accepted among tin producers and traders that a substantial portion of the reported decline in its output is spurious and actually reflects increased smuggling in a period of rising taxes, as well as a real drop attributed to stringency in the granting of new mining leases" (p. 135).

Therefore, we can expect the supply function’s response to price to be different beginning from 1973 because of these institutional constraints. This difference in response was introduced into the model as follows:

\[
(4.3.2) \quad QSMA_t = \beta_0 + \beta_1 QSMA_{t-1} + \beta_2 RPLUS_{t-1} + \beta_{22} DZMA*RPLUS_{t-1} + \text{export control dummies} + \epsilon_t
\]

where DZMA = 1 from 1973 to 1985 and 0 before that. If our assumption is valid then the null hypothesis would be:
\[ H_0 : \beta_{21} - \beta_{22} > 0 \]

The model given in (4.3.2) was estimated and the results are as follows:

\[
(4.3.3) \quad \text{QSMA}_t = 1233.4 + 0.87974 \text{QSMA}_{t-1} + 1.0323 \text{RPLUS}_{t-1} \\
\quad \quad \quad (0.39) \quad (19.0) \quad (3.89) \\
\quad - 0.66354 \text{DZMA} \times \text{RPLUS}_{t-1} - 21331 \text{D58} + 11688 \text{D60} \\
\quad \quad \quad (-4.76) \quad (-9.70) \quad (4.77) \\
\quad - 1864.0 \text{D75} - 6478.0 \text{D82} - 10148 \text{D83} - 4611.3 \text{D85} \\
\quad \quad \quad (0.83) \quad (-2.92) \quad (-4.52) \quad (-1.93) \\
\]

\[ \text{Adj. } R^2 = 0.9655 \quad \text{SEE} = 2105.6 \quad \text{D.W.} = 2.06 \]

Period: 1954-1985 \quad N=32 \text{ obs.} \quad \text{Durbin's } h = -0.60\n
When compared to equation (4.3.1) this equation has price variables which are significant and the null hypothesis is not rejected at the 5 percent level of significance. The adjusted \( R^2 \) is higher. However, with a t-value of less than 1, the coefficient of the D75 term is not significant. In examining the residuals, we find that the year 1959 has a negative outlier. As mentioned earlier, the severe export controls introduced in 1958 continued through 1959. To take into account of this we introduced a new dummy variable D59 and dropped the insignificant D75. The estimated equation was as follows:

\[
(4.3.4) \quad \text{QSMA}_t = 4103.2 + 0.83364 \text{QSMA}_{t-1} + 1.0513 \text{RPLUS}_{t-1} \\
\quad \quad \quad (1.20) \quad (17.5) \quad (4.48) \\
\quad - 0.69546 \text{DZMA} \times \text{RPLUS}_{t-1} - 21538 \text{D58} - 4621.0 \text{D59} \\
\quad \quad \quad (-5.79) \quad (-11.1) \quad (-2.01) \\
\quad + 10459 \text{D60} - 6414.7 \text{D82} - 10456 \text{D83} - 5439.5 \text{D85} \\
\quad \quad \quad (4.53) \quad (-3.32) \quad (-5.27) \quad (-2.50) \\
\]

\[ \text{Adj. } R^2 = 0.9746 \quad \text{SEE} = 1838.1 \quad \text{D.W.} = 2.38 \]

Period: 1954-1985 \quad N=32 \text{ obs.} \quad \text{Durbin's } h = -1.10

The overall statistical fit as indicated by the adjusted \( R^2 \) has improved and all the individual coefficients are significant. The residual plot still showed an outlier for 1978.
This is probably due to the under reporting of production in the previous year because of increased smuggling in 1977. Since there are no reliable estimates of the extent of smuggling from individual countries, nothing was done about the outlier. As noted before, there is no \textit{a priori} reason for linearity. Other functional forms and different price lags were tried and equation (4.3.4) was the best choice based on the criteria discussed in the methodology subsection 4.1.1.

\subsection*{4.4 Mine production of tin for Bolivia}

The regression estimates obtained for Bolivia based on the general model as shown in table 4.3 is:

\begin{equation}
\text{QSBO}_t = 5419.5 + 0.8693 \text{QSBO}_{t-1} - 0.1936 \text{RPLUS}_{t-1} \\
-10799 \text{D58} - 4716.7 \text{D60} + 2982.0 \text{D75} \\
\end{equation}

\begin{center}
\begin{tabular}{ccc}
Adj. $R^2$ & = 0.7301 & SEE = 2318.9 & D.W. = 1.46 \\
Period: 1955-1985 & N = 31 obs. & Durbin's h = 1.62 \\
\end{tabular}
\end{center}

In the case of Bolivia, the price variable, $\text{RPLUS}_{t-1}$ is not significant and did not have the expected positive sign. Moreover, the export control variables, D60 and D75, both have the wrong signs also. The residual plot shows one positive outlier for 1959 and 4 negative outliers from 1982 to 1985. Figure 4.2 shows the mine production of tin in Bolivia from 1950 to 1988. There are a number of interesting features in the figure. Tin production fell sharply in 1958 to 18,000 tonnes from the 28,000 tonnes produced in 1957, no doubt in response to the export control imposed by the ITC. But in 1959, while most other ITC
countries maintained their level of production at about the 1958 level, Bolivia increased its output to 24,000 tonnes.

As we saw in chapter 2, after the April 1952 revolution in Bolivia, the mines controlled by the three largest mining companies were nationalized and the Bolivian Mining Corporation (COMIBOL) was established. Subsequently, during the export control periods, the largely government owned tin industry in Bolivia was unable to maintain its production at low levels for too long due to political and social reasons. In 1959, Bolivia made a private arrangement to barter more than 5,000 tonnes of tin against rice and other agricultural commodities with the U.S. Department of Agriculture. The tin was purchased by the United States for its strategic stockpile. As Fox (1974) stated "to the Bolivians, short of dollars for essential imports and with an income almost halved by two years of export restriction, the proposal was a godsend" (p. 307). This explains the increase in the 1959 production. So we decided to use a dummy variable, D59, to capture this increase.

Since the 1952 revolution, the Bolivian tin industry has been plagued by various problems which are detailed by Ayub and Hashimoto (1985) in their World Bank sponsored study of the Bolivian tin industry. One consequence of this is that when export controls were lowered in 1960, the Bolivian tin industry was unable to increase its output
Figure 4.2: Real price and mine production of tin, Bolivia, 1950-1988
immediately. To quote Fox (1974) again:

Bolivia had economically the most rigid structure of all the producers. Nationalisation of the major mines in 1952, gross labour indiscipline and export control had succeeded in almost halving her total output within five years. The industry was disorganised and had made it clear that it had not the resilience to meet any increase in the export quota (p. 304).

This explains the negative coefficient for D60.

As for the anomaly of increased production in the export control year of 1975, there is no clear explanation. In some countries, during export control periods, tin production was maintained at a rate higher than the limited export rate; they preferred to carry the excess production as inventory which was then exported in the years when export controls were removed. The apparent lack of effect of the 1975 export control on the 1975 Bolivian production could be due to this.

Another feature of interest is the drop in production from 1982 to 1985, despite the fact that Bolivia was not an ITC member and hence was not subject to export control. This was largely due to the massive economic and political problems faced by Bolivia. Ayub and Hashimoto (1985) alluded to this:

The pertinent question about the present crisis in Bolivian mining is not why it occurred but what prevented it from happening earlier. The commodity price boom of 1979-80, the devaluation of the Bolivian currency by 25 percent in November 1979, and the elimination of the export tax in early 1980 were some events that postponed the day of reckoning; but these were not sufficient to maintain the momentum of growth in the sector. The severe political instability commencing in 1978, the frequent disruption of production after that year, the deteriorating balance of payments situation of the country, which hampered imports of needed inputs, the precipitous decline in the price of metals after early 1981, and the drying up of foreign
credits had a devastating effect on mining operations, both public and private. After 1980 COMIBOL started to register financial losses even on before-tax income. The exchange rate policy also has had a debilitating effect on mining operations since early 1982 (p. 18).

As for the future prospects of tin mining in Bolivia, at the time of their writing (in 1983), Ayub and Hashimoto (1985) said:

Short-term prospects for increased output and improved productivity in Bolivian tin mining are not bright. Past neglect of exploration and mine development, the chaotic state of COMIBOL, the unresolved situation of workers' participation in the nationalized sector, lack of credit, as well as the present system of exchange rates, which discourages all exporting activities including mining, are some of the factors which could prevent a recovery of tin production from its estimated 1983 level of about 22,000 tonnes - the lowest level since the late 1950s and early 1960s (p. 70).

Since 1982, Bolivia has faced even more serious economic dislocations. Inflation has been very severe; according to the IMF's *International Financial Statistics*, the consumer price index was 100 in 1980, 300 in 1982 and 15294 in 1984. The next year it spiralled to 1,812,000. This led to more labour problems and has had even more drastic effects on tin production.

We propose an alternate model for Bolivia which takes into account some of the problems discussed above:

\[
QSBO_t = \beta_0 + \beta_1 QSBO_{t-1} + \beta_2 RPLUS_{t-1} + \beta_3 D58 + \beta_4 D59 + \beta_5 D60 \\
+ \beta_6 \text{Tبول} + \epsilon_t
\]

where TBOL is a time trend variable which is used to capture the impact of the socioeconomic problems faced by Bolivia on its tin production, beginning from 1982. We have
dropped the export control dummy variables for 1975 since it does not appear to be binding on production level for that year and D59 has been added to account for the increase in production due to the special barter sale made to the U.S. The estimated equation based on this model is as follows:

\[(4.4.3)\quad QSBO_t = 6215.5 + 0.7899 QSBO_{t-1} - 0.04953 RPLUS_{t-1} - 10480 D58 + 3778.3 D59 - 4751.1 D60 - 1621.6 TBOL\]

\[\text{Adj R}^2=0.8697 \quad \text{SEE}=1610.9 \quad \text{D.W.}=2.43\]

Period: 1955-1985 N=31 obs. Durbin’s h = -1.49

Again the price variable is not statistically significant. So the equation was regressed with different lagged prices and a three year lagged price gave a better estimate:

\[(4.4.4)\quad QSBO_t = 6490.7 + 0.7345 QSBO_{t-1} + 0.13065 RPLUS_{t-3} - 10034 D58 + 3631.6 D59 - 4498.6 D60 - 1886.4 TBOL\]

\[\text{Adj R}^2=0.8772 \quad \text{SEE}=1564.3 \quad \text{D.W.}=2.24\]

Period: 1955-1985 N=31 obs. Durbin’s h = -0.893

When compared to (4.4.3), this equation gives a marginally better fit. The price variable has a t-value of 1.27, which, though still not significant at the 5 percent level, is better than the case in (4.4.3) and has the expected sign. Durbin's h statistic and the runs test indicate an absence of serial correlation.

Different functional forms were tried and the best estimate based on the regression diagnostics was:
(4.4.5) \[ \ln QSBO_t = 3.1754 + 0.5907 \ln QSBO_{t-1} + 0.1125 \ln RPLUS_{t-3} \]
\[ -(3.62) \quad (5.61) \quad (2.09) \]
\[ -0.4335 D58 + 0.1835 D59 - 0.1878 D60 - 0.08784 TBOL \]
\[ (-7.67) \quad (2.87) \quad (-3.36) \quad (-6.27) \]
\[ \text{Adj R}^2 = 0.9147 \quad \text{SEE} = 0.05309 \quad \text{D.W.} = 2.28 \]
Period: 1955-1985 N=31 obs. Durbin's h = -0.947

This was selected as the supply equation for Bolivia during the period 1955 to 1985.

4.5 Mine production of tin for Indonesia

The regression estimates for Indonesia based on the general model as shown in table 4.3 is as follows:

(4.5.1) \[ QSIN_t = -1488.7 + 0.9195 QSIN_{t-1} + 0.3549 RPLUS_{t-1} \]
\[ (-0.78) \quad (13.6) \quad (2.61) \]
\[ -2962.5 D58 + 2071.3 D60 - 1606.8 D75 \]
\[ (-1.21) \quad (0.86) \quad (-0.66) \]
\[ -1814.5 D82 - 7111.4 D83 - 1882.0 D85 \]
\[ (-0.72) \quad (-2.87) \quad (-0.79) \]
\[ \text{Adj. R}^2 = 0.8786 \quad \text{SEE} = 2320.8 \quad \text{D.W.} = 1.98 \]
Period: 1954-1985 N=32 obs. Durbin's h = -0.35

Though the price coefficient was significant and positive as expected, many of the export control dummy variables were insignificant at the 5 percent level. The plot of Indonesian tin output in figure 4.3 shows that the mine production of tin fell from 35,000 tonnes in the early 1950s to just over 10,000 tonnes by 1966. During the same period, the real price of tin increased somewhat. From 1967, tin output appears to have varied in line with price changes until 1985.
Figure 4.3: Real price and mine production of tin, Indonesia, 1950-1988
The Indonesian tin industry has always been under state control, first by the Dutch colonial government and later by the independent Indonesian government which began exercising its control over mining management in 1953 by taking over the tin operations in the island of Bangka off Sumatra. By 1958, the nationalization was complete as the operations in the other two tin-producing islands of Belitung and Singkep also came under the control of the government. This was also the period when President Sukarno began his era of "Guided Democracy" which resulted in more than a decade of poor economic performance. In writing about the Indonesian tin industry, Fox (1974) states that through the 1960s, it suffered from almost every disease that could afflict an industry - from the continued depreciation of ageing dredges, from the continuous shortage of spare parts for mining machinery, from the mis-buying of wrong equipment, from gross inefficiency in management and from the political interference to be expected in an industry...(p. 35).

After Sukarno was deposed in a military coup in 1965, the general economic conditions began improving. The tin industry's output bottomed out in 1966 and with the help of foreign aid, especially from Holland, the tin industry began its recovery.

The years from 1954 to 1966 can be seen as a period when output did not respond to price. This hypothesis was incorporated into the model as follows:

\[
(4.5.2) \quad QSIN_t = \beta_0 + \beta_1 QSIN_{t-1} + \beta_{21} RPLUS_{t-1} + \beta_{22} DZIN \times RPLUS_{t-1} + \text{export control dummies} + \epsilon_t
\]

where \( DZIN = 1 \) up to and including 1966 and 0 after that. If our assumption is valid then the null hypothesis would be:

\[ H_0: \beta_{21} + \beta_{22} = 0. \]
The model given in (4.5.2) was estimated and the results are as follows:

\[ QSIN_t = 1247.6 + 0.8718 \text{ QSIN}_{t-1} + 0.2603 \text{ RPLUS}_{t-1} - 0.3144 \text{ DZIN} \times \text{RPLUS}_{t-1} - 1908.3 \text{ D58} + 2898.9 \text{ D60} - 1820.5 \text{ D75} - 1621.8 \text{ D82} - 7148.4 \text{ D83} - 2503.7 \text{ D85} \]

\[ (-0.68) \quad (14.4) \quad (1.96) \quad (-2.64) \]

\[ (-0.93) \quad (1.45) \quad (-0.91) \]

\[ (-0.77) \quad (-3.44) \quad (-1.27) \]

Adj. \( R^2 = 0.9085 \quad \text{SEE} = 1915.0 \quad D.W. = 2.56 \]

Period: 1954-1985 N=32 obs. Durbin's h = -1.73

The null hypothesis that the sum of the price coefficients is equal to zero is not rejected at the 5 percent level of significance. However, a number of export control dummy variables are still not significant and the Durbin's h statistic of -1.73 indicates the presence of serial correlation at the 5 percent level of significance.

The residual plot shows two outliers which were more than 2 standard errors away from the mean of zero; the 1964 outlier is positive and the 1984 outlier is negative. There is no clear explanation for the increased output in 1964, which actually followed an unusually sharp drop in the output during 1963. In the chaotic periods of the early 1960s, these abrupt variations in output could have been due to incorrect statistical reporting. As for the 1984 outlier, the drop in output occurred during a period of sustained and large cutback in exports. As was noted in the last section when we discussed Bolivian tin production, it has been a common practice in countries where the tin industry is nationalized, for tin production to be maintained at a rate higher than the limited export rate; they preferred to carry the excess production as inventory to be sold when export controls were renewed. In the case of Indonesia, perhaps once it realized that the export
controls were going to continue for some time, the 1984 cutback may have been to bring production in line with permitted export levels.

The equation was reestimated with an additional variable, D84, to represent the 1984 cutback; the results were as follows:

\[
(4.5.4) \quad QSIN_t = 1156.8 + 0.8869 QSIN_{t-1} + 0.2638 RPLUS_{t-1} - 0.3493 DZIN \cdot RPLUS_{t-1} \\
\quad - 2054.3 D58 + 2851.9 D60 - 2163.9 D75 \\
\quad - 2108.5 D82 - 7607.2 D83 - 4527.5 D84 - 2800.0 D85 \\
\quad (0.71) \quad (16.4) \quad (2.23) \quad (-3.27) \\
\quad (-1.12) \quad (1.60) \quad (-1.21) \\
\quad (-1.11) \quad (-4.09) \quad (-2.55) \quad (-1.59)
\]

\[\text{Adj. } R^2 = 0.9275 \quad \text{SEE} = 1704.4 \quad \text{D.W.} = 2.82 \]

Period: 1954-1985 \quad N=32 \text{ obs.} \quad \text{Durbin's } h = -2.45

Again, the null hypothesis of \( H_0: \beta_{21} + \beta_{22} = 0 \) is not rejected at the 5 percent level of significance. The t-values for most of the export control dummy variables increased though all except D83 and D84 are not significant. The serial correlation problem is more pronounced in this equation as shown by the higher Durbin's h-statistic. Applying the OLS procedure to a relationship with correlated disturbances results in unbiased but inefficient estimation and invalid inference procedures (Johnston, 1984, p. 310).

There are three general reasons for autocorrelated disturbances: omission of explanatory variables, misspecification in the form of the relationship and measurement error in the dependent variable. As a means of checking for omitted variables, different price lags were tried and the one-period price lag given in the above equation proved to
be the best choice. To check for misspecification, different functional forms such as the log-linear and the log-log forms were tried and the linear model still provided the best fit.

To correct for serial correlation there are a number of alternative estimation procedures. The Cochrane-Orcutt process is one of the most commonly used procedures; however, according to Johnston (1984), this may lead to inconsistent estimates. For partial adjustment models with lagged dependent variables, he recommends using the Maximum-Likelihood (ML) estimation method with a grid search for the value $\phi$, the autocorrelation coefficient. The supply function was estimated again using the ML technique with a grid search and the results are as follows:

\[
\begin{align*}
\text{QSIN}_t &= 918.0 + 0.8978 \text{QSIN}_{t-1} + 0.2633 \text{RPLUS}_{t-1} - 0.3444 \text{DZIN} \times \text{RPLUS}_{t-1} \\
&\quad - 1888.8 \text{D58} + 2146.4 \text{D60} - 2643.9 \text{D75} \\
&\quad - 1925.3 \text{D82} - 7879.9 \text{D83} - 4508.6 \text{D84} - 2840.5 \text{D85} \\
&\quad (-1.46) (1.74) (-2.20) (-1.40) (-5.67) (-3.22) (-2.04)
\end{align*}
\]

\[
\begin{align*}
\text{Adj. } R^2 &= 0.9419 \\
\text{SEE} &= 1225.4 \\
\text{D.W.} &= 2.12 \\
\phi &= -0.4500 \\
\text{Period: } 1954-1985 \\
\text{N} &= 32 \text{ obs.}
\end{align*}
\]

The estimated value of the serial correlation was -0.45 with an asymptotic $t$-value of -2.79. After the correction for serial correlation, the coefficient of adjustment and the price coefficients did not alter very much. There have been changes in some of the coefficients for the export control dummy variables, though there are still three of them, D58, D60 and D82, which have $t$-values less than 2.02, the critical value at the 95 percent confidence level. The null hypothesis of $H_0: \beta_{21} + \beta_{22} = 0$ was not rejected at the 5 percent level of significance. So, this equation becomes the supply function for Indonesia.
4.6 Mine production of tin for Thailand

The regression estimates for Thailand based on the general model as shown in table 4.3 is as follows:

\[
QSTH_t = 1244.3 + 0.5708 QSTH_{t-1} + 0.8548 RPLUS_{t-1} - 6359.8 D58 + 157.1 D60 - 8187.0 D75 - 4259.2 D82 - 6074.5 D83 - 6075.7 D85
\]

\[
\begin{align*}
(1.43) & & (6.74) & & (5.08) \\
(-4.27) & & (0.10) & & (-5.16) \\
(-2.71) & & (-4.05) & & (-4.16)
\end{align*}
\]

Adj. \( R^2 = 0.9555 \) \( \text{SEE} = 1431.1 \) \( \text{D.W.} = 1.23 \)

Period: 1954-1985 \( N = 32 \) obs. \( \text{Durbin's } h = -2.05 \)

Of all the supply functions reported in table 4.3, Thailand's supply function has the lowest value of \( \beta_1 \) and the highest value of \( \beta_2 \). This indicates that Thailand's supply is the most flexible in responding to price changes. The coefficient of adjustment \( (1-\beta_1) \) is 0.43 which implies that 43 percent of the average annual production is explained by variations in the price and dummy variables. However, a major problem with the above estimates is the presence of serial correlation as manifested by the high value of Durbin's h-statistic.

As in the case of Indonesia, different functional forms and price lags of various lengths were tested; the linear model with a one-period price lag gave the best fit. The serial correlation was then corrected by using the ML method with a grid search and the results were as follows:
Figure 4.4: Real price and mine production of tin, Thailand, 1950-1988
\begin{align*}
QSTH_t & = 1415.7 + 0.3872 \, QSTH_{t-1} + 1.1526 \, RPLUS_{t-1} \\
& \quad - 5187.9 \, D58 + 503.0 \, D60 - 8843.7 \, D75 \\
& \quad - 883.6 \, D82 - 3653.0 \, D83 - 4841.3 \, D85 \\
\text{Adj. } R^2 & = 0.9679 \quad \text{SEE} = 1031.2 \quad \text{D.W.} = 1.89 \\
\text{Period: } 1954-1985 \quad N = 32 \text{ obs.} \quad \phi = 0.73 \\
\end{align*}

The estimated value of the autocorrelation coefficient was 0.73 with a t-value of 5.33. After the correction for serial correlation, the price coefficient has increased from 0.85 in equation (5.6.1) to 1.15 in this equation; $\beta_1$ has decreased. Both these changes indicate a greater flexibility in the supply function. The dummy variables, D60 and D82 are not significant at the 5 percent level. As can be seen from figure 4.4, Thailand’s tin output for 1959 was not restricted to the level of 1958. Like Bolivia, Thailand too bartered about 2000 tonnes of tin, which is about 20 percent of its 1959 production, for agricultural commodities with the United States government. So when the export limits were raised in 1960, Thailand’s production was on the way up.

These two dummy variables were dropped and the supply function was reestimated again using the ML with the grid search method. The results are as follows:
\[(4.6.3) \quad QSTH_t = 1349.9 + 0.3462 \, QSTH_{t-1} + 1.2330 \, RPLUS_{t-1} \]
\[\begin{align*}
& (0.86) \quad (3.98) \quad (6.83) \\
& - 5028.5 \, D58 - 9069.6 \, D75 \\
& (-5.67) \quad (-8.94) \\
& - 3118.1 \, D83 - 4686.2 \, D85 \\
& (-3.65) \quad (-4.33)
\end{align*}\]

\[\text{Adj. } R^2 = 0.9697 \quad \text{SEE} = 1045.0 \quad D.W. = 1.87\]

Period: 1954-1985 \(N=32\) \(\text{obs.}\)

This becomes the estimated supply function for Thailand.

4.7 Mine production of tin for Australia

The regression estimates for Australia based on the general model as shown in table 4.3 is as follows:

\[(4.7.1) \quad QSAU_t = 234.4 + 0.9799 \, QSAU_{t-1} + 0.0300 \, RPLUS_{t-1} \]
\[\begin{align*}
& (0.48) \quad (14.7) \quad (0.39) \\
& - 1606.3 \, D75 - 680.2 \, D82 - 3362.7 \, D83 \\
& (-1.82) \quad (-0.76) \quad (-3.70) \\
& - 1382.6 \, D85 \\
& (-1.61)
\end{align*}\]

\[\text{Adj. } R^2 = 0.9550 \quad \text{SEE} = 840.9 \quad D.W. = 1.98\]

Period: 1954-1985 \(N=32\) \(\text{obs.}\)

The price coefficient is close to zero and is not significant. The coefficient of adjustment \((1-\beta_1)\) is 0.02, which is extremely low for a market oriented economy like Australia. From the plot of Australian tin output shown in figure 4.5, it can be seen that there was a sharp rise in tin output from 1964 to 1972. This was a period when new tin mines came on stream in Australia. This increase in capacity caused a sudden spurt in tin output from Australia during that period. This implied that the coefficient of the lagged output, \(\beta_1\),
Figure 4.5: Real price and mine production of tin, Australia, 1950-1988
would have a different value during this period. So the general model was altered to incorporate this feature and is as follows:

\[
(4.7.2) \quad QSAU_t = \beta_0 + \beta_{11} QSAU_{t-1} + \beta_{12} DZAU \cdot QSAU_{t-1} + \beta_2 RPLUS_{t-1} + \text{export control dummies} + \epsilon_t
\]

where \( DZAU = 1 \) for the years 1964 to 1972 and 0 otherwise. This model was estimated and the results are as follows:

\[
(4.7.3) \quad QSAU_t = -375.8 + 0.9123 QSAU_{t-1} + 0.1712 DZAU \cdot QSAU_{t-1} + 0.1052 RPLUS_{t-1} - 1319.9 D75 - 186.2 D82 - 2762.8 D83 - 1646.3 D85
\]

\[
\begin{array}{cccc}
\text{Adj. } R^2=0.9725 & \text{SEE}=658.3 & \text{D.W.}=2.33 \\
\text{Period: 1954-1985} & \text{N}=32 \text{ obs.} & \text{Durbin’s } h=-1.01
\end{array}
\]

The value of \( \beta_{11} \) has declined while \( \beta_{12}, \) the coefficient that takes into account the new capacity added, is significant at the 5 percent level. The price coefficient is higher but not significant. In examining the residuals, there was a negative outlier for 1984 which was more than twice the standard error of the estimate (SEE). This occurred the severe export control years of 1983 to 1985. Since the coefficient for D82 was insignificant and small in value, D82 was dropped and a new export control variable D84 was added to the model. The estimated equation is now as follows:
Although this equation appears to have higher t-values, it has a serial correlation problem. Different functional forms were tried and the linear model gave the best fit. Various price lags were used in the estimation and the one period price lag used above gave the best fit. To correct for the presence of the serial correlation problem, the equation was reestimated using the ML grid search procedure and the results are as follows:

$$QSAU_t = -341.1 + 0.9249 QSAU_{t-1} + 0.1589 DZAU*QSAU_{t-1} + 0.1011 RPLUS_{t-1} - 1429.9 D75 - 2908.9 D83 + 0.1451 DZAU*QSAU_{t-1} + 0.1451 DZAU*QSAU_{t-1} + 0.0858 RPLUS_{t-1} - 1202.0 D75 - 3152.7 D83 + 0.0858 RPLUS_{t-1} - 1202.0 D75 - 3152.7 D83 + 1761.9 D84 - 1736.9 D85 + 1761.9 D84 - 1736.9 D85$$

$$\text{Adj. } R^2 = 0.9800 \quad \text{SEE} = 560.0 \quad \text{D.W.} = 2.60$$

Period: 1954-1985 N=32 obs. Durbin's h = -1.80

This becomes the estimated supply function for Australia.

4.8 Mine production of tin for Nigeria and Zaire

Nigeria and Zaire were the two African tin producing members of the International Tin Council (ITC). The estimated equation for the combined output of the two countries based on the general model as shown in table 4.3 is as follows:
There are serious problems of misspecification in this equation. \( \beta_1 \), by its definition, should not be more than 1; the price coefficient is insignificant and is close to zero. All the export control dummy variables except for D58 and D60 are insignificant and in three cases have the wrong signs. The reasons for this are quite clear when one examines the plot of the combined output of tin for Nigeria and Zaire in figure 4.6.

In the early 1950s, they were producing over 20,000 tonnes but by 1985, their output has declined to less than 4,000 tonnes. There were many reasons for this. In the case of Zaire, when it became independent in 1960, it was embroiled in a serious civil war due to an attempted secession by the copper-rich province of Katanga. (Zaire was known as Belgian Congo before that.) A United Nations peace-keeping force was sent to restore order. The tin industry of Zaire "entered into a long period of plundering, maltreatment and disorder from both official and unofficial armies" (Fox, 1974, p. 57). The industry is now partly owned by the government. It never recovered from the effects of the civil war in part due to the economic and political climate in Zaire which was not conducive to the industry's revival.
Figure 4.6: Real price and mine production of tin, Nigeria and Zaire, 1950-1988
In the case of Nigeria, the civil war involving the attempted secession by Biafra in 1967-70 did not affect the tin mining areas. However, the loss of many semi-skilled workers who were Ibos (the people of the secessionist Biafra) and the restriction on the import of mining equipment and supplies, due to the war, gave the impetus to the long term decline of the Nigerian tin industry. The sharp and sudden rise in the revenues from the export of petroleum since 1974 led to a decline in other industries (the Dutch disease effect) which affected the tin mining industry also.

So it can be seen that for one reason or another, from about 1967, tin output from these two countries have not responded to the increase in the real price of tin. This also means that export controls in the 1970s and 1980s were not binding and thus it is not surprising to get insignificant coefficients. As can be seen in figure 4.6, in 1961 there was a sharp drop in output which was entirely due to the outbreak of civil war in Zaire and the ensuing intense fighting. Taking all these factors into account, the following alternative model is proposed:

\[
(4.8.2) \quad QSZN_t = \beta_0 + \beta_1 QSZN_{t-1} + \beta_{21} RPLUS_{t-1} + \beta_{22} DZZN \times RPLUS_{t-1} \\
+ \beta_3 D\text{CWZ61} + \beta_4 D58 + \beta_5 D60 + \epsilon_t
\]

where \(DZZN=1\) for all years greater than 1966 and 0 otherwise; and \(D\text{CWZ61}\) is a dummy variable to represent the supply shock due to the outbreak of civil war in Zaire in 1961. If our assumption on the ineffectiveness of price on output after 1967 is valid then the null hypothesis of \(H_0: \beta_{21} + \beta_{22} = 0\) should not be rejected.
The model given in (4.8.2) was estimated and the results are as follows:

\[(4.8.3) \quad QSZN_t = -420.3 + 0.9749 \quad QSZN_{t-1} + 0.1262 \quad RPLUS_{t-1} - 0.1272 \quad DZZN*RPLUS_{t-1} \]
\[- 6040.0 \quad D58 + 2219.1 \quad D60 - 2504.3 \quad DCWZ61 \]
\[-(-0.43) \quad (25.1) \quad (1.83) \quad (-3.14) \]
\[-\quad (-9.25) \quad (3.40) \quad (-3.92) \]

\[\text{Adj. } R^2=0.9892 \quad \text{SEE}=610.5 \quad \text{D.W.}=1.93 \]
\[\text{Period: } 1954-1985 \quad \text{N}=32 \text{ obs.} \quad \text{Durbin's } h=0.19 \]

The null hypothesis that the sum of the price coefficients is equal to zero is not rejected at the 5 percent level of significance. All but one of the coefficients are significant at the 5 percent level of significance. As usual various functional forms and price lags were tried and the linear model with a one period price lag gave the best fit. So this equation becomes the supply function for Zaire and Nigeria.

4.9 Mine production of tin for the non-ITC countries

Chapter 2 showed that the output of the non-ITC countries formed only a small proportion of the world output; but by 1985, they were producing about a third of the non-socialist world output. The estimated equation for the output of the non-ITC countries based on the general model shown in table 4.3 is as follows:

\[(4.9.1) \quad QSNC_{t} = -1085.1 + 1.1726 \quad QSNC_{t-1} - 0.0899 \quad RPLUS_{t-1} \]
\[-(-0.84) \quad (21.6) \quad (-0.54) \]

\[\text{Adj. } R^2=0.9616 \quad \text{SEE}=2386.9 \quad \text{D.W.}=2.65 \]
\[\text{Period: } 1954-1985 \quad \text{N}=32 \text{ obs.} \quad \text{Durbin's } h=-2.02 \]
Figure 4.7: Real price and mine production of tin, non-ITC countries, 1950-1988

![Graph showing real price and mine production of tin, non-ITC countries, 1950-1988.](image-url)
The adjustment parameter, i.e., the coefficient of the lagged output, is beyond its valid range of 0 to 1. The high Durbin-Watson and h-statistics indicate the presence of serial correlation. The price coefficient is very low and not significant. All these seem to indicate a severe problem of misspecification. As figure 4.7 shows, the output from ITC countries appears to have kept pace with price rises until about 1980. After that, even as the price was declining, the output was increasing at a very rapid pace of growth. This sharp growth in output is, to a large extent, due to two sources: first, the growth in Brazil's output due to the new discoveries of rich deposits of tin ore in the 1980s; second, the increase in the smuggling of tin ore from Malaysia, Thailand and Indonesia. As we noted in chapter 2, tin miners in those three countries smuggled tin ore to Singapore and other places to avoid ITC imposed export controls. In the ITC official statistics this is euphemistically referred to as tin from "unspecified origins".

In an attempt to deal with the smuggled tin, we introduced a dummy variable, DSMGL, which had a value of 1 from 1982 to 1985 and 0 otherwise. We would expect the coefficient of DSMGL to be positive since it raises the output of non-ITC countries during that period. As for Brazil's growth in tin output, we decided to treat Brazil's output as an exogenous variable. This implied that in the equation that will be estimated, the dependent variable (QSRW) is the output of the non-ITC countries (QSNC) minus the output of Brazil (QSBR). The results of the estimation are as follows:
\[(4.9.2) \quad QSRW_t = 1115.8 + 0.71677 \cdot QSRW_{t-1} + 0.3262 \cdot RPLUS_{t-1} + 4688.8 \cdot DSMGL \quad (1.15) \quad (8.60) \quad (2.70) \quad (4.31)\]

<table>
<thead>
<tr>
<th>Adj. $R^2$</th>
<th>SEE</th>
<th>D.W.</th>
<th>Durbin's</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.9429</td>
<td>1605.4</td>
<td>2.40</td>
<td>-1.365</td>
</tr>
</tbody>
</table>

Period: 1954 - 1985, N = 32 obs

All the coefficients have the correct sign and are significant at the 5 percent level. Though the Durbin-Watson and the h statistics are higher than usual, they are still within acceptable limits. An examination of the residual plot shows two outliers, a positive one in 1983 and a negative one in 1984. This could be due to the fact that smuggling was at its peak in 1983, based on the estimates made by the ITC. According to its Tin Statistics, 1975-1985, tin from unspecified origins from 1981 to 1985 was 6000, 9850, 16550, 11440 and 11000 tonnes respectively. This variation in the levels of smuggled tin led to the outliers. Since the equation has a reasonably good fit except for the two outliers, we decided to use it in the simulation exercise in chapter 6. The supply of tin from the non-ITC countries can now be written as an identity:

\[(4.9.3) \quad QSNC = QSRW + QSBR\]

Since we have included the smuggled tin in the output of the non-ITC countries, the non-ITC supply function represents the response of the non-ITC countries plus the non-official sector of the ITC countries. This means that the supply functions of Malaysia, Indonesia and Thailand that were estimated in the earlier sections represent only the official sector of the ITC countries.
4.10 Supply elasticities of price for tin

Table 4.4 shows the coefficients of adjustment and price elasticities of the different tin producers. The elasticities are computed from the equations discussed in the previous sections. They are based on the mean values of the price and output variables over the 31 periods used in the estimation of the equations. In general the adjustment coefficients range from a low of 0.025 for Zaire and Nigeria to 0.654 for Thailand. Higher coefficients indicate a higher level of flexibility in the country's tin industry. Countries with a large number of small-scale low fixed cost mines will in general be more flexible. As pointed out in appendix 2, the gravel pump mining method is more flexible than dredging or lode mining technology. Much of Thailand's output comes from gravel pump mines as well as small scale off-shore suction boat operations. Thus, its high coefficient of adjustment is indicative of its technology mix. In contrast, Australia and Bolivia use underground mining technology and as a result their output is not as flexible with respect to changes in prices. On an *a priori* basis, we should expect Malaysia to have an adjustment coefficient higher than what is reported in table 4.4, given that more than half its output is produced by gravel pump and other small scale mines. However, as we noted earlier, government policies which have made acquiring and renewing mining leases difficult, have affected the industry's flexibility.

Short run price elasticities follow the same pattern, with Thailand having the highest price elasticity. This was also the case in the World Bank study which reported short run
Table 4.4: Supply elasticities of price for tin

<table>
<thead>
<tr>
<th>Country or region</th>
<th>Coefficient of adjustment</th>
<th>Price elasticities</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Short run</td>
<td>Long run</td>
<td></td>
</tr>
<tr>
<td>Malaysia</td>
<td>0.166*</td>
<td>0.169*</td>
<td>1.018*</td>
<td></td>
</tr>
<tr>
<td>Bolivia</td>
<td>0.279*</td>
<td>0.067</td>
<td>0.240</td>
<td></td>
</tr>
<tr>
<td>Indonesia</td>
<td>0.102*</td>
<td>0.112*</td>
<td>1.096*</td>
<td></td>
</tr>
<tr>
<td>Thailand</td>
<td>0.654*</td>
<td>0.607*</td>
<td>0.928*</td>
<td></td>
</tr>
<tr>
<td>Australia</td>
<td>0.058*</td>
<td>0.118*</td>
<td>2.05*</td>
<td></td>
</tr>
<tr>
<td>Zaire and Nigeria</td>
<td>0.025*</td>
<td>0.097</td>
<td>3.88</td>
<td></td>
</tr>
<tr>
<td>Non-ITC</td>
<td>0.283*</td>
<td>0.194*</td>
<td>0.685*</td>
<td></td>
</tr>
</tbody>
</table>

Notes: 1. The asterisks indicate that the coefficient or elasticity is significant at the 5 percent level.  
2. Non-ITC elasticities exclude Brazil.

price elasticities of 0.60, 0.31, 0.24 and 0.21 for Thailand, Malaysia, Bolivia and Indonesia. Our price elasticities are much less for the latter three countries. The main reason is our inclusion of data from the 1975 to 1985 period. Their data covered only 20 years from 1955 to 1975. The 1975 to 1985 period is when the tin industry in Malaysia and Bolivia was on the decline due to government policies which were detrimental to the growth of the mining industry.

In general, one has to treat price elasticities of supply, computed from econometric studies using time series data, with some reservation. Baldwin (1983) provides an excellent discussion on the shortcomings of econometric estimates of elasticities in the tin industry. Firstly, earlier estimates of price elasticities do not take into account of the degree of severity of production restrictions during export control years. We have tried to alleviate this to some extent by using different dummy variables for different years. Secondly, in computing these elasticity estimates, we assume that the tin market is a competitive one.
However, the industry has from time to time behaved in a non-competitive manner. This was particularly the case in the early 1980's, when the behaviour of the ITC producer members was more akin to that of the OPEC cartel. Another factor that may influence price elasticities is that new mines opened easily and promptly in periods of high prices but did not shut down when prices fell. This is a problem in many industries with high fixed costs.\(^2\) This implies that the short run elasticity will be high in a period of rising prices and lower if computed in a period of declining prices. Given these factors, it is clear that a more detailed approach is needed to compute price elasticities of supply.

4.11 Concluding remarks

In this chapter we have estimated the supply functions for the individual ITC producer countries as well as for non-ITC countries as a whole. It is obvious that in addition to the price of tin, two very important exogenous factors influenced the behaviour of tin producers and hence their supply functions during the period under study. The first was an external factor, i.e., the economic activities of the International Tin Council, in particular, the imposition of export controls. The two periods of severe export controls were especially important. The first, which was imposed between 1958-80, occurred within the first five years of the life of the International Tin Agreements. The second set of severe export controls of 1983 to 1985 occurred within the final five year period of the ITAs. As we saw, it culminated in the collapse of the ITC. The influence of the ITC on

\(^2\)See Porter (1980) for a good discussion on this phenomena.
the supply of tin has been discussed in many earlier studies. The second major factor that
influenced tin supply in the major tin producing countries was the internal political
developments in these countries. Whether it was the economic mismanagement of
President Sukarno's "guided democracy" in Indonesia, or the political problems of Bolivia
or the New Economic Policy introduced by Malaysia in 1971 or the civil war in Zaire, they
all had profound effects on the supply functions of tin in these countries. Our study has
made an attempt to examine the impact of institutional effects such as these in more detail
than earlier studies of the tin industry.

Finally, in our study we have not included another source of supply of tin, i.e.
secondary tin. The major reason for this omission is that with the exception of the United
States, there are no complete and reliable data on the production and use of secondary tin.
Both the production and consumption data provided by the International Tin Council was
strictly confined to primary tin. A second reason is that when compared to other non-
ferrous metals, tin has the lowest figure for scrap consumption (Ghosh et al, 1987, p. 71).
Since tin is mostly used as an alloy with other metals (e.g. with steel in tin plate, with lead
or antimony in solder, with copper and zinc in bronze and brass), it is difficult to produce
refined metal from scrap. Recycled tin is used directly without separation (e.g. when
bronze or brass is recycled, the tin is not separated out). This, perhaps, is the main reason
why data on recycled tin is spotty and inconsistent. As we mentioned in the discussion on
secondary tin in chapter 2, the World Bank model (Chhabra et al, 1978) also omitted the
production of secondary tin.
5. CONSUMPTION AND PRICE OF TIN

In this chapter, a consumption function for tin is first specified in general terms. In the second section, the estimated consumption equations are presented and the results discussed. In the third section we will specify the remaining equations to complete the model. In the final section we will discuss the estimated price equations.

5.1 Specification of a consumption function for tin

Consumption demand for tin is derived demand since it is rarely consumed directly in its pure form. It is mainly used in the manufacturing of tinplate, solder, brass and other industrial alloys, and tin chemicals. Like copper and zinc, tin is a typical industrial metal that is consumed in a wide range of industries. The cost of tin is normally a very small fraction of the total cost of the output of these industries, since it is just one of the many inputs in the production process. Assuming that tin-using industries minimize the cost of production, the consumption of tin will depend not only on its price, but also on the prices of its substitutes as well as on the output of these industries and the technology used. Consumption of tin is also affected by exogenous events such as prolonged strikes in tin-using industries. The consumption function of tin can be expressed as follows:

\[ QC = f(P,Ps, Y, T, Z) \]

where

- \( QC \) = consumption of tin;
- \( P \) = price of tin;
- \( Ps \) = price of its substitutes;
\[ Y = \text{output of tin-using industries}; \]
\[ T = \text{a variable representing the technology used}; \text{ and} \]
\[ Z = \text{variable(s) representing exogenous events}. \]

Just like production, consumption does not respond to price variations immediately due to technological constraints and capital specificity. In some uses of tin in which tin or its substitutes may both be used or, in certain kinds of solders where the proportion of tin can vary, an increase in the price of tin relative to its substitutes may lead to short and medium run decreases in the consumption of tin. These changes are reversible in the sense that if the relative price declines, consumption will increase. To capture the distributed lag in price we tried using the polynomial distributed lag model but the results were not satisfactory. Given that the impact will most likely follow a decay pattern as portrayed by the partial adjustment mechanism, we have introduced a one period lagged consumption variable to capture this effect.

In many other uses of tin, given the technological processes that are available at a given time, consumers will be unable to replace tin with other materials. For example, firms manufacturing beer and soft drink cans may have installed machinery making cans from tin-coated steel; the capital specificity in this case implies that the firms have to continue with the use of tin-coated steel as an input. In some other uses such as in the manufacture of certain tin based chemicals, there are no realistic alternatives to tin. However, if these tin-consuming firms expect the changes in the relative price of tin to be
persistent in the long run, they may consider making changes to their technological processes so as to reduce the use of tin or eliminate it completely by using substitute materials. For example, can making firms may install new machinery which produces aluminium cans rather than tin-plated steel cans. These changes can be costly and time consuming. However, if the savings made in the input costs through substitution or reduction in the intensity of usage is bigger than adjustment or switching costs in the production process, such changes will take place.

Some of these changes are permanent and in the past have resulted in a permanent loss of market for tin. For example, the development of electrolytic tinplating technology in the 1940s place in a period of tin shortage due to World War II. This technology was eventually adopted by all major tinplate producers. As we saw in chapter 2, electrolytic tinplating enabled tinplate manufacturers to apply a much thinner coating of tin on steel and still obtain all the anti-corrosion benefits of the tin layer. This resulted in a substantial reduction in the use of tin although the tonnage of tinplate produced increased during the last four decades. Even if the price of tin was to now drop substantially, tinplate manufacturers are not going to revert to the old hot-dip method.

In other cases the reverse has happened. For example, due to environmental concern over lead poisoning, in many kinds of solder tin is replacing lead, although tin is more expensive. In some situations, a new technology may necessitate the increased use of tin. An example in point is the introduction of wave soldering process in the electronics
industry that requires a solder which is richer in tin than the traditional solders. In our model, we have used a time trend variable to capture the effect of these technological changes on the consumption of tin.

The most important substitutes for tin are aluminium and plastic, especially in the packaging industry. Other substitutes are copper, zinc and lead. Since aluminium is the main substitute for tin, its price was used as a proxy for the price of substitutes. Detailed data on the output of tin-using industries (Y) is not available. Therefore, the index of industrial production (IIP) was chosen as a proxy for Y.

Economic theory does not provide an \textit{a priori} hypothesis concerning the choice of the functional form. So assuming a linear form and incorporating the changes that were discussed in the last few paragraphs, we get:

\begin{equation}
QC_x = \beta_0 + \beta_1 QC_{x-1} + \beta_2 RP_{t-1} - \beta_3 RP_{AL_{t-1}} + \beta_4 IIP_{x_t} + \beta_5 T + \epsilon_t
\end{equation}

where

- $QC_x$ = quantity of tin consumed in country $x$;
- $RP$ = real price of tin;
- $RP_{AL}$ = real price of aluminium;
- $IIP$ = index of industrial production;
- $T$ = time trend; and
- $\epsilon_t$ = random error term.

$\beta_1$, which is related to the coefficient of adjustment, should be positive and have a value between 0 and 1. $\beta_2$ is the own price effect on consumption and should be negative.
\( \beta_3 \) is the cross price effect of a substitute on consumption and should be positive. \( \beta_4 \) is a coefficient representing the effect of industrial production on consumption. This should be positive since increased output leads to increased use of tin, *ceteris paribus*. \( \beta_5 \) is a coefficient representing the effect of technology on the consumption of tin. In tinplating technology, the trend has been towards lower intensity of usage. This would lead us to expect \( \beta_5 \) to be negative. However, in other uses of tin such as in the production of solder, the trend is not that clear. The quantity of solder required per car in the automobile industry has declined due to technological improvements. In the electronics industry, however, the trend has been towards the usage of solder which has a higher content of tin. In the chemical industry, the use of tin has been increasing due to the introduction of new tin based chemicals. So, in overall terms, we are not able to sign \( \beta_5 \). To summarize we expect: \( \beta_1, \beta_3 \) and \( \beta_4 > 0 \), and \( \beta_2 < 0 \).

### 5.2 Estimation of the consumption equations

A consumption function based on equation (5.1.2) was first estimated for the total consumption of the western world (WW) in the aggregate form. Variations in the consumption patterns of the different countries will be captured more effectively in a model which disaggregates the total consumption according to the major consuming areas. Therefore, separate consumption equations were estimated for the five leading tin consuming countries and two regions covering the rest of the world. The countries and regions are the United States (US), Japan (JA), West Germany (WG), the United
Kingdom (UK), France (FR), the other industrialized countries (IC) and the developing countries (DC). In following subsections, we will first provide summary statistics of the data used in the regressions and then examine the regression estimates for the general model.

5.2.1 Data

For all our regressions, annual data for the period of 1954 to 1985 (32 observations) was used. A list of the variables used and the source of the data is provided in appendix 4. The consumption of tin, QCxt, for country or region x in period t, was obtained from various issues of Tin Statistics published by the International Tin Council. All consumption is given in metric tonnes. The real price of tin was obtained by converting the LME spot tin price into the local currency, and then deflating it by the wholesale price index of that country. In the case of the other industrialized countries (IC), the developing countries (DC) and the western world (WW), the U.S. real price of tin was used.

The aluminium market has a "two-tier" pricing system. Before World War II, producer pricing was the only basis for aluminium trading. Until the 1970s, the aluminium market was a highly concentrated market. So most trading was done by contract sales based on producer prices. By the late 1970s, there were many new suppliers in the market resulting in increased competition. "As these new sources began putting their production into the market, there was substantial expansion of spot sales by dealers rather than

Taking all these developments into account, for the United States, the aluminium price used in the regression was based on producer prices until 1979 and the dealer market price after that. The real price was obtained by deflating the nominal price by the United States wholesale price index and expressing this in U.S. dollars per metric tonne. For all other countries and regions, the nominal price was based on the United Kingdom producer price until 1979 and the LME price after that. The real price of aluminium in each case was obtained by converting the London price into the local currency, and then deflating it with the wholesale price index of that country. In the case of other industrialized countries (IC), developing countries (DC) and the western world (WW), the London price was converted to U.S. dollars and deflated by the U.S. wholesale price index to get the relevant real price of aluminium.

Summary statistics for the variables used in the regressions are given in table 5.1. During the 32 year period, the United States with an average consumption of 51,278 tonnes was the largest consumer of tin in the western world. Its consumption was almost
Table 5.1: Summary statistics for variables used in estimating consumption equations

<table>
<thead>
<tr>
<th>Variable</th>
<th>Mean</th>
<th>St. Dev.</th>
<th>C.V.</th>
<th>Min</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Quantity in tonnes:</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>United States (QCUS)</td>
<td>51278</td>
<td>8130.3</td>
<td>0.159</td>
<td>33019</td>
<td>61440</td>
</tr>
<tr>
<td>Japan (QCJA)</td>
<td>22871</td>
<td>9519.4</td>
<td>0.416</td>
<td>6600</td>
<td>38676</td>
</tr>
<tr>
<td>West Germany (QCWG)</td>
<td>13156</td>
<td>3108.1</td>
<td>0.259</td>
<td>6672</td>
<td>22856</td>
</tr>
<tr>
<td>United Kingdom (QCUK)</td>
<td>15756</td>
<td>5604.9</td>
<td>0.356</td>
<td>5838</td>
<td>22796</td>
</tr>
<tr>
<td>France (QCFR)</td>
<td>10176</td>
<td>1196.5</td>
<td>0.118</td>
<td>6900</td>
<td>11700</td>
</tr>
<tr>
<td>Other Ind. Countries (QCIC)</td>
<td>40458</td>
<td>6797.2</td>
<td>0.168</td>
<td>28753</td>
<td>54090</td>
</tr>
<tr>
<td>Developing Countries (QCDC)</td>
<td>18333</td>
<td>4635.3</td>
<td>0.253</td>
<td>11716</td>
<td>27632</td>
</tr>
<tr>
<td>Western World (QCWW)</td>
<td>172028</td>
<td>17066</td>
<td>0.099</td>
<td>140700</td>
<td>214200</td>
</tr>
<tr>
<td><strong>Real tin prices per tonne:</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>United States* (RPLUS - $)</td>
<td>9816.2</td>
<td>3346.4</td>
<td>0.341</td>
<td>5773.8</td>
<td>17621</td>
</tr>
<tr>
<td>Japan (RPLJA - Yen)</td>
<td>2625800</td>
<td>640780</td>
<td>0.244</td>
<td>1670600</td>
<td>3984300</td>
</tr>
<tr>
<td>W. Germany (RPLWG - DM)</td>
<td>22756</td>
<td>5111</td>
<td>0.225</td>
<td>16044</td>
<td>30539</td>
</tr>
<tr>
<td>United Kingdom (RPLUK - £)</td>
<td>5576.6</td>
<td>1548.6</td>
<td>0.278</td>
<td>3563</td>
<td>8585</td>
</tr>
<tr>
<td>France (RPLFR - FF)</td>
<td>46712</td>
<td>16463</td>
<td>0.352</td>
<td>25269</td>
<td>72399</td>
</tr>
<tr>
<td><strong>Real aluminium prices per tonne:</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>United States (RPAUS - US$)</td>
<td>1421.9</td>
<td>185.5</td>
<td>0.130</td>
<td>926.9</td>
<td>1677.9</td>
</tr>
<tr>
<td>Japan (RPALJA - Yen)</td>
<td>385380</td>
<td>64512</td>
<td>0.167</td>
<td>239410</td>
<td>455570</td>
</tr>
<tr>
<td>W. Germany (RPALWG - DM)</td>
<td>3361.6</td>
<td>598.8</td>
<td>0.178</td>
<td>2109.6</td>
<td>4269.3</td>
</tr>
<tr>
<td>United Kingdom (RPALUK - £)</td>
<td>808.7</td>
<td>109.9</td>
<td>0.136</td>
<td>480.2</td>
<td>959.9</td>
</tr>
<tr>
<td>France (RPALFR - FF)</td>
<td>6598.3</td>
<td>796.4</td>
<td>0.121</td>
<td>4737.5</td>
<td>8092.8</td>
</tr>
<tr>
<td>Others* (RPALUS - US$)</td>
<td>1401.7</td>
<td>199.7</td>
<td>0.142</td>
<td>891.2</td>
<td>1780.9</td>
</tr>
</tbody>
</table>

**Index of Industrial Production (1980 = 100.0):**

<table>
<thead>
<tr>
<th></th>
<th>Mean</th>
<th>St. Dev.</th>
<th>C.V.</th>
<th>Min</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td>United States (IIPUS)</td>
<td>72.08</td>
<td>24.16</td>
<td>0.335</td>
<td>35.2</td>
<td>114.6</td>
</tr>
<tr>
<td>Japan (IIPJA)</td>
<td>58.00</td>
<td>36.22</td>
<td>0.625</td>
<td>8.2</td>
<td>121.9</td>
</tr>
<tr>
<td>West Germany (IIPWG)</td>
<td>73.28</td>
<td>22.99</td>
<td>0.314</td>
<td>30.0</td>
<td>103.0</td>
</tr>
<tr>
<td>United Kingdom (IIPUK)</td>
<td>84.59</td>
<td>16.40</td>
<td>0.194</td>
<td>56.4</td>
<td>108.1</td>
</tr>
<tr>
<td>France (IIPFR)</td>
<td>70.61</td>
<td>24.34</td>
<td>0.345</td>
<td>29.0</td>
<td>101.3</td>
</tr>
<tr>
<td>Other Ind. Countries (IIPIC)</td>
<td>70.14</td>
<td>25.18</td>
<td>0.359</td>
<td>30.6</td>
<td>109.9</td>
</tr>
<tr>
<td>Developing Countries (IIPDC)</td>
<td>63.47</td>
<td>29.27</td>
<td>0.461</td>
<td>20.0</td>
<td>109.0</td>
</tr>
<tr>
<td>Western World (IIPWW)</td>
<td>69.14</td>
<td>25.57</td>
<td>0.370</td>
<td>29.6</td>
<td>106.0</td>
</tr>
</tbody>
</table>

Notes: *The U.S. real tin price is also used in the regressions for other industrialised countries, developing countries and the western world.

*Other industrialized countries, developing countries and the western world.
30 percent of the average western world's consumption over that period. The developing countries consumed barely more than 10 percent of the total world consumption. Japan has the largest variation in consumption with a coefficient of variation (CV) of 41.6 percent. In all the seven countries and regions there is variation in the consumption of tin; however, in the western world, overall consumption of tin appears to be more stable with a CV of less than 10 percent.

The real tin prices are based on the same nominal price of tin at the London Metal Exchange (LME). The differences in the coefficients of variation are due to foreign exchange movements and differences of the wholesale price indices of those countries. What is more interesting is that the coefficient of variation of tin price is higher than that of the price of aluminium in each country indicating that tin prices have been more volatile during this period. This is largely due to the monopoly power that aluminium producers had until the 1970s. As noted previously, until the 1970s most aluminium trading was based on prices set by producers.

5.2.2 Results of the estimates for the general model

Table 5.2 presents the results of the estimates for consumption equations based on the general model given by equation (5.1.2). Dummy variables DWG59, DWG60 and DWG61 are used in the estimation for West Germany to represent unusual stockpiling activity in that country during that period. The first line in the table is the equation
Table 5.2: Regression estimates of consumption equations based on the general model

<table>
<thead>
<tr>
<th>Equation No:</th>
<th>(5.2.1)</th>
<th>(5.2.2)</th>
<th>(5.2.3)</th>
<th>(5.2.4)</th>
<th>(5.2.5)</th>
<th>(5.2.6)</th>
<th>(5.2.7)</th>
<th>(5.2.8)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\beta_0$: Constant</td>
<td>6761.8 (0.70)</td>
<td>-4402.2 (-1.03)</td>
<td>3725.2 (3.16)</td>
<td>6845.6 (2.44)</td>
<td>2414.8 (1.95)</td>
<td>-2631.6 (-0.66)</td>
<td>4263.6 (1.61)</td>
<td>27995 (1.79)</td>
</tr>
<tr>
<td>$\beta_1$: QCX</td>
<td>0.6457 (5.19)</td>
<td>0.6733 (5.62)</td>
<td>0.0950 (1.87)</td>
<td>0.3058 (2.56)</td>
<td>0.4553 (4.51)</td>
<td>0.8512 (9.76)</td>
<td>0.5849 (3.40)</td>
<td>0.5490 (5.38)</td>
</tr>
<tr>
<td>$\beta_2$: RPLX</td>
<td>-0.4863 (-1.31)</td>
<td>-0.001946 (-1.36)</td>
<td>-0.2573 (-6.47)</td>
<td>-0.4629 (-1.99)</td>
<td>-0.01728 (-1.09)</td>
<td>-0.4693 (-1.85)</td>
<td>-0.1326 (-0.86)</td>
<td>-3.2164 (-3.62)</td>
</tr>
<tr>
<td>$\beta_3$: RPALX</td>
<td>1.7977 (0.36)</td>
<td>0.02638 (2.61)</td>
<td>1.2221 (4.44)</td>
<td>0.2386 (0.09)</td>
<td>0.1966 (1.72)</td>
<td>1.2650 (0.42)</td>
<td>0.4353 (0.26)</td>
<td>15.892 (1.52)</td>
</tr>
<tr>
<td>$\beta_4$: IIPx</td>
<td>492.49 (2.75)</td>
<td>157.16 (1.74)</td>
<td>91.35 (4.65)</td>
<td>211.21 (3.86)</td>
<td>108.55 (4.22)</td>
<td>361.06 (2.85)</td>
<td>20.33 (0.60)</td>
<td>1589.6 (4.03)</td>
</tr>
<tr>
<td>$\beta_5$: T</td>
<td>-1352.8 (-2.68)</td>
<td>-115.62 (-0.30)</td>
<td>$\Dollar_x.01$ (2.44)</td>
<td>-700.10 (-4.82)</td>
<td>-306.86 (-3.87)</td>
<td>-828.74 (-2.39)</td>
<td>181.70 (1.35)</td>
<td>-3101.3 (-2.95)</td>
</tr>
<tr>
<td>$\beta_6$: DWG59</td>
<td>4646.7 (8.47)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\beta_7$: DWG60</td>
<td></td>
<td>11715.0 (20.1)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\beta_8$: DWG61</td>
<td></td>
<td></td>
<td>6821.4 (8.38)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

| N (obs.) | 32 | 32 | 32 | 32 | 32 | 32 | 32 | 32 |
| R^2 | 0.8001 | 0.9350 | 0.9735 | 0.9693 | 0.8491 | 0.9120 | 0.9326 | 0.8246 |
| SEE | 3644.5 | 2426.1 | 506.4 | 982.3 | 464.8 | 2016.2 | 1203.6 | 7146.7 |
| DW | 1.61 | 2.34 | 1.74 | 2.05 | 2.71 | 2.55 | 1.91 | 1.71 |
| Durbin's h | 1.39 | -1.91 | 0.55 | -0.24 | -2.78 | -2.24 | 0.43 | 0.70 |

Notes:  
1. The figures in parenthesis are asymptotic t-values.  
2. The $R^2$ given in this table is adjusted $R^2$.  

numbers for each of the estimated equation.

All the coefficients have the expected signs, although some of them are not statistically significant at the five percent level. $\beta_1$, the regression coefficient of the lagged consumption term, $QC_{t-1}$, is positive in all the equations and is within the expected limit of 0 to 1. It is also significant at the 5 percent level for all cases except for West Germany, where it is significant at the 10 percent level. The value of $\beta_1$ is the lowest for West Germany at 0.0950 and highest for other industrialised countries at 0.8512. This implies that West German consumption is the most flexible in the sense that more than 90 percent of the variation in its consumption is explained by the price and production variables.

$\beta_2$, the coefficients of the price variable, $RPLx_{t-1}$, has the expected signs. Only in two cases, West Germany and the western world as a whole, are they significant at the 5 percent level. Short and long run price elasticities are discussed later in section 5.2.4, when the final form of the consumption functions have been determined.

In general, the effect of the aluminium price is not statistically very significant. It is significant at the 5 percent level only for West Germany and Japan. There are a number of reasons why the coefficients for aluminium price may not represent the substitution effect completely. Firstly, aluminium is not the only substitute for tin. Secondly, the time trend variable may capture part of the substitution effect; permanent shifts away from the use of tin would be captured by this variable. Thirdly, the deflation
of the price of tin by the wholesale price index also captures some of the substitution effect. The deflation relates the cost of tin as an input to the price of the output in which it is used and reflects its desirability relative to other inputs.

In all cases, $\beta_4$, the coefficient which measures the income effect on the consumption of tin has the expected positive sign and is significant at the 5 percent level in all cases except Japan and the developing countries. In the case of Japan, the figures have to be treated with some caution due to the presence of autocorrelation as indicated by the high value of Durbin's $h$ statistic. Autocorrelation leads to inefficient estimators and invalid inference procedures.

The technology variable represented by a time trend has negative and significant coefficients for the United States, United Kingdom, France, other industrialized countries and the western world as a whole. It is positive and significant in the case of West Germany. In the case of Japan and the developing countries, $\beta_5$, is not significant.

The adjusted $R^2$ ranges from 0.80 for the United States to 0.97 for West Germany. However, given that one of the regressors is the lagged dependent variable, it is not surprising to get such high values of $R^2$. The Durbin's $h$ statistic indicates the presence of autocorrelation in three cases: Japan, France and other industrialised countries. As was noted in the last chapter, the presence of autocorrelation leads to unbiased but inefficient estimation of the parameters and to invalid inference procedures. Omitted variables,
misspecification in the functional form and measurement errors in the dependent variable are some of the main causes of autocorrelation in the error term. So for the three cases mentioned above, other explanatory variables and different functional forms will be tried to obtain well behaved residuals.

5.2.3 Final estimates of the consumption functions.

The estimates that were presented in the previous subsection are based on a linear model with a one period lag for the price variables. For each country or region, logarithmic functional forms as well as price lags of up to 4 periods were tried. For the consumption functions of the United States, West Germany, United Kingdom and the developing countries, the linear equations given earlier in table 5.2 turned out to be the best estimates.

In the case of Japan, the initial estimate given in table 5.2 has a problem of autocorrelation. After trying different price lags and functional forms, an equation with a three period price lag gave the best estimates:

(5.2.9) \[ QCJA_t = -32.69 + 0.4698 QCJA_{t-1} - 0.002233 RPLJA_{t-3} + 0.02335 \text{RPAUA}_{t-3} + 297.79 \text{IIPJA}_t - 492.24 T \]

\[ \begin{align*} 
(0.01) & & (3.44) & & (-1.91) \\
(2.65) & & (3.28) & & (-1.62) \\
\end{align*} \]

Adj. \( R^2 = 0.9388 \)
SEE = 2354.3
D.W. = 2.02

Period: 1954-1985
N = 32 obs.
Durbin's h = 0.517
Both tin price and income (industrial production) coefficients have higher t-values and with the lower Durbin's h statistic, the null hypothesis of an absence of autocorrelation cannot be rejected. Equation (5.2.9) becomes the final consumption function for Japan.

For France, trying different functional forms and price lags did not improve the estimates provided by equation (5.2.5) in table 5.2. So we decided to correct for the autocorrelation by using the maximum likelihood grid search method.\(^1\) The estimated equation is as follows:

\[
(5.2.10) \quad QCFR_t = 2124.6 + 0.54762 QCFR_{t-1} - 0.018008 RPLFR_{t-1} \\
+ 0.1683 RPLFR_{t-1} + 90.14 IIPFR_t - 253.99 T \\
\text{Adj. } R^2 = 0.8817 \quad \text{SEE} = 370.97 \quad \text{D.W.} = 2.46
\]

Period: 1954-1985 \quad N = 32 \text{ obs.} \quad \phi = -0.490 \quad (-3.08)

The autocorrelation coefficient, \(\phi\), is significant at the 5 percent level. This equation becomes the estimated consumption function for France.

An estimation with a price lag of three periods proved to be a better choice for the other industrialized countries and the estimated equation is as follows:

\(^1\)As we saw in the last chapter, Johnston (1984) recommended the use of this method rather than the iterative Cochrane-Orcutt process in correcting for autocorrelation in a model with a lagged dependent variable.
The estimated consumption function for developing countries given in table 5.2 has price and income coefficients which are not significant although they have the expected signs. These coefficients remained insignificant in the various formulations of the function estimated and so we decided to retain the estimates based on the general model.

Since the focus of this study is more on the impact of the ITAs on the tin producing countries, to somewhat simplify the simulation model in the next chapter, we will be use the aggregated total consumption equation in the simulation experiments rather than the disaggregated individual consumption functions. The residual plot for the western world consumption equation contained four outliers. The first two were in 1957 and 1958 and were negative indicating an unusual decline in consumption. According to Baldwin (1983):

A major portion of the decline can be attributed to a sharp drop in U.S. private consumption in 1957 and 1958, which reinforced the impact of the 1955 cessation of government purchases for the strategic stockpile, and similarly steep declines in Japanese consumption in 1957 and in British consumption the following year. These two years were years of recession throughout the industrialised world (p. 133).

A dummy variable D5758 which was set to 1 in 1957 and 1958 and 0 otherwise was used to capture the effect of this recession.

\[(5.2.11)\]  
\[QCIC_t = -6895.6 + 0.6768 QCIC_{t-1} - 0.4125 RPLUS_{t-3} + 5.5697 RPLUS_{t-3} + 495.45 IIPIC_t - 1122.8 T \]
\((-1.59)\)  \((6.44)\)  \((-1.84)\)  
\[+ 5.5697 RPLUS_{t-3} + 495.45 IIPIC_t - 1122.8 T \]
\[\text{Adj. } R^2=0.9162 \quad \text{SEE}=1968.1 \quad D.W.=2.42 \]

Period: 1954-1985  N=32 obs.  Durbin's h=-1.559
The remaining two outliers which were positive were for 1973 and 1976. These two years were the years in which there was a lot of speculation in the commodity markets. According to Baldwin (1983),

from mid-1973,... apparent consumption of tin rose, with the increased purchases attributed largely to individuals and to firms who did not customarily trade in tin moving into the tin market as part of a shift out of cash holdings and into commodities in a period of rapid inflation and shifting exchange rates on world currency markets. In late 1974 and 1975, in the opinion of knowledgeable observers, these outsider's holdings of tin were sold, reducing apparent consumption below the amounts of tin actually required and used by industrial consumers. The effect of disposals of these speculative holdings were augmented and prolonged by the worldwide recession of 1975 (p. 133).

As a result of this the increase in consumption in 1976 was higher than the normal increase following a recession. To account for these changes, we used another dummy variable D7376. The equation was reestimated with these two new dummy variables:

\[
Q_{CWW_t} = 31141.0 + 0.5746 Q_{CWW_{t-1}} - 2.9302 R_{PLUS_{t-1}} \\
+ 24.819 R_{PALUS_{t-1}} + 854.65 I_{IPWW_{t}} - 1413.6 T \\
- 16991 D_{5758} + 17659 D_{7376} \\
\]

\[
\begin{align*}
(5.2.12) & \quad T & = 31141.0 & + 0.5746 Q_{CWW_{t-1}} & - 2.9302 R_{PLUS_{t-1}} \\
& & (3.09) & (8.58) & (-4.92) \\
& & & + 24.819 R_{PALUS_{t-1}} & + 854.65 I_{IPWW_{t}} & - 1413.6 T \\
& & (3.57) & (2.94) & (-1.90) \\
& & & - 16991 D_{5758} & + 17659 D_{7376} & \\
& & (3.57) & (4.42) & \\
\end{align*}
\]

\[
\begin{align*}
\text{Adj. } R^2 &= 0.9275 \\
\text{SEE} &= 4915.7 \\
\text{D.W.} &= 1.75 \\
\text{Period:} & \quad 1954-1985 \\
\text{N=32 obs.} & \\
\text{Durbin's } h &= 0.496
\end{align*}
\]

Compared to equation (5.2.8) in table 5.2, this equation has higher t-values for lagged consumption and price variables. The residual plot showed no residual bigger than two standard errors and the standard error itself has become considerably smaller moving from 7146.7 to 4915.7. This equation was used in the simulation experiments performed in the next chapter.
Table 5.3: Demand elasticities of price and income for tin

<table>
<thead>
<tr>
<th>Country or Region</th>
<th>Coefficient of Adjustment</th>
<th>Price elasticities</th>
<th>Income elasticities</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Short run</td>
<td>Long run</td>
</tr>
<tr>
<td>United States</td>
<td>0.354*</td>
<td>-0.092</td>
<td>-0.259</td>
</tr>
<tr>
<td>Japan</td>
<td>0.532*</td>
<td>-0.249</td>
<td>-0.469</td>
</tr>
<tr>
<td>West Germany</td>
<td>0.905</td>
<td>-0.437*</td>
<td>-0.483</td>
</tr>
<tr>
<td>United Kingdom</td>
<td>0.694*</td>
<td>-0.161</td>
<td>-0.232</td>
</tr>
<tr>
<td>France</td>
<td>0.452*</td>
<td>-0.080</td>
<td>-0.177</td>
</tr>
<tr>
<td>Other industrialized countries</td>
<td>0.323*</td>
<td>-0.097</td>
<td>-0.300</td>
</tr>
<tr>
<td>Developing countries</td>
<td>0.415*</td>
<td>-0.070</td>
<td>-0.169</td>
</tr>
<tr>
<td>World</td>
<td>0.451*</td>
<td>-0.181*</td>
<td>-0.401*</td>
</tr>
</tbody>
</table>

Notes: 1. The elasticities were computed at mean values of consumption, prices and indices of industrial production.
2. The values that have astriesks are significant at the 5 percent level.

5.2.4 Demand elasticities of price and income

The estimated coefficient of adjustment and the short and long run price and income elasticities are provided in table 5.3. All of them have the correct signs and in all cases income elasticities were higher than price elasticities. Since the demand for tin is derived demand, and tin is just one of the many inputs into the production process, we do expect its demand to be influenced more by the general level of industrial output rather than by price.

Price elasticities in the short run range from a low of -0.07 for the developing countries to 0.437 for West Germany, with the overall price elasticity for world
consumption of tin at -0.181. These figures support the findings of the earlier cited World Bank model (Chaabra et al, 1978). Their short run price elasticities range from 0.11 to 0.49. In interpreting these values, it is important to note that, except for West Germany and the world as a whole, price elasticities were not significant at the 5 percent level. So these numbers have to be regarded as very rough approximations of the true elasticities. In general, as expected, the long term price elasticities are larger than the short term elasticities. In addition, many of the reservations that were expressed about the supply elasticities in section 4.10 are also valid here.

5.3 Specification of inventory supply and demand functions for tin

In chapter 4, we dealt with the supply of primary tin and in the first two sections of this chapter the demand for consumption of tin was discussed. If a commodity can be stored stockholding becomes an important factor in the determination of its price. The presence of inventories or stocks allows for the formation of intertemporal relationships through the expectations which may occur between one period and the next. Tin is a classic storable commodity being low in volume, high in value and chemically stable over long periods of time. To complete our model, we need to add equations that would explain the demand for and the supply of tin stocks.
5.3.1 Stock demand function

In general, inventory demand behaviour is influenced by two main motives for holding stock: transaction and speculation.\(^2\) In the case of transactions demand, stocks are held by consumers, producers and merchants to smooth out differences in supply and consumption; producers and middlemen hold tin stocks to avoid loss of sales of tin and end users of tin keep inventories as working stock to reduce or eliminate down-time of machinery. In such cases the end-of-period stock, \(S_t\), can be expressed as a function of consumption (\(QC_t\)). The level of stocks held by speculators will depend on the expected price, interest rates and storage costs. So combining the two reasons for holding stocks, we get:

\[
(5.3.1) \quad S_t = f(QC_t, P'_t, i_t, C_t, T)
\]

where

- \(S_t\) = tin stocks at the end of period t;
- \(QC\) = consumption of tin;
- \(P'_t\) = expected price of tin;
- \(i_t\) = average annual interest rate in period t;
- \(C_t\) = average cost of storage; and
- \(T\) = a trend variable.

The trend variable is used to capture the long-run effects of more efficient stock control techniques used in the industry to reduce the level of working stocks required.

---

\(^2\)The account presented here is based on Hwa (1981), Labys (1973) and Ghosh et al (1987).
The major problem in estimating equation (5.3.1) is that the data on tin stocks that is reported by the ITC is neither comprehensive nor consistent. Previous studies on tin have faced the same problem. The World Bank study reported that "accurate information on industry and trade inventories has not been published and it was impossible therefore to analyze in detail the behaviour of inventories" (Chhabra et al, 1978). In her study on the efficiency of the tin futures market, Brasse (1986) stated that "reliable data existed for most variables with the exception of tin stocks." In discussing the tin situation in the 1980s, Engel (1989), who was the deputy buffer stock manager of the International Tin Council, stated that "the total stocks of tin metal, a figure which can never be known, comprise reported and unreported stocks, the latter generally being working stocks with consumers." He went on further to argue that movements of stocks from unreported to reported and vice-versa reflect both actual price levels and market expectations of what prices are expected to be in the future.

The situation is similar for inventory data of other minerals too. According to Ghosh et al (1987), typically the inventory demand equation "is inverted to express price in terms of stocks since otherwise, in forecasting or model simulation the price is forced to move too much in order to clear the market. This is a consequence of the incompleteness and inaccuracy of stock data which result in poorly fitting stock demand equations. The inversion approach, on the other hand, results in equations which suffer from errors in variable bias, and give forecasts that are too smooth" (p. 35). If the stock demand equation (5.3.1) were to be inverted, we will get:
Since we do not have any data on storage cost, the variable was dropped; in any case, it would be a very small figure since tin metal is low in volume. There is one other factor that may influence the nominal price of tin. This is the general level of inflation which will be positively correlated with the price of tin. To account for inflation, we will use the real price of tin, i.e., nominal price deflated by the United States wholesale price index, which is used as a proxy for inflation. Instead of using stock and consumption variables linearly in the price equation, it is a common procedure to use the ratio of stocks to consumption \((S_t/QC_t)\) as an explanatory variable (Labys, 1973; Ghosh et al., 1987; Wagenhals, 1984a). The reason for using the ratio is to produce sharp price response to exceptionally high stocks or exceptionally low stocks relative to the annual consumption of tin (Smith and Schink, 1976).

If we assume a linear function and a partial adjustment process for price adjustment, we can rewrite (5.3.2) as:

\[
(5.3.3) \quad RPLUS_t = \beta_0 + \beta_1 RPLUS_{t-1} + \beta_2 (QCWW/STK)_t + \beta_3 INT_t + \beta_4 T + \epsilon_t
\]

where \(RPLUS_t\) = average annual real price of tin in 1980 US$ per tonne;
\(QCWW\) = quantity of tin consumed in the western world;
\(INT_t = 100(1+i)\) where \(i\) = average annual U.S. prime lending rate;
\(STK_t\) = implied stock of tin at the end of year \(t\);
\(T\) = time trend variable; and
\[ \epsilon_t = \text{random error term.} \]

The coefficient of the lagged price, \( \beta_1 \), should be positive. If the stock:consumption ratio increases, *ceteris paribus*, the real price would decrease, which implies that \( \beta_2 \) should be negative. The higher interest rate will lead to lower demand for tin stocks which would result in lower prices, other things remaining equal. So, \( \beta_3 \) is expected to be negative. As inventory control techniques improve, the amount of stocks required for transaction and precautionary reasons can be lowered for a given level of output or consumption of tin. This means \( \beta_4 \) is expected to be positive. In summary, we expect \( \beta_1 \) and \( \beta_4 > 0 \) and \( \beta_2 \) and \( \beta_3 < 0 \). The estimation results are discussed in section 5.4.

### 5.3.2 Stock supply function

Essentially, the stock supply equation is equivalent to the market clearing identity given as:

\[
S_t = S_{t-1} - QS_t + QC_t
\]

where \( S_t \) is the privately held stock at the end of period \( t \) and QS and QC are the supply and consumption, respectively, of the commodity. In the case of tin, as we saw in chapter 2, in addition to private stocks, the United States government had a large strategic stockpile from which tin was sold at various occasions and the ITC operated a buffer stock at different times during the period under consideration. Another source of supply of tin stocks was the net export of primary tin from the centrally planned socialist countries.
Incorporating all the above sources of supply of tin stocks, we get the identity:

\[(5.3.5) \quad STK_t - STK_{t-1} = QSWW_t - QCWW_t + NXCPE_t + NSGSA_t - NPITC_t \]

where

- \(STK_t\) = privately held stocks at the end of period \(t\);
- \(QSWW\) = supply of primary tin from the western world;
- \(QCWW\) = consumption of tin in the western world;
- \(NXCPE\) = net export of primary tin from the centrally planned socialist countries;
- \(NSGSA\) = net sales of tin from the U.S. strategic stockpile of tin;
- \(NPITC\) = net purchases for the ITC buffer stock.

\(NXCPE\) and \(NSGSA\) are treated as exogenous variables. The net exports from the socialist countries were computed from the tin trade statistics provided in *Tin Statistics* published by the ITC. In our model, stock data is computed on the basis of implied stock (STK) where we started with the 1946 data for stock and computed the implied stock for the succeeding years from equation (5.3.5).

The following inventory identities are required to complete the system. The total western world supply of tin, \(QSWW\), is given by the identity:

\[(5.3.6) \quad QSWW = QSMA + QSTH + QSIN + QSBO + QSAU + QSZN + QSNC \]

The seven terms on the right hand side of this identity are the dependent variables in the seven regressions that were estimated in chapter 4. There are two alternative models for total consumption. The first is equation (5.2.12) which is the estimated equation for the
aggregated consumption. In the second model, consumption functions were estimated for seven countries and regions and the total consumption of primary tin in the western world, QCWW, is given by:

\[
QCWW = QCUS + QCJA + QCWG + QCFR + QCUK + QCIC + QCDC
\]

5.4 Estimation of the price equation

A price equation based on (5.3.3) was first estimated using the ordinary least squares method and the results are as follows:

\[
RPLUS_t = 6490.4 + 0.8504 RPLUS_{t-1} - 3583.8 (STK/QCWW)_t - 44.74 INT_t + 90.89 T
\]

\[
\begin{align*}
(0.43) & \quad (5.09) & \quad (-1.67) \\
(-0.29) & \quad (1.56)
\end{align*}
\]

Adj. \( R^2 \) = 0.7951 \quad SEE = 1507.8 \quad D.W. = 1.82

Period: 1955-1985 \quad N = 31 obs. \quad Durbin's h = 1.031

Only the lagged price variable is significant at the 5 percent level. All other variables are not significant although they have the expected signs. The standard error of the estimate at 1507.8 is about 15 percent of the mean value of the dependent variable. The residual plot showed many outliers especially in the mid 1970s. The sequential Chow test \( F_{19,12} = 3.3090 \) indicated that there was a structural break at 1973. The unstable international economic environment since the oil crisis may be an important factor in explaining the structural break that occurs in the regression equation for the price of tin.
The data was separated into two parts: the first from 1955 to 1972 and the second from 1973 to 1985. Separate regressions were run for each period based on the specification given by equation (5.3.3) and the result for the first period is as follows:

$$\textbf{(5.4.2)} \quad RPLUS_t = 5345.6 + 0.6797 RPLUS_{t-1} - 3584.9 (STK/QCWW)_t - 20.30 \text{ INT}_t + 22.80 T \quad \begin{array}{l} (0.30) \quad (3.42) \quad (-1.42) \\ (-0.11) \quad (0.27) \end{array}$$

Adj. $R^2 = 0.7082$ \quad SEE = 814.78 \quad D.W. = 1.70

Period: 1955-1972 \quad N = 18 \text{ obs.} \quad \text{Durbin's } h = 1.073

Only the lagged price is significant at the 5 percent level. All other variables are insignificant. There are two outliers for 1964 and 1965 in the residual plot. The actual prices are higher than the predicted prices by more than 2 standard errors in those two years. From late 1963 until the end of 1965, Indonesia and Malaysia were in a conflict and there were skirmishes along their common border in the island of Borneo. There were fears that there might be a full fledged war between these two neighbours. This led to a speculative rise in the price of tin during these two years.

To incorporate this unusual increase in price into the price equation, dummy variable, $DIND$, which has values of 1 in 1964 and 1965 and 0 otherwise, was used. The results of the new estimation are as follows:

$$\textbf{(5.4.3)} \quad RPLUS_t = -8105.8 + 0.5239 RPLUS_{t-1} - 1607.0 (STK/QCWW)_t + 111.48 \text{ INT}_t + 29.89 T + 2251.7 DIND \quad \begin{array}{l} (-1.30) \quad (7.62) \quad (-1.84) \\ (0.81) \quad (1.06) \quad (10.1) \end{array}$$

Adj. $R^2 = 0.9668$ \quad SEE = 274.66 \quad D.W. = 2.97

Period: 1955-1972 \quad N = 18 \text{ obs.} \quad \text{Durbin's } h = -2.52
The statistical fit as measured by the adjusted $R^2$ and the SEE has improved. The t-values for all the variables except the lagged price, are still not significant. The sign of the interest rate term is opposite to what was expected although it is not significant. The Durban's h statistic indicates the presence of a negative first-order autocorrelation. The interest rate was dropped from the equation since it did not have the expected sign and was not significant. The reestimated equation is as follows:

\[
RPLUS_t = 3136.8 + 0.5372 RPLUS_{t-1} - 1520.0 (STK/QCWW)_t + 62.25 T + 2166.5 DIND \\
(5.81) (7.24) (-1.61) (2.63) (9.19)
\]

Adj. $R^2=0.9610$ SEE=297.77 D.W. = 2.79

Period: 1955-1972 N = 18 obs. Durbin's h = -1.79

In this formulation the equation had a lower Durben's h statistics and the residual plot showed no outliers. This equation was selected as the price equation for the period 1955 to 1972.

For the 1973 to 1985 period, the model based on (5.3.3) was estimated and the results are as follows:

\[
RPLUS_t = -16197 + 0.7313 RPLUS_{t-1} - 13462 (STK/QCWW)_t + 165.6 INT_t + 289.1 T \\
(-0.51) (2.84) (-1.43) (0.56) (0.92)
\]

Adj. $R^2=0.7951$ SEE=2075.7 D.W. = 2.22


The interest rate and time trend variables are not significant at the 5 percent level. The interest rate term has a positive coefficient instead of the expected negative coefficient.
The residual plot has three outliers: two positive outliers in 1974 and 1977 and a negative outlier in 1975. The sharp increase in the price of tin in 1974 was largely due to the inflationary expectations of consumers and other market participants which arose from the oil crisis during that period. In 1974, there was a boom in all metal prices for the same reason. The price increase was intensified by the entry into the tin market of individuals and firms who did not usually trade in commodities, (Baldwin, 1983, p. 133). As was noted in subsection 5.2.3, these outsiders' holdings of tin were sold in 1975 thus depressing the market price which was already under downward pressure as a result of the reduced consumption of tin arising from the world wide recession during that year. The price boom and bust sequence observed in the tin market in 1974 and 1975 was also evident in other industrial metal markets during that period.

The unusual increase in the price in 1977 was, however, largely due to factors specific to the tin market. According to Brasse (1986) the price increase that began in the second half of 1977 and continued through 1978 was due to the misplaced expectations of market traders:

The US GSA program was officially suspended in June 1978 but rumours were rife from the previous year onwards of a new Bill to be passed through Congress authorising the sale of 30,000 tons of tin (roughly one-sixth of world annual consumption of tin) out of a stock pile of 200,629 tons. The Bill was not in fact passed until December 1979. The result of these misplaced expectations and the consequent running down of industrial stocks was a dramatic rise in the price of tin (p. 52-3)

To account for the unusual price movements in these years, two dummy variables DS7477 and DS78 were introduced. DS7477 is the dummy variable that represents the unusual
increase in the price of tin these two years. D75 is a dummy variable, which has a value of 1 in 1975 and 0 in other years.

When the equation was reestimated with these two dummy variables the interest rate and time trend variable continued to be insignificant with t values less than 1.0. These two variables were the dropped and the estimated equation is as follows:

\[
\begin{align*}
RPLUS_t &= 2927.5 + 0.9727 \text{ RPLUS}_{t-1} - 6017.5 \text{ (STK/QCWW)}_t \\
&\quad + 3239.7 \text{ D7477} - 3774.2 \text{ D75} \\
&\quad (2.08) (8.44) (-2.74) (3.65) (-3.15)
\end{align*}
\]

\[
\text{Adj. } R^2 = 0.8557 \quad \text{SEE} = 1089.3 \quad \text{D.W.} = 1.59
\]

Period: 1973-1985 \quad N = 13 obs. \quad Durbin's h = 0.457

The coefficient of all the variables are significant at the 5 percent level and this equation was selected as the price equation for the second period: 1973 to 1985. In the next chapter the model developed in chapter 4 and this chapter will be validated and used for policy simulation.
6. MODEL VALIDATION AND POLICY SIMULATIONS

In the previous two chapters, we have estimated the different components of an econometric model of the international tin industry. In this chapter the model will be validated in a dynamic setting by running an \textit{ex post} historical simulation for the period of interest to us, i.e., from 1956 to 1985. Next, we will simulate a market free from ITC interventions for the period of 1956 to 1985 and provide a quantitative evaluation of the effects of the international tin agreements on the international tin industry.

6.1 \textit{Ex post} historical simulation of the model

Although the individual equations that were estimated in the last two chapters have a high degree of statistical fit, the validity of the model as a whole depends on how these equations interact with each other in a dynamic system. If the model can replicate the actual behaviour of the tin market on an \textit{ex post} basis, then we can be reasonably confident that the model captures the actual market behaviour fairly well. In the next subsection, some of the measures that are used in the evaluation of multi-equation econometric models will be discussed. Following this, we will present and discuss the historical simulation results.
6.1.1 Evaluation of multi-equation models

Evaluation of a single equation regression model is a well established process.\(^1\) The significance of the model and its individual estimated coefficients can be judged by examining the results of a series of statistical tests such as \(R^2\), F and t statistics, standard errors of the estimates and other related statistics. The underlying assumptions of the model can also be evaluated by a series of diagnostic tests. In addition to all these tests, as Pindyck and Rubinfeld (1981) assert, we must use some judgement in deciding whether to accept or reject a single equation model:

One must decide whether the structural specification of the model is reasonable and whether the estimated coefficients make sense. The model's evaluation must also depend on the purpose for which a model was built. A model designed for forecasting purposes should have as small a standard error of forecast as possible, while t statistics are more important in a model designed to test a specific hypothesis or measure some elasticity (p. 361).

In the case of a multi-equation model, the evaluation criteria are more complicated. First, it is difficult to get a system of equations in which all equations have high statistical significance. More importantly, the model as a whole may have a dynamic structure which is much richer than that of any of the individual equations which make up the system. Hence, a good test of the validity of the dynamic structure of a model is its performance in an \textit{ex post} historical simulation. Such a simulation can either be one-period or dynamic. In a one-period simulation, actual values of the lagged endogenous variables are used.\(^1\) In

\(^1\)Much of the discussion here is based on chapters 12 to 14 of Pindyck and Rubinfeld (1981).
the case of a multi-period dynamic simulation, the simulated values of the lagged endogenous variables are used as dependent variables to predict the current value of the endogenous variables. It is quite clear that dynamic simulation provides a more rigorous test of the model and "is clearly the exercise most like forecasting" (Klein and Young, 1980, p. 65).

In our case, we used dynamic simulation to test our model. There are a number of specific measures to determine how well the simulated values track the actual values of the endogenous variables over the chosen time path. The most commonly used measure is the root-mean-square (RMS) simulation error, which is the square root of the average of the squares of the errors over the simulation period. Since the deviations of the simulated variable from its actual time path are squared, the larger deviations are given a bigger weight in the RMS error. In contrast, the mean absolute error (MAE), which is the average of the absolute values of the errors over the simulation period, gives equal weight to all the deviations. Both the RMS and MAE can be expressed in percentage terms as root-mean-square percent error (RMSPE) and mean absolute percent error (MAPE). In addition to low RMS and MAE simulation errors, we also would like to see how well the model predicts the turning points in the historical data.

Another useful simulation statistic that is employed to evaluate historical simulations is Theil's inequality coefficient, U, which has a value between 0 and 1.\(^2\) If

\(^2\)Pindyck and Rubinfeld (1981, p. 364-366) provide more details.
there is perfect fit, then $U$ is 0. If simulated values are always zero when actual values are non-zero, or vice versa, then $U$ takes on the value of 1. Theil has further decomposed the inequality coefficient into three fractions or proportions: $U^M$, $U^S$ and $U^C$, called the bias, variance and covariance proportions, respectively. The sum of the three proportions is 1. $U^M$ measures the extent to which the mean values of the simulated and actual series deviate from each other. Hence, a good model will have a $U^M$ value close to zero. A value above 0.1 or 0.2 would indicate the presence of a systematic bias which may require the revision of the model. $U^S$ is a measure of the ability of the model to replicate the degree of variability of the chosen variable. So if $U^S$ is large, it implies that the actual series has a much higher degree of variability than the simulated series or vice versa. Again a low value of $U^S$ is desirable. The third and final component, $U^C$, is the fraction of the error due to residual variance and it measures the unsystematic error in the simulated values of the variable in question. For any variable, the ideal distribution of the fractions of Theil's inequality coefficient will be $U^M = U^S = 0$ and $U^C = 1$.

6.1.2 Ex post historical simulation results

The tin model that was estimated in the last two chapters was simulated over the 30 year period of 1956 to 1985. The simulation is dynamic since the model used simulated values of the lagged endogenous variables as independent variables in the computation of current values of the endogenous variables. The estimated equations from chapters 4 and 5 that were used for the simulation model are reproduced in appendix 5. In the case of
Table 6.1: Summary statistics for historical dynamic simulation, 1956-85.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Corr coeff</th>
<th>RMSPE (%)</th>
<th>MAPE (%)</th>
<th>Theil's U</th>
<th>U^M</th>
<th>U^S</th>
<th>U^C</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Prices:</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nominal (PLUS)</td>
<td>0.997</td>
<td>3.87</td>
<td>2.95</td>
<td>0.024</td>
<td>0.036</td>
<td>0.118</td>
<td>0.846</td>
</tr>
<tr>
<td>Real (RPLUS)</td>
<td>0.993</td>
<td>3.87</td>
<td>2.95</td>
<td>0.021</td>
<td>0.015</td>
<td>0.130</td>
<td>0.855</td>
</tr>
<tr>
<td><strong>Inventory:</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>STK</td>
<td>0.859</td>
<td>24.42</td>
<td>19.19</td>
<td>0.117</td>
<td>0.169</td>
<td>0.011</td>
<td>0.820</td>
</tr>
<tr>
<td><strong>Aggregated Quantities:</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Consum. (QCWW)</td>
<td>0.940</td>
<td>3.12</td>
<td>2.58</td>
<td>0.016</td>
<td>0.010</td>
<td>0.027</td>
<td>0.963</td>
</tr>
<tr>
<td>Produc. (QSWW)</td>
<td>0.985</td>
<td>2.38</td>
<td>1.95</td>
<td>0.012</td>
<td>0.021</td>
<td>0.139</td>
<td>0.840</td>
</tr>
<tr>
<td><strong>Disaggregated Supply:</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Malaysia (QSMA)</td>
<td>0.991</td>
<td>3.00</td>
<td>2.39</td>
<td>0.014</td>
<td>0.032</td>
<td>0.206</td>
<td>0.762</td>
</tr>
<tr>
<td>Bolivia (QSBO)</td>
<td>0.908</td>
<td>6.54</td>
<td>5.49</td>
<td>0.035</td>
<td>0.015</td>
<td>0.123</td>
<td>0.862</td>
</tr>
<tr>
<td>Indonesia (QSIN)</td>
<td>0.982</td>
<td>6.88</td>
<td>4.11</td>
<td>0.024</td>
<td>0.045</td>
<td>0.013</td>
<td>0.943</td>
</tr>
<tr>
<td>Thailand (QSTH)</td>
<td>0.982</td>
<td>5.74</td>
<td>4.31</td>
<td>0.029</td>
<td>0.008</td>
<td>0.002</td>
<td>0.990</td>
</tr>
<tr>
<td>Australia (QSAU)</td>
<td>0.993</td>
<td>6.48</td>
<td>5.43</td>
<td>0.028</td>
<td>0.001</td>
<td>0.009</td>
<td>0.990</td>
</tr>
<tr>
<td>Nigeria &amp; Zaire (QSZN)</td>
<td>0.990</td>
<td>10.13</td>
<td>7.77</td>
<td>0.032</td>
<td>0.029</td>
<td>0.191</td>
<td>0.780</td>
</tr>
<tr>
<td>Non-ITC (QSNC)</td>
<td>0.992</td>
<td>8.42</td>
<td>6.72</td>
<td>0.033</td>
<td>0.003</td>
<td>0.114</td>
<td>0.883</td>
</tr>
</tbody>
</table>

consumption, we decided to use a single aggregated consumption function for the western world to reduce the complexity of the model. The simulation programme was written in Fortran.

Summary evaluation results for each of the endogenous variables are presented in table 6.1. Considering that the dynamic simulation was performed over a period of 30 years, the overall performance of the model is very satisfactory. Except for the inventory variable, the correlation coefficient between the simulated and actual values is more than 0.90 for all variables. The RMSPE is less than 10 percent for most variables. In particular, the RMSPE for price and total production and consumption is less than 4
percent. This compares favourably with the World Bank model where the simulation was done over a much shorter period of 15 years from 1961 to 1975 (Chhabra et al, 1978). In that model, the RMSPE for nominal price, total consumption and total production were 9.8, 2.6 and 3.1 percent, respectively, while the comparable figures in our model are 3.9, 3.1 and 2.4 percent, respectively.

With the exception of the inventory variable, Theil's inequality coefficient is less than 0.04 for all variables. Overall, the bias and variance fractions are low while the fraction due to unsystematic error as measured by the covariance proportion is relatively high. Next we will examine in more detail the performance of the model for the four main endogenous variables: total consumption, total production, real price and inventory.

Figure 6.1 shows the actual observed values and the dynamic simulation values of the total consumption of tin in the western world during 1956 to 1985. In general, the simulation model tracks actual consumption rather well. In particular, the turning points in 1958, 1973 and 1975 are captured quite accurately. However, from 1966 the simulated consumption is less than the actual consumption for at least 7 years. Theil's inequality coefficient is very low for the total consumption as can be seen from table 6.1. The fraction representing the unsystematic error is higher than 0.96. Even though we used a single equation to represent the aggregated total consumption, we are still able to obtain a good set of simulated values.
Figure 6.1: Dynamic simulation of total consumption of tin, 1956-85

[Diagram showing the consumption of tin from 1956 to 1985, with actual and simulated data plotted over the years.]
FIGURE 6.2: Dynamic simulation of total production of tin, 1956-85
Figure 6.2 shows the plot for the simulated and actual supply of tin. Again, the sharp downturns in tin production in the 1958-59 and the 1981-85 periods are captured reasonably well by the model. Overall, the simulated supply tracks the actual production of tin very closely. In almost all the years between 1967 and 1979, the simulated production is less than the actual production, though most of the deviations are very small. The deviations are proportionately bigger in many of the individual supply functions. However, in the model, total production is obtained from an identity which sums all of the individual equations; by and large, the errors have cancelled each other out. However, Theil's U statistics for the proportion representing the variation was a little high indicating it does not capture the variability well. Many of the supply functions have a very high value for the inverse of the coefficient of adjustment; in some cases, this was very close to 1. This, combined with low price elasticities, gave rise to the low degree of variability.

The plot of the actual and simulated real price of tin at the London Metal Exchange expressed in 1980 US dollars per tonne is shown in figure 6.3. Recall from chapter 5 that the real price of tin was estimated with two separate equations. The first was used to simulate the period over which it was estimated, that is, from 1956 to 1972. The second equation which estimated the price of tin during the turbulent years of the 1970s and the early 1980s, was used to simulate price for the remaining period. The use of two equations seems to help obtain a very low RMS percent error. The simulated price tracks the actual price over the time path very closely, particularly in the first half of the period. The major turning points are replicated accurately. However, in the late 1970s
Figure 6.3: Dynamic simulation of London Metal Exchange real price of tin, 1956-85
and the early 1980s, there is some deviation from the actual path. For example, the highest actual price was in 1979 but the highest simulated price was obtained a year earlier. The largest percentage deviation of 11.3 percent occurred in 1982 when the actual price dropped sharply but the simulated price increased marginally. The drop in the actual price is largely due to the sharp appreciation of the US$ against sterling in 1982. The LME sterling price of £7305 per tonne in 1982 was in fact higher than the 1981 price of £7085 per tonne. Our price equation did not have a variable to capture this currency fluctuation effect; even in the original ordinary least square estimation, the residual was relatively large for 1982.

Finally, the plot of the actual and simulated tin inventory variable is shown in figure 6.4. On the whole, the simulated inventory matches most of the turning points of actual inventory, especially the maximum level in 1981 and the minimum in 1964. Nevertheless, there are a number of years where the deviations are very large. In 1977, the deviation was at a maximum of 58 percent. The overall RMS percentage error is 24.4 percent, which is relatively large. In absolute terms, the deviations are particularly large in the 1970s. The errors in the predicted values of inventory are a result of accumulated errors in the simulated values of consumption and production. If the cumulative errors are in the opposite directions for both these variables, i.e., if the consumption is continuously underpredicted for a number of periods and production overpredicted over much of the same period, or vice versa, then the effect on stocks will be magnified. This is what happened in the 1970s. From 1970 to 1979, simulated production was less than the actual
Figure 6.4: Dynamic simulation of tin stocks, 1956-85
production while from 1975 to 1977, consumption was overpredicted. Thus, the gap between the simulated stock and the actual stock grew to a maximum in 1977.

Another reason for these large errors is the inadequacy of stock data. As we mentioned in chapter 5, the "actual" stock figures that we are using were computed on an implied excess supply basis commencing from 1949. The largest errors occurred in the 1975 to 1979 period. That was also a period when there was much volatility in tin prices which in turn affects the reported stocks (Engel, 1989).

Models of other minerals have had similar problems with simulated stocks. As mentioned earlier, the World Bank tin model had a RMS error of 19.1 percent over the 1961-75 period. In his econometric model of the world copper market, Wagenhals (1984b) reported mean absolute percent errors (MAPE) of 12.7 percent to 79.7 percent for stocks at different locations. Gupta (1982) who constructed an econometric model of the world zinc industry, reported MAPEs of 39.7 percent for non-US stocks and 17.6 percent for stocks in the United States. Both these studies did not report RMS percent errors. Given that RMS errors penalize larger deviations more severely, their RMS percent errors would have been much larger. Ghosh et al (1987, p. 109) reported RMS errors ranging from 11.1 percent to 56.8 percent for the different categories of stocks in three versions of their quarterly econometric model of the international copper market.
To summarize, the *ex post* historical simulation results indicate that the econometric model of the tin market that was developed in chapter 4 and 5 explains the behaviour of the international tin industry during the 30 year period of 1956 to 1985 rather well. In the next section, we will use this model to simulate a scenario where the tin market is free from the interventions of the International Tin Council.

6.2 Policy simulation

In this section, we will attempt to provide some quantitative measures of the impact of the international tin agreements on the performance of the international tin industry. We will first examine some of the problems encountered in defining the measures of costs and benefits of a commodity stabilization program. Then we will discuss the results obtained from the simulation experiment performed with the model described in the first section of this chapter.

6.2.1 Welfare gains from price stabilization

We have already reviewed in chapter 1, the arguments for and against the desirability of price stabilization. One of the earliest discussions on gains from price stabilization was provided by Waugh (1944) who showed that when price instability is caused by stochastic variations in supply, producers would be better off and consumers would be worse off if these prices were stabilized at their means. Oi (1961) showed that
if the price instability arises from stochastic shifts in demand, consumers would be better off and producers would be worse off if the prices were stabilized at their means. Both assumed a linear model of supply and demand. Massell (1969) integrated these arguments in a single framework and showed that, in addition to the above results, in a linear model with stochastic disturbances, price stabilization will improve overall world welfare, though, depending on what causes the price variability, one group will be better off while the other will be worse off after price stabilization. It is therefore reasonable to expect that stabilization will increase net welfare as conventionally measured by economists.

Turnovsky (1978) has argued that if nonlinear functions with multiplicative disturbances have been assumed, then the outcome is more complex. He shows that the effects of stabilization depends on the interaction between the supply and demand elasticities and the random disturbances. Many of the theoretical models in the literature assume complete price stabilization. In practice, however, most stabilization programs, including the ITC's, aim for partial stabilization, i.e., one in which prices would be kept within a band with upper and lower limits. Both Ghosh et al (1987) and Newbery and Stiglitz (1981) show that in general complete stabilization is infeasible and undesirable. A buffer stock aiming at perfect stabilization will eventually break down either because the buffer stock authority would run out of financial resources or because an eventual stockout will occur with unit probability.
The issue of interest to us is the choice of welfare criterion that is used to measure any benefits of stabilization. Many theoretical models use the concept of economic surplus, which normally consists of the simple aggregate of consumers' surplus and producers' surplus (e.g. Turnovsky, 1978). Measuring economic surplus is, however, subject to considerable difficulty. For example, Ghosh et al (1987) argue that most of the theoretical results are derived in a static setting, while econometric commodity modelling exercises are performed in a dynamic setting, which makes it very difficult to apply those measures of benefit. Newbery and Stiglitz (1981), among others, have emphasized gains from reducing risk for risk-averse market participants. Much policy attention, however, focuses on foreign exchange earnings. This does not mean that the concept of economic surplus is being ignored. Another way of stating this preoccupation with export earnings is to observe that the shadow value of foreign exchange is very high in some countries so that maximizing surplus is similar to maximizing export earnings.

Many empirical studies, therefore, have concentrated on price and revenue. Labys (1980) in his excellent review of commodity price stabilization models, cites a number of other studies which use these measures. Subsequent to that, there have been many other studies using price and revenue changes to compare stabilization programs. Tan (1984), in her study of the rubber market, analyzed the effect of price stabilization on the distribution of prices, producer incomes and total sales. Lee and Blandford (1980) who used optimal control theory to analyze international buffer stocks for cocoa and copper, used prices and producer revenues as measures of benefit.
In our study, we are comparing the actual performance of the tin market under the ITC regulated regime with the simulated performance assuming non-intervention by the ITC. Based on the above discussion, we will use the following measures to evaluate the impact of the ITC stabilization programme on the tin market:

(i) the change in the average annual real price of tin which gives an indication of whether the ITC operations resulted in a higher price for producers and consumers;

(ii) coefficients of variation (CV) of the actual and simulated prices to evaluate whether the ITC operations stabilized tin prices;

(iii) the change in the discounted total producer revenues in 1980 US dollars over the 30 year period which will give us a crude measure of the magnitude of the transfer benefits, if any, to tin producing countries from the tin consuming countries; we have ignored costs because of the lack of data; and

(iv) coefficients of variation of the actual and simulated real revenues to determine the impact of ITC operations on the instability of producer revenues.

In the next two subsections, the simulation results will be presented and the benefits of the ITC operations evaluated based on the above criteria.
6.2.2 Simulation results under the non-intervention scenario

As we saw in chapter 2, the ITC used two policy instruments in its attempt to regulate the world tin market: buffer stock operations and export controls. We have introduced buffer stock sales and purchases in the model through the stock identity shown in appendix 5. Export controls were represented by dummy variables in the estimated supply functions of the ITC member countries.

In order to simulate a market free from ITC interventions, first the ITC purchases and sales were dropped from the stock identity. Then, the export control dummies were dropped from the supply equations of Malaysia, Bolivia, Indonesia, Thailand, Australia and, Zaire and Nigeria that are shown in appendix 5. All other exogenous variables, including the sales from the United States government stockpiles, remained unaltered.

The model was then simulated from 1956 to 1985, which was the period during which the economic provisions of the international tin agreements operated. Summary results are provided in table 6.2. Both average production and consumption are slightly higher under the non-intervention scenario. The size of the average stock increased substantially from 57219 tonnes to 94231 tonnes. There appears to be a decrease of 9.7 percent in the real annual average price to $9082 per tonne. The coefficient of variation (CV) for real price has increased from 32.4 to 44.4 percent. Thus, the results appear to give support to the argument that the ITAs have helped in reducing the volatility of the
Table 6.2: Summary statistics for non-intervention simulation, 1956-85

<table>
<thead>
<tr>
<th>Product</th>
<th>Actual Mean</th>
<th>Actual C.V.</th>
<th>Non-intervention Mean</th>
<th>Non-intervention C.V.</th>
<th>Difference in Mean</th>
<th>Difference Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Malaysia</td>
<td>60709</td>
<td>19.0%</td>
<td>62848</td>
<td>9.4%</td>
<td>2139</td>
<td>3.5%</td>
</tr>
<tr>
<td>Bolivia</td>
<td>26639</td>
<td>16.7%</td>
<td>27345</td>
<td>11.2%</td>
<td>706</td>
<td>2.7%</td>
</tr>
<tr>
<td>Indonesia</td>
<td>22732</td>
<td>26.4%</td>
<td>25131</td>
<td>30.1%</td>
<td>2399</td>
<td>10.6%</td>
</tr>
<tr>
<td>Thailand</td>
<td>20273</td>
<td>31.9%</td>
<td>19976</td>
<td>33.2%</td>
<td>-297</td>
<td>-1.5%</td>
</tr>
<tr>
<td>Australia</td>
<td>7365</td>
<td>51.7%</td>
<td>7470</td>
<td>55.3%</td>
<td>105</td>
<td>1.4%</td>
</tr>
<tr>
<td>Zaire and Nigeria</td>
<td>11964</td>
<td>45.8%</td>
<td>13683</td>
<td>40.6%</td>
<td>1719</td>
<td>14.4%</td>
</tr>
<tr>
<td>Total ITC</td>
<td>149681</td>
<td>14.5%</td>
<td>156454</td>
<td>9.2%</td>
<td>6773</td>
<td>4.5%</td>
</tr>
<tr>
<td>Non-ITC</td>
<td>21389</td>
<td>56.6%</td>
<td>20748</td>
<td>53.8%</td>
<td>-641</td>
<td>-3.0%</td>
</tr>
<tr>
<td>Total production</td>
<td>171070</td>
<td>13.6%</td>
<td>177201</td>
<td>11.3%</td>
<td>6131</td>
<td>3.6%</td>
</tr>
<tr>
<td>Total consumption</td>
<td>173800</td>
<td>9.1%</td>
<td>177604</td>
<td>7.8%</td>
<td>3804</td>
<td>2.2%</td>
</tr>
<tr>
<td>Inventory</td>
<td>57219</td>
<td>42.4%</td>
<td>94231</td>
<td>74.1%</td>
<td>37012</td>
<td>64.7%</td>
</tr>
<tr>
<td>LME price (US$/tonne):</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nominal</td>
<td>6596</td>
<td>72.5%</td>
<td>5690</td>
<td>75.2%</td>
<td>-906</td>
<td>-13.7%</td>
</tr>
<tr>
<td>Real (1980 US$)</td>
<td>10060</td>
<td>32.4%</td>
<td>9082</td>
<td>44.4%</td>
<td>-978</td>
<td>-9.7%</td>
</tr>
</tbody>
</table>

price of tin. In addition, the ITC operations have resulted in a higher average price.

All ITC member countries except Thailand would have had higher production under the non-intervention scenario. As we saw in chapter 4, Thailand, whose tin production is almost entirely operated by the private sector, had the highest price elasticity among the ITC member countries. Thus lower average prices would have resulted in lower production. The decrease in production resulting from lower prices appear to be larger than the production increases arising from the absence of quotas. In the other ITC member countries, the situation is the reverse resulting in a net increase in tin production, ranging from 2.7 percent for Bolivia to 14.4 percent for Zaire and Nigeria. Total ITC
Figure 6.5: Total production of tin, 1956-85 (non-intervention scenario)
production increased by 4.5 percent. In contrast, output from the non-ITC sources declined by 3.5 percent because of the lower average prices.

Figures 6.5 and 6.6 show the actual and simulated plots of the time path for total western world production and consumption of tin. The absence of the severe ITC export controls in the non-intervention scenario in the 1958-60 period means that simulated production did not fall as sharply as actual production did during that period. This coupled with a simulated consumption, which did not differ very much from the actual consumption, led to a sharp increase in tin stocks. In figure 6.7, which shows the time path of tin stocks, it can be seen that simulated stocks rose sharply to reach a high of about 160,000 tonnes in 1959 and 1960. This put a downward pressure on the real price of tin, which remained below the actual price from 1958 to the mid 1960s. Figure 6.8 shows the time path of the real price of tin.

The lower prices in the non-intervention regime eventually reversed the situation. First, the lower prices boosted consumption sharply from 1961 to 1966 as can be seen from figure 6.6. It also led to a drop in production; as shown in figure 6.5, from 1964 to 1973, the simulated production was less than the actual production. This combination of higher consumption and lower production led to a reduction in stocks, which by the early 1970s was lower than actual stocks by a large margin. This resulted in higher than actual prices throughout most of the 1970s.
Figure 6.6: Total consumption of tin, 1956-85 (non-intervention scenario)
Figure 6.7: Tin stocks, 1956-85 (non-intervention scenario)
Recall from previous chapters that the other period of severe export controls was from 1982 to 1985. During the 1980s, the simulated production was much higher than the actual production, as can be seen from figure 6.5. From 1983 to 1985, the simulated production was on the average about 15 percent higher than actual production. In fact from 1975 to 1980, the simulated production has been higher and the simulated consumption has been lower than the corresponding actual figures, due to the higher prices in the non-intervention regime during the 1970s. This gave rise to another build up of simulated stocks, which can be seen from figure 6.8. Consequently, simulated prices started declining and from 1979 they were lower than the actual prices which were supported by the ITC through buffer stock purchases and through the imposition of severe export controls. In the absence of the ITC operations, our model predicts that the real price of tin would have been sharply lower. In 1984 and 1985, the model predicted the LME real price of tin to be $4648 and $3058 per tonne, respectively. This was 56.3 and 71.4 percent lower than the corresponding actual prices. Such a big difference in prices is largely due to the increased supply from new sources like Brazil and China. It is interesting to note that after the ITC operations collapsed in October 1985, the average real price of tin in 1986 dropped by 48 percent to $5554 per tonne which is close to our predicted price for 1984.

In summary, our model predicted that the average price of tin would have been lower and its coefficient of variation would have been higher in the absence of ITC operations. The increased output from new sources combined with the absence of ITC
Figure 6.8: Real price of tin, 1956-85 (non-intervention scenario)
operations in the early 1980s would have led to a sharp decline in the real price of tin from 1982 to 1985. Thus, from the producers' point of view, the ITC operations did have positive effects on prices both in terms of the higher price level and the lower degree of instability. We will discuss the realism of these predictions after we have analyzed producer revenues under the non-intervention scenario in the next sub-section.

6.2.3 Impact of the international tin agreements on producer revenues

Table 6.3 shows the actual producer revenues and predicted revenues under the non-intervention scenario for the four main ITC member countries: Malaysia, Bolivia, Indonesia and Thailand. Producer revenue for each country or group of countries is the product of the real annual price and the quantity of tin produced during that year. The total revenue was obtained by summing the annual revenues of the 30 year period of 1956 to 1985. The net present value was obtained by discounting back to 1956 the difference between the actual and simulated revenue in each of the 30 years at the stated discount rate. All the revenue figures in tables 6.3 and 6.4 are expressed in millions of 1980 US dollars. The choice of a discount rate is controversial. According to Just et al (1982):

social discount rates which have been employed in the literature have ranged from 0 to 16 percent. This wide range is suggestive of the great amount of controversy that has surrounded social discounting........ the real rates of social discount used in the literature fall in the range 0 to 4 percent (pp. 305-6).

However, given that we have had much higher real rates of interest during most of the 1980s, a 4 percent real discount rate may be too low. A real discount rate of 6 percent
may be more appropriate. In any case, we have computed the NPV at real discount rates of 2 to 12 percent in steps of 2 percent.

Before we compare the actual revenues with the simulated revenues, it is interesting to note that compared to tin prices, producer revenues had a much higher degree of instability, as measured by the coefficient of variation (CV). The CV of the actual real price as reported in table 6.2 is 32.4 percent while all the CVs of the actual revenues in table 6.4 are higher than that. Similarly, in the non-intervention scenario, the CV of the simulated real price was 44.4 percent and the CVs of the simulated revenues in all cases were higher than that. As for revenue instability under the two alternative regimes, the non-intervention regime gave rise to higher CVs for the ITC member countries but marginally lower for the non-ITC countries. For ITC members as a whole, the CV was 51.2 percent in the non-intervention scenario compared to 41.0 percent under the ITC regime. Thus, ITC operations did help somewhat in reducing instability in producer revenues, though it was still higher than the instability in price.

From table 6.3, in all cases the actual revenue under the ITC regime was higher than the predicted revenue assuming the non-intervention scenario. Overall, total revenues would have been 6.5 percent lower in the absence of ITC interventions. But what is interesting is that the non-ITC countries would have lost proportionately more from the absence of ITC operations in the tin market. They would have suffered a 17.9 percent drop in their total revenue from the production of tin compared to a 4.8 percent decline
Table 6.3: Producer revenues for selected countries, 1956-85

<table>
<thead>
<tr>
<th>Variables</th>
<th>Malaysia</th>
<th>Bolivia</th>
<th>Indonesia</th>
<th>Thailand</th>
<th>ITC</th>
<th>Non-ITC</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Actual:</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total Revenue</td>
<td>18393.79</td>
<td>8201.08</td>
<td>7141.41</td>
<td>6645.83</td>
<td>46089.87</td>
<td>7095.82</td>
<td>53185.68</td>
</tr>
<tr>
<td>Mean Revenue</td>
<td>613.13</td>
<td>273.37</td>
<td>238.05</td>
<td>221.53</td>
<td>1536.33</td>
<td>236.53</td>
<td>1772.86</td>
</tr>
<tr>
<td>(C.V.)</td>
<td>36.9%</td>
<td>41.3%</td>
<td>53.6%</td>
<td>62.7%</td>
<td>41.0%</td>
<td>72.8%</td>
<td>42.4%</td>
</tr>
<tr>
<td><strong>Non-intervention:</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total Revenue</td>
<td>17277.01</td>
<td>7700.70</td>
<td>7058.80</td>
<td>6111.75</td>
<td>43888.39</td>
<td>5828.37</td>
<td>49716.66</td>
</tr>
<tr>
<td>Mean Revenue</td>
<td>575.90</td>
<td>256.69</td>
<td>235.29</td>
<td>203.72</td>
<td>1462.95</td>
<td>194.28</td>
<td>1657.22</td>
</tr>
<tr>
<td>(C.V.)</td>
<td>44.7%</td>
<td>51.5%</td>
<td>63.7%</td>
<td>74.3%</td>
<td>51.2%</td>
<td>69.2%</td>
<td>52.6%</td>
</tr>
<tr>
<td><strong>Difference:</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total Revenue</td>
<td>1116.71</td>
<td>500.38</td>
<td>82.61</td>
<td>534.08</td>
<td>2201.47</td>
<td>1267.45</td>
<td>3469.03</td>
</tr>
<tr>
<td>Mean Revenue</td>
<td>37.23</td>
<td>16.68</td>
<td>2.75</td>
<td>17.80</td>
<td>73.38</td>
<td>42.25</td>
<td>115.63</td>
</tr>
<tr>
<td>Percent Diff.</td>
<td>6.1%</td>
<td>6.1%</td>
<td>1.2%</td>
<td>8.0%</td>
<td>4.8%</td>
<td>17.9%</td>
<td>6.5%</td>
</tr>
<tr>
<td><strong>NPV of Difference at discount rate of:</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2%</td>
<td>769.24</td>
<td>325.21</td>
<td>66.21</td>
<td>362.23</td>
<td>1510.58</td>
<td>753.23</td>
<td>2263.88</td>
</tr>
<tr>
<td>4%</td>
<td>557.03</td>
<td>221.79</td>
<td>64.38</td>
<td>260.39</td>
<td>1107.56</td>
<td>463.43</td>
<td>1571.05</td>
</tr>
<tr>
<td>6%</td>
<td>421.08</td>
<td>158.45</td>
<td>66.71</td>
<td>196.76</td>
<td>858.54</td>
<td>296.86</td>
<td>1155.44</td>
</tr>
<tr>
<td>8%</td>
<td>329.42</td>
<td>118.07</td>
<td>69.10</td>
<td>154.62</td>
<td>694.17</td>
<td>198.90</td>
<td>893.10</td>
</tr>
<tr>
<td>10%</td>
<td>264.47</td>
<td>91.21</td>
<td>70.20</td>
<td>125.03</td>
<td>578.10</td>
<td>139.74</td>
<td>717.87</td>
</tr>
<tr>
<td>12%</td>
<td>216.30</td>
<td>72.55</td>
<td>69.85</td>
<td>103.11</td>
<td>490.98</td>
<td>102.89</td>
<td>593.89</td>
</tr>
</tbody>
</table>

Note: All revenue figures are in millions of 1980 US dollars.

in the gross revenues of the ITC member countries. While it is ironic that the cartelization of the tin market did not help the members as much as the outsiders, it is not unexpected. The non-ITC countries acted as fringe suppliers behaving as price takers and they produced as much tin as was economically feasible at the minimum support price set by the ITC. In the non-intervention scenario, tin prices were lower which led to lower output from these countries. From table 6.2, it can be seen that the non-ITC output was 3
percent lower and the average real price was lower by 9.7 percent. Together this resulted in the 17.9 percent decline in their revenue, shown in table 6.3.

In the case of the ITC countries, the drop in revenue was not as severe because lower prices were somewhat compensated by higher output due to the absence of export controls. This was particularly true of countries which were less sensitive to price changes, i.e., where the price coefficients of the estimated equations are low. In such cases, the change in revenue accompanying the increased output due to the removal of quotas would have had a bigger effect than that arising from the reduction in output due to lower prices. If we refer back to table 6.2, it can be seen that of the four major tin producers, Indonesia had the largest increase in output while Thailand's average simulated output was lower than the actual output. This is reflected in the simulated producer revenues in table 6.3, where Indonesia has the smallest drop of 1.2 percent compared with Thailand's 8.0 percent decline. Both Malaysia and Bolivia would have suffered a 6.1 percent decline in their revenues from the production of tin.

The total ITC revenue figures in table 6.3 did not take into account of the profits and losses of operating the buffer stocks scheme. Table 6.4 presents the gross revenues, buffer stock revenues and costs, the net revenues of the ITC member countries, revenues of the non-ITC countries, net producer revenues and total consumer expenditure. In computing the revenues and costs for the buffer stock operations, a number of simplifying assumptions have been made.
First, the administrative expenses of the ITC have been omitted from the calculations. The expenses are small compared to the magnitude of the costs of operating the buffer stock. In any case, even if the ITC had not been in existence, it is highly likely that there would have been some international tin organization to produce statistics and the tin producing countries would have spent a comparable amount in the administration of that organization.

Second, it is assumed that the net purchases or sales for the year are made at the average price for that year. In actual practice, the ITC buffer stock manager intervened in the market at different times during the year and his average purchase or sale price is unlikely to coincide with that year's average price. Due to the lack of more detailed data, we must settle for this simplification.

Third, at the end of 1985, when the price support operation collapsed, the buffer stock manager was left holding more than 50,000 tonnes of physical tin as well as outstanding liabilities amounting to more than £500 million or US$700 million. The creditors obtained title to the tin stocks and sold it to recover part of the amount owed to them by the ITC. After numerous court trials, the remaining liabilities were settled out of court for a much lower sum of £182.5 million or US$302 million on 30 March 1990 (Business Times, 11 April 1990). The producer members of the ITC had to pay only half the cost, the other half being paid by the consumer members. In our NPV calculations, we have ignored the value of the inventory that was left at the end of 1985 because the
liabilities outstanding were higher than the value of the inventory. The settlement cost of $151 million was also not included since the buffer stock revenues and costs were calculated up to 1985 only.

Fourth, the warehousing costs and the transaction costs of buffer stock purchases and sales were omitted. This would not have been a big amount. The overall effect of the above simplifications would be an overestimation of the net profits of the buffer stock operations. Another factor that has to be considered is the problem of tin smuggling that was discussed in chapter 4. Since the non-ITC output includes tin that was smuggled out of some ITC countries, the true benefit to non-ITC countries would be a little lower than what we have computed. Correspondingly the true increase in producer revenues for the ITC countries due to ITC's price stabilization scheme would be higher than what is reported in tables 6.3 and 6.4.

In table 6.4, the inclusion of the buffer stock loss does not affect the results very much. The gross difference in revenue for ITC member countries was $2.201 billion dollars while the net figure was $2.137 billion. Even if the true operating losses were double or triple the computed amount of $64.56 million, it would not have affected the net revenues very much, when it is discounted back to 1956.

If we assume a social discount rate of 6 percent, the net increase in discounted revenue for tin producers arising from the ITC operations would be $1.14 billion, of which
$843 million accrued to the ITC member countries and the remaining $297 million to non-ITC countries. Thus, the ITC interventions in the tin market appear to have benefitted the tin producers both in terms of reducing revenue instability and raising the net discounted revenue from the sale of tin.

The last column in table 6.4 shows that, in contrast to producers, the consumers ended up incurring higher expenditures for the tin they used. Their expenditure would have been $4.54 billion or 8.6 percent less than their actual expenditure, if an unregulated market had operated. At a 6 percent real discount rate, the discounted value of their savings would have amounted to $1.56 billion if the ITC had not intervened. While they
had negative transfer benefits, they had positive benefits from the reduction of risk arising from the reduced instability of tin prices under the ITC regime. If the consuming countries paid more than the free market price for the tin that they purchased because of ITC operations, then the question arises as to why did many of these countries support the ITAs. In their analysis of the politics of the international commodity agreements, Finlayson and Zacher (1988) maintain that "the major Western consuming countries have had close political and economic ties with the producing states and have been willing to make small economic sacrifices to maintain amicable relations...." (p. 119).

From the above discussion, we can make the following conclusions. First, the tin producing countries have benefitted from the ITC price support operations on all four measures that we listed in section 6.2.1. The ITC operations have reduced both price and revenue instability while raising the real price and discounted real revenues for the producer countries. Second, among the producing countries, non-ITC countries benefitted proportionately more than ITC members from the ITC operations. Third, consuming countries benefitted from the reduction in price instability but incurred a higher expenditure in the purchase of tin.

6.2.4 Limitations of the simulation results

The conclusions that were stated above have to be qualified for a number of reasons. It is true that our model can replicate the historical period quite accurately as
shown in section 6.1. However, in simulating the model under the non-intervention scenario, we have made a number of simplifying assumptions which could affect the validity of the results.

First, it is doubtful that the estimated coefficients of the supply functions would have been the same in the absence of the international tin agreements (ITAs). The coefficients of our estimates would be stable only over a small range on either side. The presence of the ITC is a major factor which affected production decisions in the tin mining industry both in ITC member countries as well as in non-ITC countries. For example, the East Kemptville tin mine project in Canada which started production in 1985 was begun on the assumption that the tin prices in the medium run would not go below the ITC floor price. If a free market had operated, given the lower average prices, it is likely that the project would not have taken off.

Similarly, export controls affect the long run average cost of production in some ITC countries. With these restrictions, some firms would not be operating at the most cost efficient level of output. Events since the 1985 collapse bear this out. Companies like Renison Tin in Australia have increased their output despite the lower prices because the increased output has lowered their average cost of production. Changes in the structure of the tin industry since 1985 are discussed in the next chapter. From these examples, it is clear that the value of the regression coefficients of the price and lagged output variables
in the supply functions of the tin producing countries would have been different. We, however, have assumed that the coefficients would remain unchanged.

A second assumption which may affect our results significantly is that the pattern of tin disposals from the United States strategic stockpile would have been the same in the absence of the ITAs. This is highly unlikely. As Smith and Schink (1976) have pointed out, the U.S. stockpile sales were used to keep tin prices from rising too high. Referring to the interactions between the ITC and the U.S. government they state that "the outcome has been a loose, informal 'commodity agreement' in which the GSA\(^3\) defended fairly high, but unknown, ceiling prices and the ITA, fairly low, known floor prices" (p. 721). The pattern of the stockpile sales since the time of that writing has given no reason to change their conclusion regarding the role of the GSA. In the absence of the ITAs, if tin prices had been lower, it is likely that the US would have disposed less tin from the strategic stockpile. For example, from 1981 to 1985, a total of over 18,000 tonnes were sold from the stockpile. As shown earlier in figure 6.8, if a free market had operated during that period, the price of tin would have been lower than the ITC supported price. This might have discouraged the U.S. government from disposing the 18,000 tonnes of tin which in turn would have ameliorated the sharp drop in the simulated price. Thus, the difference between the actual and the simulated price would have been lower.

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\(^3\)The GSA or General Services Administration is the U.S. agency which handles the disposal of the strategic stockpiles.
A third assumption that was made for the policy simulation was that the sales and purchases of the socialist countries would have remained unchanged. We treated these transactions as exogenous variables. In reality, their production and consumption would have been influenced by price changes, too. So, if a free market had operated, their consumption and production pattern would have been different.

We also treated Brazil's sharp increase in output due to the new major discoveries of tin deposits as an exogenous factor. However, it is not certain whether all the new Brazilian tin mines would have been able to raise enough capital to start their operations in the absence of a minimum support price defended by the ITC. Once the mines are established, they can continue operating even in the face of lower prices as long as their variable cost is less than the price.

We have assumed that private stockholding for convenience and precautionary motives would not have been different in the absence of a buffer stock authority. As many writers have pointed out this is not true (Newbery and Stiglitz, 1981 and Ghosh et al, 1987). Thus the coefficient of the stock term in our price equation would have been different if the pattern of private stockholding had changed.

Given all these factors, it is safe to say that our results may be overstating the benefits to producers from the ITC operations. In any case, the change in revenues was only 6.4 percent lower under the non-intervention scenario which is not very big. While
the results are important in a simulation exercise like this, what is more important is the insight that the simulation model gives regarding the effects of the international tin agreements on the international tin market during this period. For example, from the simulation it is clear that in the 1980s the ITC was defending a floor price that was much higher than what would have been sustainable in the long run in a free market. So it was acting more like a cartel than an organization dedicated to pure price stabilization activities. In fact, one of the policy options that we will review in the next chapter is whether a new cartel of tin producers is viable.
7. POLICY OPTIONS

In this chapter, we will first review briefly the developments in the tin market since the collapse of the ITC operations in October 1985. In the second part of the chapter, some alternative policy options that are available for the tin producing countries will be discussed.

7.1 Post-1985 developments in the tin industry

The international tin market has undergone a number of changes since the October 1985 crash. Table 7.1 shows the mine production of tin for selected countries as well as total western world production and consumption of tin for the period of 1985-1989. It also reports the annual average real and nominal price of tin for the same period. The most dramatic change has been the sharp drop in the price of tin as can be seen from table 7.1. Some countries have responded to the price change by increasing their output while others have cut back their production. Concentration both at the country level and at corporate level has increased in the last four years. Meanwhile the saga of the ITC default went through the courts and was finally resolved due to a Canadian initiative. The Association of Tin Producing Countries (ATPC) has taken a higher profile since the demise of the ITC. In this part of the chapter, we will first examine the structural changes in the industry. Then we will review some of the institutional developments briefly.

1Unless otherwise stated, the materials for this section are drawn from various issues of Tin International, Malaysian Tin and the annual reports of the Association of Tin Producing Countries.
Table 7.1: Mine production, consumption and price of tin in the western world, 1985-89

<table>
<thead>
<tr>
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</thead>
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<tr>
<td>Malaysia</td>
<td>36.9</td>
<td>29.1</td>
<td>30.4</td>
<td>28.9</td>
<td>32.3</td>
</tr>
<tr>
<td>Indonesia</td>
<td>21.8</td>
<td>24.6</td>
<td>26.2</td>
<td>29.6</td>
<td>32.5</td>
</tr>
<tr>
<td>Thailand</td>
<td>16.6</td>
<td>16.8</td>
<td>14.8</td>
<td>14.2</td>
<td>15.7</td>
</tr>
<tr>
<td>Bolivia</td>
<td>16.1</td>
<td>10.5</td>
<td>8.1</td>
<td>10.5</td>
<td>14.4</td>
</tr>
<tr>
<td>Australia</td>
<td>6.9</td>
<td>8.5</td>
<td>7.7</td>
<td>7.0</td>
<td>7.7</td>
</tr>
<tr>
<td>Brazil</td>
<td>26.5</td>
<td>26.4</td>
<td>28.5</td>
<td>44.0</td>
<td>50.2</td>
</tr>
<tr>
<td>Others</td>
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<td>24.1</td>
<td>21.5</td>
<td>21.5</td>
<td>16.7</td>
</tr>
<tr>
<td>Total Production</td>
<td>158.1</td>
<td>140.0</td>
<td>137.2</td>
<td>155.7</td>
<td>169.5</td>
</tr>
<tr>
<td>China (exports)</td>
<td>7.2</td>
<td>5.4</td>
<td>16.6</td>
<td>18.0</td>
<td>14.7</td>
</tr>
<tr>
<td>Total Consumption</td>
<td>160.8</td>
<td>151.7</td>
<td>155.1</td>
<td>167.0</td>
<td>169.1</td>
</tr>
<tr>
<td>Price (US$/tonne):</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nominal</td>
<td>12283</td>
<td>6199</td>
<td>6843</td>
<td>7160</td>
<td>8500</td>
</tr>
<tr>
<td>Real (1980 US$)</td>
<td>10690</td>
<td>5554</td>
<td>6140</td>
<td>6017</td>
<td>6855</td>
</tr>
</tbody>
</table>

Notes: 1. All production and consumption figures are in 1000 tonnes. 2. Figures for 1989 are provisional and subject to revision.

Source: Various issues of the annual reports of the Association of Tin Producing Countries.

7.1.1 Structural changes in the tin industry

Tin trading resumed at the Kuala Lumpur Tin Market (KLTM) on 3 February 1986. As shown in table 7.1, the average price of tin dropped by 50 percent in nominal terms and 48 percent in real terms in 1986. Since then it has recovered somewhat. In mid-1989, there was a short period when the nominal price of tin rose sharply at the KLTM to reach the pre-collapse levels that prevailed in 1985, but after that it has declined and for the first 6 months of 1990 it has been moving in a range of US$6,000 to $7,000 per tonne in nominal terms. In October 1987, the Kuala Lumpur Commodity Exchange (KLCE) introduced a contract on tin futures for spot and forward trading up to 12 months ahead.
Meanwhile the London Metal Exchange resumed trading in the tin contract on 1 June 1989 with some changes. An important change is that the prices are now quoted in US$ per tonne instead of £ per tonne which was the practice until October 1985.

Total western consumption of tin in 1988 and 1989 is higher than in 1985. The lagged effect of price changes on tin consumption is the reason why it took 2 to 3 years before consumption responded to the sharply lower price levels. Total production in 1989 is higher than in 1985 after going through a low point of 137,200 tonnes in 1987. Just as in the case of consumption, given the lagged effect of price changes on tin supply functions, it took about two years after the 1985 collapse in tin prices for the total output to reach its lowest point. However, with the recent increase in prices, total output has increased since 1987 and it appears that the industry is more responsive to price changes. The other interesting feature from table 7.1 is that in 1989 the consumption and production figures are about equal while in the previous years production has been lower than consumption. The cumulative shortfall in production has helped in reducing the high level of inventory that was left after the ITC default in 1985.

If we examine the distribution of tin production among the various countries, we can observe many changes in the pattern of tin output. Brazil has emerged as the undisputed leader in the production of tin-in-concentrates. By 1989, it was producing almost 30 percent of the western world's output of tin. Malaysia, which was the largest producer of tin for most of this century, is now the third largest with Indonesia moving up
to second position. While Malaysian output has declined since 1985, Indonesian output has increased more than 50 percent during the same period. Thailand is still the fourth largest producer and its output has also decreased to some extent. Bolivian output of tin dropped sharply in 1986 and 1987. Its 1987 output of 8,100 tonnes is its lowest production in this century. Since then, the level of output appears to have recovered. Australian output increased slightly over the four year period.

As for other countries, the sharp drop in price has resulted in a steep decline in their output of tin. Part of the explanation for such a steep drop may lie in the fact that tin that was smuggled out of the ITC countries during the ITC export control period were included under this category; with the effective removal of production quotas after the 1985 tin crisis, smuggling has virtually ceased to exist, thus lowering the reported output of tin under this category.

What is interesting about the changes since 1985 is that in light of the sharp drop in the price level, some countries, notably Brazil and Indonesia, have increased their output while mine production of tin has declined in other countries. One explanation for this lies in the cost structure of the industry. Brazil has the lowest average production cost of mining tin largely due to its very high grade of ore. In addition, many of the new mines have come on stream during this period. Another factor of great influence in the Brazilian tin mining industry is the extent of illegal tin mining by the garimpeiros. These are unlicensed tin prospectors who have been using small scale technologies including panning
to extract tin ore from newly discovered tin deposits. The high grade of the ore makes it economically viable to use such relatively inefficient techniques. The Brazilian government has been unsuccessful in trying to curb their activities.  

In the case of Indonesia, earlier its output was restricted by the ITC quotas. Now that it is free from quotas, it has been able to raise its output given its lower cost structure. In addition, the Indonesian government is now beginning to allow some foreign participation in the tin mining industry. This too has contributed to the increase in production. Up to 1985, Bolivia had the highest cost of production. When the price dropped it became very uneconomic for many of its mines to operate. As a result, a number of them ceased operations which led to the big drop in output. Now, there are plans to privatize COMIBOL, the state owned mining company (Malaysian Business, May 1-15, 1990, p. 75). This may result in a more efficient tin mining industry in Bolivia in the future.

In Malaysia, the impact of lower prices has resulted in a restructuring of the industry. In 1985, the dredging sector accounted for 30.6 percent of the total output of 36,900 tonnes while the gravel pump sector produced 50.2 percent of the total. By 1987, the dredging sector had raised its share of the output to 41.8 percent while the more labour intensive gravel pump sector’s share declined to 38.1 percent. As we saw in chapter 2, the dredging sector has high fixed costs and low variable costs while the cost structure

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2Some of the tin mined by the garimperios are smuggled out of Brazil to Peru or Bolivia. A fuller account of the Brazilian tin industry is given in Malaysian Tin, Volume 16 No. 1, 1988, pp. 3-7.
in gravel pump mining is the reverse. The low prices that prevailed in 1986 and 1987 were lower than the variable costs of many gravel pump mines in Malaysia and as such the mine closures were higher in this sector. This is also reflected in employment figures. In 1985, there were almost 17,000 workers in the tin mining industry which had already seen a sharp drop in employment in the early 1980s. By 1987, the number of workers decreased by 35 percent to less than 11,000 while the output declined only by 17.6 percent.

Similarly, in Australia most of the high cost mines have ceased operations while the Renison tin mine located in Tasmania has expanded operations to work at full capacity, thus lowering its average cost of production. Renison’s increase in output has more than compensated for the decreases arising from the closures of the other major tin mines in Australia which is why the overall Australian tin production did not decrease. Renison produces more than 75 percent of Australia’s current output of tin. In fact combined with the output of its Indonesian subsidiary, the Renison group has emerged as the third largest tin producing company in the world accounting for about 7 percent of the western world’s output (Heap, 1989). The largest is the Paranapanema group which accounts for more than two thirds of Brazil’s output. The second largest tin producer is the Indonesian state owned company P. T. Tambang Timah. The fourth largest is the Malaysian Mining Corporation, a publicly listed company in which the Malaysian government has a controlling stake. There appears to be a consolidation in the tin industry with concentration increasing both at the country and corporate levels.
Among the centrally planned socialist countries, China's exports have increased sharply since 1987. However, the data for China was obtained from indirect sources and is not reliable. Nevertheless, it is clear that in the future, Brazil and China are going to be important players in the tin market in addition to the traditional four main ITC producers: Malaysia, Indonesia, Thailand and Bolivia.

7.1.2 Institutional developments from 1986 to 1990

The International Tin Council (ITC) finally settled its outstanding liabilities to its creditors at the end of March 1990 in an out of court agreement due to an initiative of the Canadian government. Canada was a consumer member of the ITC. After initial negotiations failed in March 1986, the banks and brokers who lent the ITC part of the financial resources used for its price support operations, sued the ITC in British courts. Until the end, the ITC was successful in claiming immunity from court actions by private parties. In May 1988, the Canadian government began an initiative to settle the debts out of court which was eventually successful in settling the debts for £182.5 million which is about one-third the amount originally demanded by the creditors. Meanwhile, all activities including the data collecting services have been wound down and the ITC has ceased to exist.

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3A series of columns on tin by Paul Newman in the Business Times over 1989 and 1990 give a fuller account of the progress of the negotiations between the creditors and the ITC.
Since the 1985 tin crisis, the Association of Tin Producing Countries (ATPC), which is headquartered in Kuala Lumpur, Malaysia, has taken a higher profile in the industry. It was established in August 1983 and is made up of the producer members of the ITC: Australia, Bolivia, Indonesia, Malaysia, Nigeria, Thailand and Zaire. In the beginning its main role was to coordinate the negotiating position of the producer members in the International Tin Council. But it was also a move to have a fallback position for producers in case existing producer consumer arrangements fail.

One of ATPC's most significant activities in the last three years has been the implementation of the 'Supply Rationalization Scheme' (SRS), the stated objective of which is "to ensure the depletion of the overhanging surplus in a predictable, orderly and expeditious manner" (ATPC, 1986, p. 21). Under the SRS, there is no explicit target price which the members are aiming for; instead, each member country is given a production quota. In the first SRS, which came into effect on 1 March 1987, the total annual permissible output by the seven member countries was set at 96,000 tonnes. The SRS was extended in subsequent years and the total permissible production for ATPC members in 1988 and 1989 was set at 101,900 and 106,400 tonnes respectively. Since its inception, the ATPC has been unsuccessfully attempting to get Brazil and China to become members. Both these countries pledged to support this scheme by voluntarily restricting their exports to certain set levels negotiated with the members of the ATPC. However, in the past three years these voluntary export targets have not been honoured by Brazil and China. In the
case of Brazil, the government has been unable to limit illegal tin mining by the *garimpeiros*, while China's reasons for not sticking to the agreement are unclear.

Critics of the SRS have argued that it is basically ineffective; they claim that most member countries will not be able to produce more than the set quotas because of economic reasons. They argue that this is all a psychological ploy by the ATPC to boost the sentiments of the market. They point out to the fact that during the first two years in which the SRS was in effect, tin production of Bolivia and Thailand had fallen far short of the quotas allocated to them. Even Malaysia and Australia have been unable to fulfil the quotas some of the time. On the other hand, Indonesia has exceeded her quota each time. However, ATPC officials, argue that the SRS has been effective in reducing the level of stocks over the last three years and that the quotas are effectively reducing the output.

The problem with the SRS is that there is no effective policing mechanism to detect and deter non-observance of the agreement by members or outsiders like Brazil and China. The sharp decline in prices in the first half of 1990 seems to indicate that the SRS is not really working well. In 1989, tin output of all the top five ATPC members except Thailand exceeded the quota set under the third SRS. As for Brazil and China, their actual output was more than 50 percent higher than their voluntary quotas! It is obvious that the run up

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4These views were expressed in interviews with some participants at the Metal Bulletin's 1st International Tin Conference held at Penang, Malaysia in June 1989.

5Interviews with ATPC officials
in the price of tin in mid-1989 has resulted in production above the allocated quotas. So it appears that the critics of the SRS may be right. We will address the issue of the viability a tin cartel in the next section when we deal with policy options.

7.2 Policy options

It is clear that for some time in the future, it is politically not possible to set up a joint producer-consumer organization like the International Tin Council to intervene in the market to stabilize prices. In the current situation, tin producers have two options. The first option is that producers may consider forming a cartel along the lines of OPEC. Alternatively, they can live with the vagaries of the free market. We will first examine the viability of the establishment of a cartel in the tin industry. Then we will discuss the implications of a free market and policies that can be adopted by the tin producing countries to improve the efficiency of the tin market.

7.2.1 Prospects for the cartelization of the tin industry

To have a successful cartel the following conditions must exist. First, the cartel must have a high degree of monopoly power, i.e., it must have control over a large share of total potential and actual output. It helps in the coordination process if the number of participants is small. Second, threats from substitutes must be minimal. In other words,

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6The discussion here is based on Scherer (1980) and Osborne (1976).
the price elasticity of demand must be small both in the short and long run. Thus, increased prices would not lead to a large drop in sales. Third, the cost structures of firms must be similar. In addition, it helps if the firms do not have a high fixed cost and low variable cost structure. Firms with high fixed costs will have the temptation to chisel in times of low demand. Fourth, demand for the product must be relatively stable. If there is much instability in demand, cartel members will be under great pressure to break ranks during periods of low demand. This is especially true in industries with high fixed costs. Fifth, producers must be willing and able to withhold sufficient amounts of their product to affect the market. For this to happen some of the earlier conditions must exist. There must be sufficient concentration in the industry. Their cost structures must be similar. In addition it helps enormously if they have shared beliefs and common interests. This is particularly true if the cartel members are nation states. In such cases, cultural similarities and common historical experiences will facilitate the formation of a cartel. Sixth, the cartel must have some mechanism to detect and deter cheating.

Does the tin industry have these characteristics? The first condition is easily met in the industry. After the shakeout following the sharp drop in price since 1985, the marginal producers seem to have been eliminated. Six countries, Brazil, Indonesia, Malaysia, Thailand, Bolivia and Australia produced 84, 86 and 90 percent of the western world's output of tin in 1987, 1988 and 1989, respectively. If China, which is the dominant tin producer in the communist bloc joins this group, they will control at least 85 percent of the total world output of tin. As for potential output, these same countries, especially China,
Brazil and Indonesia, have most of the known reserves in the world. However, there are two caveats to this conclusion. First, if prices go higher, there are a number of minor producers, like South Africa, Zimbabwe, Zaire, the United Kingdom and Peru, who will increase their output. A second factor which looms largely is the United States strategic stockpile. The stockpile contained 185,000 tonnes of tin at the end of 1985 and this is equivalent to a year's consumption of the western world. The United States is still the largest consumer of tin in the world. A threat to use stockpile sales to undermine the tin cartel is very credible given the past history.

With reference to price elasticities, tin has a very low short run price elasticity but in the long run there are very few uses for tin in which it is not substitutable. We saw earlier in this study that tinplate has faced strong competition from aluminium and plastic throughout most of the post war period. In fact with the current concern for the environment, recycled tin may come to play an increasingly important role in the supply of tin. Cartelization and price hikes will just hasten this process. This indicates that while the producers may be able to earn monopoly profits in the short run by forming a cartel, its long term viability is not assured.

The cost structure of the tin industry is not similar in all these countries. As we noted earlier, Brazil and Indonesia have very low costs of operation and both are short of foreign exchange in differing degrees. Although the restructuring and cost cutting measures carried out in Thailand, Malaysia and Bolivia since the tin crisis of 1985 have
been relatively successful, their cost of production is still high compared to that of Brazil and Indonesia. Moreover, Bolivia and Australia have high fixed costs and low variable costs due to the technology employed, i.e., underground mining. Thus it is quite clear that the cost structure is quite varied among the top tin producing countries. Cost structures change in the long run. For countries like Brazil, their current cost of production is very low because its deposits are rich. As these ores are depleted the cost of extraction will increase. In resource economics literature, it is generally accepted that there is an inverse relationship between extraction costs and the size of the reserve base (Pindyck, 1978b). When aggregate reserves increase, extraction costs become lower and vice versa. So, if a country can continue discovering new reserves which are equal to or higher than extraction from earlier discoveries, its extraction costs will tend to fall.

For Brazil, in the last decade, the size of the reserve base has expanded sharply thus lowering its cost of production. Is it possible for Brazil to continue discovering new tin deposits to maintain its aggregate reserve base at the current level? Given its abundant land area, the possibility of Brazil continuing to maintain or even increase its aggregate reserve base for the next decade or two should not be ruled out. However, Livernois and Uhler (1987) have shown that increasing the reserve base does not necessarily lower the cost of production. According to them, there are two other factors that influence the inverse relationship between costs of extraction and size of the reserves: "(1) other characteristics of deposits besides their state of depletion affect the level of extraction costs (2) deposits with characteristics producing lower extraction costs tend to be found first"
(Livernois and Uhler, 1987, p. 196). If this is true for Brazil, then the cost of production may increase in the future and the cost situation among producer members may become similar. Such a trend would be favourable to the formation of a cartel.

Another factor that has to be considered is the stability of demand for tin. The estimation of the consumption functions in chapter 5 makes it clear that demand for tin is determined to a large extent by the industrial production of the industrialized countries. So the business cycle in these countries will continue causing instability in the demand for tin.

Currently, given the recent experiences of the ATPC's Supply Rationalization Scheme (SRS), there does not appear to be the willingness among any of the big producers to withhold sufficient amounts of tin to affect the market. The main reason for this failure lies in the divergence of interests among the potential cartel members. Brazil and Indonesia have large low cost reserves and it is in their interests not to be frozen at the current output shares. They want to increase their market shares. According to a recent press report, the Indonesia state-owned tin mining company P. T. Tambang Timah is attempting to obtain World Bank aid to expand its production capacity.7

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7See article titled "Indonesia takes on Brazil at its own game" in Business Times, 9 May 1990. The president of the company is quoted as saying that the company has resolved "to cut production costs from the current US$5,700 to US$6,000 a tonne to $4,500, expand annual capacity from 23,800 tonnes to at least 27,000 tonnes."
Both these countries and China are in need of foreign export earnings. This is particularly true of Brazil. So there is a great incentive to cheat in any agreement they arrive at. There is another reason Brazil and China are unlikely to participate in a cartel. The three major Southeast Asian producers have a long history of cooperation in various schemes involving the restriction of output dating from the 1930s. We have discussed these attempts in appendix 3. Bolivia, Nigeria and Zaire were also part of these arrangements. Australia, a more recent member, may go along with export restrictions for political reasons. It wants to maintain good ties with its Southeast Asian neighbours, particularly with Indonesia. But Brazil is an outsider. It was not even a member of the old ITC. It takes time to develop a working relationship and build up trust. In the case of China, its motives are unclear. Its recent actions with respect to the ATPC's SRS do not encourage any faith in its ability to abide by any agreement it may make in a cartel.

Given all these factors, it is extremely unlikely that a cartel can be formed in the near future. Even if a cartel is formed, there will be great difficulties in enforcing the production quotas. In addition, the fact that in the long run substitutes can be found for most uses of tin, the long term viability of a tin producers cartel is very low.

7.2.2 Non-intervention option

The other option is for tin producers not to intervene into the market. One implication of this is that in the long run only the producers whose marginal cost is equal
to the marginal revenue will remain. This would force many of the high cost operations to close down. The process has already begun since October 1985. Countries like Brazil and Indonesia with low costs of production will continue dominating the tin industry. In such a scenario, it is in the interests of tin producers and consumers to take steps to improve the operation of a free market in tin.

**Futures markets.** To reduce the risk arising from price instability, tin producing countries should encourage tin miners to use futures markets to hedge. At present, there are two futures markets where contracts in tin futures are traded: the London Metal Exchange and the Kuala Lumpur Commodity Exchange. It will be helpful for tin miners in Latin America if they have a futures market there, too. It is important that the regulatory authorities involved take steps to prevent the recurrence of market squeezes as happened at the LME in 1982. In that episode, the Malaysian government was behind an unsuccessful attempt to corner the market. Actions such as these undermine public confidence in the market.

Another step that can be taken by governments to improve the operations of futures markets is to provide better information about the tin industry. The provision of reasonably reliable statistics of production and consumption has been one of the most useful services performed by the old International Tin Council. It is unfortunate that since its demise, there has been no other agency to continue this role. It will be very helpful for both producing and consuming countries if they ratify the agreement establishing the
United Nations sponsored International Tin Study Group (ITSG) and have it operating as soon as possible. Having an effective ITSG will enable better market transparency through the provision of reliable statistics on the industry. By April 1990, only three countries - Malaysia, Indonesia and Nigeria - have formally signed the UN agreement on the formation of the ITSG.

**Privatization.** The state owns and controls a large part of the tin mining industry in Bolivia, Indonesia and to some extent in Malaysia. To improve productivity and efficiency, one option that ought to be considered is to privatize the mining operations. Bolivia has begun taking steps in that direction. In Bolivia, studies have shown that the privately owned medium sized mines have been far more efficient than the state run COMIBOL (Ayub and Hashimoto, 1985). Even if complete privatization is not politically feasible, more autonomy should be given to these state owned companies.

**Government policies.** In addition, a proper policy mix, which provides incentives for continued restructuring to increase productivity and for additional investment, is needed to be set in place in many of these countries. For example, in Malaysia, the state governments, which have control over land matters, have very little incentive to give leases on new mining land or to extend leases of existing operations because the federal government takes 90 percent of the duties collected on the exports of tin, leaving the state government with a mere 10 percent. The president of the Malaysian Chamber of Mines
commenting on the decrease in mine production of tin in 1988 despite the higher prices prevailing during that year stated:

the decrease was attributed primarily to the depletion of high grade ground forcing miners to work or rework on lower grade ground and to the non-availability of new mining land......Perhaps, one of the major reasons for the State Governments not favouring mining operations is the current tin revenue sharing system between the Federal and State Governments. The ten percent share of tin export duty presently given to the State Governments provides little financial encouragement for them to favour granting of land for mining operations. It is, therefore, our view that in order to encourage State Governments to look at mining more favourably, this disproportionate tax distribution should be corrected immediately. It may be pertinent for such revenue sharing [to] be revised to even on an equal 50:50 basis.⁸

Another area where governments can act is to provide fiscal incentives to encourage the establishment of tin-using industries, thus increasing the total value added by downstream activities. For example, Malaysia has a large and expanding electronics industry which uses a lot of solder. With the right fiscal incentives, it is possible to attract enough foreign or local investment to enable Malaysia to be one of the largest solder manufacturers in the world.

**Research and development.** Finally, continued effort must be maintained in research and development both in the production and consumption of tin. More cost efficient and environmental friendly mining techniques must be developed. At present, there is a joint research institute known as the South East Asian Tin Research and Development Centre

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⁸Presidential address to the Chamber of Mines on 29 May 1989 reported in *Malaysian Tin*, Vol. 16 No. 3 p. 6-7.
located in Ipoh, Malaysia which focuses on mining research. As for research in increasing the end uses for tin, the ATPC funds the International Tin Research Institute (ITRI) located in the United Kingdom. In addition to its current research, it is important that the ITRI focuses increasingly on the environmental aspects of tin uses. Tin is well suited to compete on environmental grounds with other materials. For example, a tin can requires less energy to manufacture than an equivalent aluminium can and unlike plastic containers, tin is biodegradable. Its non-toxicity has helped in replacing lead in many kinds of solder. Promotion of these advantages in major consuming regions is also necessary. In all these R & D activities, it will be beneficial to involve the tin consuming firms from the beginning. This may persuade some consumers to jointly fund research projects.
8. SUMMARY AND CONCLUSIONS

This study has focused on the impact of the international tin agreements (ITAs) on the performance of the world tin industry over the thirty year period during which the ITAs operated. This chapter first summarizes the findings of this study reported in the previous chapters and then provides some suggestions for future research on the tin industry.

8.1 Summary of findings

The discussions in chapter 2 and the econometric estimates of the tin supply functions in chapter 4 clearly indicate that tin supply is dependent not only on the real price of tin but also on country specific policies and the internal political situation as well as the export controls imposed by the International Tin Council (ITC). The relative importance of country specific factors vary from country to country. For example, in Indonesia, we showed that during the Sukarno regime, the production of tin-in-concentrates was totally not responsive to price changes. In contrast, the effect of the New Economic Policy which began in Malaysia in the early 1970s was not as severe. It has just reduced the impact of price changes on production to some extent. We also showed that price response to tin supply is dependent on the mix of technology used in tin production. For example, the supply of tin from Thailand, which had a higher proportion of its output from the smaller-scale gravel pump and suction boat mining methods was more responsive
to price changes in the short run than Australia where the bulk of its tin output was from lode mines which use the highly capital intensive underground mining technique.

Concerning the consumption of tin, the discussion in chapter 2 and the econometric estimations of the consumption functions in chapter 5 show that the consumption of tin depends on the level of industrial production and the price of tin. There was also a long term technological trend against the use of tin due to a decreasing intensity of use in a number of industries. In particular, in the manufacture of tin plate which is the most important use of tin, thinner coatings of tin on steel because of technological improvements have resulted in a lower intensity of use.

The simulation results from the econometric model reported in chapter 6 show that the ITC has been successful in stabilizing prices, producer revenues and consumption expenditure compared to an alternative scenario in which there were no interventions by the ITC in the tin market. In addition, the ITC operations resulted in increases in the average price of tin as well as total discounted producer revenues. However, non-ITC producer countries benefitted more in that their revenues would have suffered a more severe drop in the absence of ITC operations compared to the drop in revenue that the ITC producer countries would have suffered.

In the discussions in chapter 2, it was shown that the ITC price support operations collapsed because of over supply of tin from two sources: non-ITC producers like Brazil
and China and cheating by some ITC member countries. Brazil's discoveries of very rich tin deposits in the Amazon valley dealt a particularly severe blow to the price control programme of the ITC. However, if the ITC had established a formal mechanism to lower its support price, perhaps it could have prolonged its operations.

In considering the changes in the tin industry since 1985, we noted that the degree of concentration at both the country and corporate level has increased. In evaluating policy options, we showed that the establishment of a cartel is not viable in the long term both on economic and political grounds. The recommended policy options include improving access to futures markets, providing better transparency of tin market operations, the establishment of government policies which provide better incentives for tin mining and tin using industries in the major tin producing countries and continued efforts in research and development with the aim of lowering costs of production and increasing the uses for tin.

8.2 Limitations of the study

We have already discussed in some detail the limitations of the simulation results at the end of chapter 6. Similarly the limitations of estimating price elasticities of supply from our econometric model were discussed in section 4.10. In this section we will discuss some additional shortcomings of this study. The econometric model in this thesis used annual data. However, annual data tends to mask variations within the year. This is
especially so with prices. For example in 1977, the maximum price was nearly 20 percent higher than the average and more than 40 percent higher than the minimum price for that year.

A second shortcoming of the study is that we have assumed competitive markets in our model. But it is clear that in the early 1980s, the tin market behaved in a non-competitive manner with the ITC producer countries severely limiting their output in what turned out to be an unsuccessful attempt to maintain the price of tin well above the competitive market price. We have also not explicitly included the market structure within the country in our model. This study has emphasized production and consumption at the country level. It did not pay that much attention to the structure of the market at the corporate level. This was mainly due to the fact that ITC export controls were imposed at the country level and also due to the low level of participation of multinationals in the tin industry. Nevertheless, tin ore is produced by firms and production decisions are made by individual firms. So a more detailed investigation at the corporate level may reveal further insights into the tin industry.

Another omission in the study is the impact of export duties and royalties on the production of tin-in-concentrates. We have assumed that the producer gets the world price of tin. However, most of the tin producing countries have some combination of export duties and royalties to capture a share of the economic rent that arises from the production of tin ore. Malaysia and Thailand had relatively high levels of export duties.
In both these countries export duties on tin are progressive, i.e., the higher the price of tin the higher is the rate of export duty, which makes the tax very responsive to price. Bolivia has one of the highest levels of mineral taxation among the major tin producers. Over the period of 1970 to 1981, the average joint burden of the various forms of mineral taxation on the tin-mining industry in Bolivia was 37 percent of gross tin revenues (Ayub and Hashimoto, 1985, p. 63). The inclusion of these taxes in an explicit manner in our model may affect some of the findings of the study. However, the structure of mineral taxation is so varied across countries and over time that it is difficult to incorporate it in the model without greatly increasing the level of complexity of the model.

8.3 Directions for future research

The shortcomings discussed in the section 8.2 provide obvious directions in which to extend this research. Specifically, a quarterly model would overcome some of the problems with price and export controls. In addition, a more explicit treatment of mineral taxes would further improve the realism of the model. In analyzing the impact of the ITAs, we have focused on the distribution of benefits between the consumers and producers. However, we have omitted any analysis of the distribution of benefits between the factors of production in the major tin producing countries. This is another area for further research.
A different direction for future research is to investigate the changes that have taken place in the tin industry in the 1980s, especially after the collapse of the ITC operations and the subsequent sharp fall in the price of tin. Future research should look into how the tin industry in each country is handling these changes and what are the changes that are taking place at the corporate level. A related area to investigate is the changing role of government participation in the tin industry in the different countries.
Appendix 1. World tin reserves and future availability

Estimates of mineral resources vary widely, depending on the specific assumptions made on technology, costs, prices and other relevant data. Table A1.1 shows tin resources that are available in the western world as reported in a recent U.S. Bureau of Mines study (Bleiwas et al, 1986). The study evaluated 146 tin deposits and regions, which covered at least 85 per cent of the western world's tin resources. The total amount of contained tin in the western world was estimated to be about 3.8 million tonnes. Of this, recoverable reserves amounted to 2.8 million tons.¹

Malaysia has the largest recoverable tin reserves in the western world at 1.1 million tonnes or nearly 40 per cent of the total. Indonesia has about a quarter and Thailand nearly 10 per cent of the western world's reserves. Thus, it appears that these three Southeast Asian countries will continue to dominate the world tin market.

However, two recent developments have reduced this domination. First, recent discoveries have resulted in a manyfold increase in Brazil's tin reserves. According to Moreno (1985):

Although not very much is known about the country's tin producing potential, the U.S. Bureau of Mines' 1982 estimate of 67,000 tonnes of contained tin is apparently now well out of date. Metals Week recently published the latest estimate for the reserves of the country's largest mine alone as being 575,000 tonnes contained tin. Facts and figures emerging

¹See Bleiwas et al (1986) for the definition of the terms 'contained tin reserves' and 'recoverable reserves.'
from Brazil are at best confused, and often exaggerated. But even if this estimate were halved, we would still be talking about a 400 to 500 per cent increase in reserves (p. 72).

The second development is related to China's potential to be a large producer of tin. The U.S. Bureau of Mines (1985, p. 849) has estimated the reserve base of China and the U.S.S.R. to be 80,000 tonnes each. However, other sources provide much higher estimates for China:

The country's tin reserves are estimated to be between 500,000 and 2,500,000 tonnes of contained tin, with no firm reliable figures of the actual size of the major deposits. O.E.C.D. estimates in 1978 placed China first as the country with the highest share (432,000 tonnes or 23.6 per cent) of world known and identified non-speculative tin reserves. The U.S. Central Intelligence Agency, also in 1978, estimated that China's reserves were at least 500,000 tonnes (Malaysian Tin, April 1986, p. 8).

Thus, China and Brazil appear to be the only nations that can challenge the dominance of Southeast Asia in the world tin market. It is, perhaps, for this reason that the Association of Tin Producing Countries (ATPC) has been trying to persuade China and Brazil to join the organization.²

²For a report on the attempts by the ATPC to co-opt China and Brazil see the Far Eastern Economic Review, 13 November 1986, pp. 112-115.

In general, the figures given in table A1.1 are rather conservative. One reason for the underestimation in tin reserves is the static nature of the forecast. It reflects demonstrated resource estimates made during 1981 and 1982, less "estimated production from producing mines for the intervening years to January 1984. This implies that no new reserves or demonstrated resources have been added to replace that production, which is
Table A1.1: Tin resources in selected countries in the western world

<table>
<thead>
<tr>
<th>Country</th>
<th>Contained reserves</th>
<th>Recoverable reserves</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Quantity (1000 tonnes)</td>
<td>Percentage of total</td>
</tr>
<tr>
<td>Malaysia</td>
<td>1315</td>
<td>34.8</td>
</tr>
<tr>
<td>Indonesia</td>
<td>865</td>
<td>22.9</td>
</tr>
<tr>
<td>Thailand</td>
<td>437</td>
<td>11.5</td>
</tr>
<tr>
<td>Australia</td>
<td>318</td>
<td>8.4</td>
</tr>
<tr>
<td>Bolivia</td>
<td>211</td>
<td>5.6</td>
</tr>
<tr>
<td>U.K.</td>
<td>128</td>
<td>3.4</td>
</tr>
<tr>
<td>Brazil</td>
<td>73</td>
<td>1.9</td>
</tr>
<tr>
<td>Othersa</td>
<td>437</td>
<td>11.5</td>
</tr>
<tr>
<td>Total</td>
<td>3784</td>
<td>100.0</td>
</tr>
</tbody>
</table>

Notes: *Other countries are Argentina, Burma, Canada, Japan, Namibia, Nigeria, Peru, South Africa, Zaire and Zimbabwe.


doubtful" (Bleiwas et al, 1986, p. 16). This was clearly demonstrated to be incorrect in the case of Brazil. Another reason is related to the limited scope of the study. It may have left out up to 15 per cent of the known tin resources in the western world since a number of smaller mines were excluded from the study.

However, the most important reason for the underestimation of the tin reserves arises from the limited information that was available. Mining companies are reluctant to release complete data on their mining operations. Furthermore, to obtain complete data, a great deal of geological exploration has to be done, which is a costly and a time-consuming endeavour, requiring a high degree of technical expertise. For many mining companies, there is very little incentive to spend money and time exploring further
resources which will not be needed in the immediate future.\(^3\) This is particularly true of smaller mines.

Finally, the estimates are based on current technology. Any improvement in the technology dealing with exploration, mining, and smelting will increase the potential supply of the metal. "In fact, resources of any mineral may best be considered as a working inventory at a particular level of economic and technological development" (Gupta, 1982, p. 10).

\(^3\)A quote from *Tin International*, May 1976, p. 158, cited by Robertson (1982, p. 165) illustrates this clearly: "...mining companies are not in business to provide intellectual comfort to analysts of resource availability." Robertson who reviewed a number of earlier estimates of reserves, also concludes that most of them were conservative.
Appendix 2. Mining and smelting technology and cost

A2.1 Mining technology

The geology of tin deposits will be first reviewed briefly, since it has a considerable influence on the mining method used. Though there are nearly twenty different tin-bearing minerals, the most common one is cassiterite, an oxide of tin, which in its purest form contains 78.8 per cent of tin. The others, which are mainly complex sulfides, are of little importance, except in Bolivia. Tin-bearing ores are usually associated with granitic rocks. The ores are found either in the granitic rocks themselves (lode deposits) or in the unconsolidated debris of such rocks (placer deposits). More than three-quarters of the western world's tin comes from placer deposits which have been formed from the gradual denudation of the tin-bearing granitic rocks. They are found in hill sides, in river beds and valleys, as well as on the floor of the sea close to the shore. Most of the tin ore mined in Southeast Asia and Brazil is of this variety. Lode deposits are more common in Australia, Bolivia, Canada, China, the U.K., the U.S.S.R. and other less important producers of tin. In lode deposits, and to a much smaller extent, in placer deposits, tin is often found in association with silver, tungsten, tantalum and a number of other elements. The extent and the ease of recovery of these byproducts can influence the cost of production significantly in some countries.

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1Bleiwas et al (1986) and Denyer (1972) provide a more detailed description of the technology involved in the production of tin. This subsection is based largely on these two sources.
Like most metals, the production of pure tin metal involves four stages: mining, concentration, smelting and refining. Mining involves the extraction of the tin-bearing ore from the earth, while concentration or beneficiation involves the recovery of the cassiterite by means of a treatment plant. The high specific gravity of cassiterite is used in the concentration process to separate it from the valueless materials associated with it. In general, due to the low proportion of the cassiterite in the untreated ore, it is more economical to locate the treatment plant at the site of the mine itself.

There are basically three main methods of mining: dredging, gravel pumping and underground mining. Dredges and gravel pumps are used to mine alluvial placer deposits while lode deposits are mined using underground mining methods.

Dredges produce about a quarter of the western world's output of tin. They are found mainly in Southeast Asia. In Indonesia and Thailand, both offshore and onshore dredges are used, while in Malaysia only onshore dredges are used. A dredge is essentially a mechanized floating factory located offshore or in an artificially created lake onshore. It uses a chain of buckets to excavate the tin-bearing earth which is then concentrated by gravitation methods in the dredge itself. The resulting concentrate which assays between 20 to 30 per cent is further processed at a land-based tin shed. Dredging is usually the most efficient method of mining tin "but requires a large flat tract of alluvial tin-bearing ground, ample water in which to float the dredge, and an absence of underground impediments such as rock pinnacles, boulders, or large stumps" (Baldwin, 1983, p. 184).
Compared to gravel pumping technology, dredging is more capital intensive. In terms of capacity, the largest units operating offshore have a capacity of up to 1,500 tonnes per year (tpy). However, the average output per dredge in Malaysia in 1985 was less than 400 tpy.

About half of the western world’s tin is produced by gravel pumps. They are used extensively in Brazil, Indonesia, Malaysia and Thailand. In a gravel pump operation, a high pressure jet of water is used to blast against the working face to break up the tin-bearing ground. The resulting slurry is then pumped up onto the palongs, which are long, inclined sluices lined with riffles. The cassiterite and other heavy minerals that are captured by the riffles are periodically collected and sent to the tin shed. Gravel pumps are less capital intensive than dredges but consume more energy and require more labour to operate. Although some large Malaysian gravel pump mines have a capacity of nearly 1,000 tpy, the average output of gravel pumps in Southeast Asia is less than 100 tpy.

The tin shed is a treatment plant located at the mine site. Gravity methods, using jigs and tables, are employed to upgrade the concentrates, that are received from the dredges and/or the palongs, to about 70 to 75 per cent of tin. Then the concentrates are dried. When required, magnetic and electrostatic methods are used to separate byproducts like columbite, ilmenite, monazite, zircon and other minerals before they are shipped to the smelter.
There are a number of studies which have compared the advantages and disadvantages of the gravel pump technology and the dredging technology. In general, where the terrain is suitable, dredging is the most efficient method of mining. For a given grade of ore, the cost of mining and beneficiation is the lowest with the dredging method. However, according to Bleiwas et al (1986):

gravel pumps have several advantages over dredging methods: (1) topography is relatively unimportant, (2) selective mining can be practised, (3) capital cost is low, (4) complete extraction of the material is possible, and (5) ground at various depths can be worked with the same equipment (p. 22).

Most lode deposits are mined using underground mining methods, which account for about 15 to 20 per cent of the western world's output of tin. Almost all of Bolivia's output is from underground mines. Other countries with underground tin mines are Australia, China and the United Kingdom. Underground mines are of varying sizes and degrees of complexity. The largest tin mine in the world, the Renison complex in Australia, is an underground mine with a capacity exceeding 5,000 tpy of tin-in-concentrates (Mining Magazine, September 1985). The average output of the large Bolivian mines is more than 1,000 tpy. But there are also many underground mines in Bolivia that are small operations, often smaller than the average gravel pump mine in Southeast Asia (Robertson, 1982, p. 20). The concentration of the ores from underground mines is a complex process. The ores have to be first crushed and ground into finer...

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2See Baldwin (1983, Chapter 8), Robertson (1982, Chapter 2) and Thoburn (1981, Chapter 6).
particles before gravity methods can be used. Several grades and compositions of concentrates may be produced depending on the complexity of the ore.

In addition to the three main mining methods described above, other mining methods which are used (though on a much more limited scale) are suction boats, open cast mining and dulang washing. Suction boats are found almost exclusively in Thailand. A suction boat is essentially a converted fishing boat with a gravel pump on board connected to a suction pipe which raises tin-bearing alluvium from the sea bed. The suction boats average only 3 to 4 tpy. In comparison, the capacity of the large offshore dredges which operate in the same waters is as high as 1500 tpy. Still, in 1985, the suction boats accounted for about 15 per cent of Thailand's tin output.

Where lode or placer deposits are close to the surface, open cast mining methods are used to recover tin. Open cast mines are found in Australia, Malaysia, Nigeria and Zaire. Dulang washing, which is largely confined to Thailand and Malaysia, usually account for about 5 per cent of the tin output in these two countries. It involves the use of a dulang or a pan to recover tin concentrates from mine tailings and river beds; it is a process which resembles the panning method used by gold miners.
A2.2 Costs of production

The production cost of tin depends on many factors, including the grade and characteristic of the ore body, mining method, size and location of the mine, byproduct prices, costs of inputs such as labour, materials and energy, and the tax structure of the country in which the mine is located. Accurate information on production costs is difficult to obtain because of its proprietary nature. Moreover, the absence of a uniform accounting system prevents strict comparability of data among different countries. The international comparison of costs is also affected by fluctuations in exchange rates. Nevertheless, there have been a number of studies of the tin mining industry that have estimated costs of production.\(^3\) The cost estimates in these studies have not always been consistent. This is largely due to the different assumptions made in each study and the different time periods during which the studies were undertaken.

However, from a review of these studies, some general observations can be made on the cost structure of the tin industry. For convenience, the following discussion is limited to the six most important tin producers in the western world: Australia, Bolivia, Brazil, Indonesia, Malaysia and Thailand, who together accounted for nearly 80 per cent of the western world's production of tin in 1985.

Brazil is clearly the lowest cost producer. The main reason for this is the high grade of the ore found in Brazilian tin deposits. The low cost of smelting and a moderate level of taxation on the tin mining industry are other reasons for the low overall cost of production. A 1982 study of the tin industry in the western world by the United States Bureau of Mines (USBM) estimated that the average cost of production of tin in Brazil, adjusted to January 1984 price levels, was US$2.70 per lb. before taxes. With a tax of $0.70, the after tax cost was $3.50 (Bleiwas et al, 1986). Current production costs would be even lower with the development of new mines with much lower costs of production (Eccles, 1985, p. 68). Thus, even at the depressed prices of about US$4.20 per lb. in early 1987, the Brazilian industry can operate profitably.

At the other end of the cost scale is Bolivia. Its underground mines have the highest production cost in the world. The reasons for this are the poor grade of the ore, the absence of adequate investment for maintenance and modernization of current operations, a lack of exploration, the poor and inefficient management of the mines, political unrest leading to conflicts between the mine workers and the government, and the very high taxes. An additional factor is the high smelting cost due to the complex nature of the Bolivian ores. This is offset, to some extent, by the sale of byproducts. The cost of production is highest in the mines operated by the nationalized mining corporation, COMIBOL, which accounts for more than 60 per cent of Bolivia’s production. One study estimated COMIBOL’s cost to be more than US$8.00 per lb. (Eccles, 1985, p. 67).
The average production costs in the Southeast Asian mining industry falls between those of Brazil and Bolivia. The average cost, however, hides the large difference in costs between the dredging and the gravel pump sectors. Eccles (1985) has estimated that the "long-run full production operating costs excluding taxes" for the Southeast Asian dredges is less than US$3.50 per lb., compared to a range of US$4.80 to $6.60 per lb. for gravel pump operations. Cost comparisons among the three countries are inconsistent. Bleiwas et al (1986) report that while the differences in unit costs of the dredging operations are not significantly large, unit costs in gravel pump operations are the lowest in Indonesia and highest in Malaysia, with the unit cost in Thailand falling in the middle, before taxes are considered. Another comparable study has similar rankings in the gravel pump sector (Eccles, 1985). Although, the Malaysian mines are technically the most efficient, they have to work on a much lower grade of ore, thus raising their production cost (Sumun, 1986).

This is clearly illustrated in table A2.1, which gives the average feed grade of the ore mined in selected countries. Some of the gravel pump and dredging operations in Malaysia are reworking previously mined areas. The tax incidence on the tin mining industry was very high in Thailand and moderately high in Malaysia, but in both countries there has been a sharp reduction in taxes, especially after the tin crisis of October, 1985.

The Australian mines are reported to have a unit operating cost of US$5.50 per lb. (Bleiwas et al, 1986). However, with the recent closure of high cost mines and the increased utilization of capacity at the highly efficient Renison underground mine in
Table A2.1: Average grade of tin ore by mining methods for selected countries

<table>
<thead>
<tr>
<th>Mining method and country</th>
<th>Average feed grade (percent of tin)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dredges:</td>
<td></td>
</tr>
<tr>
<td>Indonesia</td>
<td>0.015</td>
</tr>
<tr>
<td>Malaysia</td>
<td>0.007</td>
</tr>
<tr>
<td>Thailand</td>
<td>0.012</td>
</tr>
<tr>
<td>Gravel pumps:</td>
<td></td>
</tr>
<tr>
<td>Brazil</td>
<td>0.041</td>
</tr>
<tr>
<td>Indonesia</td>
<td>0.023</td>
</tr>
<tr>
<td>Malaysia</td>
<td>0.009</td>
</tr>
<tr>
<td>Thailand</td>
<td>0.020</td>
</tr>
<tr>
<td>Underground:</td>
<td></td>
</tr>
<tr>
<td>Bolivia</td>
<td>0.804</td>
</tr>
<tr>
<td>Australia</td>
<td>0.622</td>
</tr>
</tbody>
</table>

Tasmania, the average unit costs can now be expected to be lower.

In terms of capital requirements, gravel pump mines need the least. According to one estimate, the capital costs for a large offshore dredge were between US$20 to $30 million in the late 1970s (Baldwin, 1983, p. 186). An inland dredge, with a similar capacity, cost $7 to $10 million. On the other hand, the capital cost of a large gravel pump mine would have been in the range of $300,000 to $400,000. In all these estimates, costs of survey, exploration and site acquisition have been excluded. Capital costs for underground mines vary widely. On the average, they are comparable to the capital costs for dredges.

In general, dredges and underground mines operate with low variable costs and high fixed costs while gravel pumps have a relatively higher variable cost and lower fixed costs. Despite these differences, in the short run, the fixed costs and shutdown costs are
sufficiently high enough in the entire industry to discourage temporary closures of the mines. In the long run, however, gravel pump mines with their relatively lower fixed and lower shutdown costs are more flexible in expanding and contracting their output in response to perceived long term price changes.

**A2.3 The tin smelting industry**

The tin concentrates from the mines are shipped to a smelter where they are smelted and refined into tin metal. The smelting of the high grade "clean" concentrates from alluvial sources in Southeast Asia and Brazil is a relatively straightforward process. Smelting is carried out in reverberatory, rotary or electric smelter furnaces. The impurities that remain are then removed in the refining stage which uses either pyrometallurgical or electrolytic processes. The cost of smelting and refining the tin concentrates from Southeast Asia and Brazil is normally less than 5 per cent of the total production cost.

More complex and lower grade ores, from countries like Bolivia, have to undergo direct fuming, and/or roasting and acid leaching to remove most of the impurities and increase the grade of the concentrates, before the smelting stage. After smelting, several stages of refining may be required to obtain an acceptable grade of tin. Therefore, the cost of smelting and refining is significantly higher for these ores, although in some cases, the sale of byproducts reduces the cost.
Appendix 3. Tin controls during the interwar years

When compared to other agricultural and mineral commodities world trade in tin is relatively unimportant. However its distinctiveness is due to the long history of market interventions arising from international arrangements between governments to control its output and price.\(^1\) The first phase of these international arrangements covered the interwar period, and only the tin producing nations were involved. In contrast, both the major producing and consuming countries were parties to the tin agreements in the second phase, which lasted from 1956 to 1985. While the focus of this study is on the postwar international tin agreements (ITAs), it is important to review the interwar tin control schemes as they had much influence on the postwar ITAs.

The first intergovernmental attempt in tin control took place in the aftermath of the postwar economic slump of 1920. After touching a peak of £419 per long ton in April 1920, the price of tin started declining continuously to reach £166 per long ton in February 1921, when representatives of the colonial governments of Malaysia and Indonesia met to establish the Bandoeng pool. The pool had the limited objective of taking over the accumulated stocks of tin of nearly 20,000 tons from the governments of Malaysia and Indonesia, and other private interests and was authorized to dispose the tin only when the price reached £240 per long ton. From April 1923 to December 1924, almost all the tin

\(^1\)The material in this appendix is drawn largely from Fox (1974), Knorr (1945) and Yip (1969).
in the pool was sold at a tidy profit in a rising market at a rate of five percent per month. The monthly average price in December 1924 was £262 per ton.

The gradual pace at which tin was sold from the pool in 1923 and 1924 had masked the need for the expansion of the production capacity to meet the long term rise in the demand for tin from the tinplate and automobile industries. As a result, when the pool had exhausted its stocks, the price of tin rose sharply throughout most of 1925 and 1926, which in turn encouraged an increased flow of investments into exploration and mining activities. The impact of these investments on subsequent supply of tin was amplified in Southeast Asia by the rapid adoption of the tin dredge, a major large-scale capital-intensive technological innovation of the 1920s. Due to the time lags that exist between higher prices and subsequent investment, and between investment and production, the situation changed rapidly from one of excess demand in 1925 to one of excess supply by the end of that decade.

Thus, the pool, while succeeding in the short run in raising the price of tin, appeared to have contributed to the boom and bust conditions that the industry faced in the late 1920s. However, as Baldwin (1983) states:

Whatever its effects may have been in reality, the perceived success of the pool set the stage for a transformation of the tin industry, lasting to the present day ...................... in which tin prices and quantities put on the market have been subject to manipulation and control under intergovernmental agreements in all but a few years immediately after the disbanding of the pool and following the Second World War (p. 66).
After reaching a peak of £321 per ton in 1927, the price of tin declined steadily throughout 1928 and 1929 due to the sharply increased supply. With the onset of the Great Depression, the price plunged rapidly to reach a 30-year low of £100 per ton in May 1931. The 1925-29 period was also characterized by the increasing concentration in the industry. It was particularly pronounced at the smelting level, where the top three companies were responsible for an estimated 84 percent of the world output of tin metal in 1929. It is these conditions of excess capacity and a high level of industry concentration, among others, that facilitated the subsequent formation of the tin cartel in the early 1930s.

After an unsuccessful attempt to regulate exports by voluntary restrictions, the major tin producing firms in Malaysia, Indonesia, Bolivia and Nigeria were able to persuade their governments to enter into a formal agreement to control the output of tin. This first International Tin Agreement came into force on 1 March 1931 and lasted until the end of 1933. These four countries together were producing more than 85 percent of the world output of tin at that time. A second agreement was in effect from 1934 to 1936 and a third one from 1937 to 1941. The fourth ITA to cover the period of 1942-46 was signed but had no real effect due to the Second World War.

The main objective of the agreements was to stabilize tin prices at a "fair and reasonable level." The control mechanism that was to be employed was export controls through a quota system based on the 1929 output of the participating countries. In addition to this, a buffer stock was operated at first privately but later officially by the
International Tin Committee. This committee was the executive body set up to implement the tin agreements. Since the operations of the committee, in implementing these agreements, have been described in detail by Fox (1974), Knorr (1945) and Yip (1969), only a brief evaluation of its activities will be provided here.

From the beginning, the tin cartel faced a number of threats to its survival. Firstly, there were frequent disagreements between the low cost producers like Malaysia and Indonesia, and the high cost producers like Bolivia and Nigeria, on the level of export controls and on what constituted a "fair and reasonable" price. High cost producers favoured higher prices and a higher level of export restrictions to maintain the higher prices. Secondly, the countries outside the agreement, were a constant threat. In the first half of 1934, non-member output was nearly 25 percent of total output. So, one by one, they were bribed with very favourable terms to join the agreement. Thailand joined in 1934; Zaire, French Indo-China, Portugal and the U.K. joined the second agreement later. This meant that the four original members steadily lost their market share; in 1931 they had about 81 percent of the market but by 1938, their share had dropped to 65 percent. Thirdly, the formation of the cartel antagonized consumer interests, particularly, the United States. In the opinion of Yip (1969), this "contributed to making an agreement between the United States and the tin producers so notoriously difficult to achieve in the post-war restriction schemes" (p. 284).
Finally, the private buffer stock pool set up alongside the tin control scheme became a cause for dissent and opposition from many mine owners. According to Yip (1969), some Malaysian producers "feared that since those who administered the Agreement were also those who had interests in the pool, restriction policies might be directed to the benefit of the pool at the expense of the restricting countries" (p. 195). This suspicion was strengthened by the fact that all the pool activities were conducted in secret. Subsequent events appear to have justified their fear. When most of the tin in the pool was being sold with considerable profits during 1933, exports were restricted to 33.3 percent of the 1929 output! Thus, the producers in the four restricting countries paid a heavy price to enable the tin pool operators to make large profits.

Despite these problems, the cartel survived until the outbreak of the Second World War. Osborne (1976) argues that for a cartel to be stable, five problems have to be overcome:

The external problem........is to predict (and if possible, discourage) production by nonmembers. The internal problems are, first, to locate the contract surface; second, to choose a point on that surface (the sharing problem); third, to detect, and fourth, to deter, cheating (p. 835).

As was seen earlier, the cartel dealt with the increased output of outsiders by bribing them with generous quotas. The internal problems were less difficult to overcome due to the high degree of concentration in the industry. Since only four countries were involved in the first Agreement, it was relatively easy to agree on the allocation of quotas. Cheating was never a serious problem given that the agreements were at the governmental level. An additional factor that contributed to the durability of the tin cartel was the inability of
the tin consuming countries to take a united stand against it. The largest consumer, the United States, was strongly opposed to the cartel. But the United Kingdom, which was the second largest consumer at that time, and the Netherlands were in favour of the tin control schemes because of their extensive interests in the tin industry in their colonies.

The interwar international tin control scheme came to an effective end with the outbreak of the Second World War in September 1939. The years 1940 and 1941 saw record production of tin encouraged by purchases for the United States strategic stockpile. However, when the Japanese occupied Southeast Asia in 1942, the world output of tin was cut to less than half the 1941 level. Tin output remained low throughout the remaining years of the war, and so did consumption, due to wartime restrictions. When the war ended, the tin industry recovered quite rapidly and by 1948 supply exceeded consumption.

See Fox (1974, Chap. 8) for an account of tin control during the war years.
Appendix 4. List of variables in the model

A4.1 Data sources

IMF  

ITC  

MS  
*Metal Statistics*. Annual. Frankfurt: Metallgesellschaft Aktiengesellschaft

UN  

A4.2 Area Suffixes

**Production:**

AU  
Australia

BO  
Bolivia

IN  
Indonesia

MA  
Malaysia

NC  
Non-ITC countries

RW  
Non-ITC countries excluding Brazil

TH  
Thailand

WW  
Aggregate of all countries in western world

ZN  
Zaire and Nigeria

**Consumption:**

DC  
Developing countries

FR  
France

IC  
Other industrialized countries

JA  
Japan

UK  
United Kingdom

US  
United States

WG  
West Germany

WW  
Aggregate of all countries in western world
<table>
<thead>
<tr>
<th>Variable</th>
<th>Description</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>EXUSUK</td>
<td>Average annual exchange rate of sterling in U.S. dollars per pound sterling</td>
<td>IMF</td>
</tr>
<tr>
<td>IIPx</td>
<td>Index of industrial production in area x (1980 = 100.0)</td>
<td>UN</td>
</tr>
<tr>
<td>INT</td>
<td>100(1 + i) where i = average annual U.S. prime lending rate</td>
<td>IMF</td>
</tr>
<tr>
<td>NPITC</td>
<td>Net purchases of tin for the ITC buffer stock (tonnes)</td>
<td>ITC</td>
</tr>
<tr>
<td>NSGSA</td>
<td>Net sales of tin from the United States stockpile (tonnes)</td>
<td>ITC</td>
</tr>
<tr>
<td>NXCPE</td>
<td>Net exports of the centrally planned socialist countries (tonnes)</td>
<td>ITC</td>
</tr>
<tr>
<td>PLUK</td>
<td>Average annual price of tin at London Metal Exchange in £ per tonne</td>
<td>ITC</td>
</tr>
<tr>
<td>QCx</td>
<td>Annual consumption of primary tin in area x (tonnes)</td>
<td>ITC</td>
</tr>
<tr>
<td>QSx</td>
<td>Annual mine production of tin-in-concentrates in area x (tonnes)</td>
<td>ITC</td>
</tr>
<tr>
<td>RPALx</td>
<td>Real price of aluminium per tonne in area x obtained by deflating</td>
<td>MS &amp; IMF</td>
</tr>
<tr>
<td>RPLUS</td>
<td>Real price of tin expressed in 1980 U.S. dollars per tonne</td>
<td>ITC &amp; IMF</td>
</tr>
<tr>
<td>WPIx</td>
<td>Wholesale price index in area x (1980 = 100.0)</td>
<td>IMF</td>
</tr>
</tbody>
</table>
Appendix 5. Model equations used for simulation

In this appendix, the equations used for the simulation model are listed. For ease of reference the original equation number is used. The equations are from chapter 4 and 5.

Production equations:

Malaysia:

\[(4.3.4.) \quad QSMA_t = 4103.2 + 0.83364 QSMA_{t-1} + 1.0513 RPLUS_{t-1} \]
\[\quad - 0.69546 DZMA*RPLUS_{t-1} - 21538 D58 - 4621.0 D59 \]
\[\quad + 10459 D60 - 6421.0 D82 - 10456 D83 - 5439.5 D85 \]
\[\quad \text{Adj. } R^2 = 0.9746 \quad \text{SEE} = 1838.1 \quad \text{D.W.} = 2.38 \]

Period: 1954-1985 \( N = 32 \) obs. Durbin's \( h = -1.10 \)

Bolivia:

\[(4.4.5) \quad \ln QSBO_t = 3.1754 + 0.5907 \ln QSBO_{t-1} + 0.1125 \ln RPLUS_{t-3} \]
\[\quad - 0.4335 D58 + 0.1835 D59 - 0.1878 D60 - 0.08784 TBOL \]
\[\quad \text{Adj } R^2 = 0.9147 \quad \text{SEE} = 0.05309 \quad \text{D.W.} = 2.28 \]

Period: 1955-1985 \( N = 31 \) obs. Durbin's \( h = -0.947 \)

Indonesia:

\[(4.5.5) \quad QSIN_t = 918.0 + 0.8978 QSIN_{t-1} + 0.2633 RPLUS_{t-1} - 0.3444 DZIN*RPLUS_{t-1} \]
\[\quad - 1888.8 D58 + 2146.4 D60 - 2643.9 D75 \]
\[\quad - 1925.3 D82 - 7879.9 D83 - 4508.6 D84 - 2840.5 D85 \]
\[\quad \text{Adj. } R^2 = 0.9419 \quad \text{SEE} = 1225.4 \quad \text{D.W.} = 2.12 \]

Period: 1954-1985 \( N = 32 \) obs. Durbin's \( \phi = -0.4500 \)
\[\quad (-2.79) \]
Thailand:

\[(4.6.3) \quad \text{QSTH}_t = 1349.9 + 0.3462 \text{QSTH}_{t-1} + 1.2330 \text{RPLUS}_{t-1} - 5028.5 \text{D58} - 9069.6 \text{D75} - 3118.1 \text{D83} - 4686.2 \text{D85} \]

\[\text{Adj. } R^2 = 0.9697 \quad \text{SEE} = 1045.0 \quad \text{D.W.} = 1.87 \]

Period: 1954-1985 N=32 obs. \( \phi = 0.76 \)

Australia:

\[(4.7.4) \quad \text{QSAU}_t = -291.5 + 0.9424 \text{QSAU}_{t-1} + 0.1451 \text{DZAU}^*\text{QSAU}_{t-1} + 0.0858 \text{RPLUS}_{t-1} - 1202.0 \text{D75} - 3152.7 \text{D83} - 1747.2 \text{D84} - 1782.8 \text{D85} \]

\[\text{Adj. } R^2 = 0.9825 \quad \text{SEE} = 454.4 \quad \text{D.W.} = 2.07 \]

Period: 1954-1985 N=32 obs. \( \phi = -0.37 \)

Zaire and Nigeria:

\[(4.8.3) \quad \text{QSZN}_t = -420.3 + 0.9749 \text{QSZN}_{t-1} + 0.1262 \text{RPLUS}_{t-1} - 0.1272 \text{DZZN}^*\text{RPLUS}_{t-1} - 6040.0 \text{D58} + 2219.1 \text{D60} - 2504.3 \text{DCWZ61} \]

\[\text{Adj. } R^2 = 0.9892 \quad \text{SEE} = 610.5 \quad \text{D.W.} = 1.93 \]

Period: 1954-1985 N=32 obs. Durbin's h = 0.19
Non-ITC except Brazil:

\((4.9.2)\) \(QSRW_t = 1115.8 + 0.71677 QSRW_{t-1} + 0.3262 RPLUS_{t-1} + 4688.8 DSMGL\)

\(\text{Adj. } R^2 = 0.9429 \quad \text{SEE} = 1605.4 \quad \text{D.W.} = 2.40\)

Period: 1954 - 1985 \(N = 32 \text{ obs} \quad \text{Durbin's } h = -1.365\)

Total non-ITC:

\((4.9.3)\) \(QSNC = QSRW + QSBR\)

Total production in the western world:

\((5.3.6)\) \(QSWW = QSMA + QSTH + QSIN + QSBO + QSAU + QSZN + QSNC\)

Aggregated consumption of western world:

\((5.2.12)\) \(QCWW_t = 31141.0 + 0.5746 QCWW_{t-1} - 2.9302 RPLUS_{t-1} + 24.819 RPALUS_{t-1} + 854.65 IIPWW - 1413.6 T - 16991 D5758 + 17659 D7376\)

\(\text{Adj. } R^2 = 0.9275 \quad \text{SEE} = 4915.7 \quad \text{D.W.} = 1.75\)

Period: 1954-1985 \(N = 32 \text{ obs} \quad \text{Durbin's } h = 0.496\)

Supply of stock:

\((5.3.5)\) \(STK_t - STK_{t-1} = QSWW_t - QCWW_t + NXCPE_t + NSGSA_t - NPITC_t\)
Price equations:

\[
RPLUS_t = 3136.8 + 0.5372 \, RPLUS_{t-1} - 1520.0 \, (STK/QCWW)_t + 62.25 \, T + 2166.5 \, DIND
\]

\[
\begin{align*}
\text{(5.4.4)} & \quad \text{Adj. } R^2 = 0.9610 & \quad \text{SEE} = 297.77 & \quad \text{D.W.} = 2.79 \\
\text{Period: 1955-1972} & \quad N = 18 \text{ obs.} & & \text{Durbin's } h = -1.79
\end{align*}
\]

\[
RPLUS_t = 2927.5 + 0.9727 \, RPLUS_{t-1} - 6017.5 \, (STK/QCWW)_t + 3239.7 \, D7477 - 3774.2 \, D75
\]

\[
\begin{align*}
\text{(5.4.6)} & \quad \text{Adj. } R^2 = 0.8557 & \quad \text{SEE} = 1089.3 & \quad \text{D.W.} = 1.59 \\
\text{Period: 1973-1985} & \quad N = 13 \text{ obs.} & & \text{Durbin's } h = 0.457
\end{align*}
\]
Bibliography


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