The World Tin Economy: An Econometric Analysis

June 1978

Prepared by: Jaibir Chhabra, Enzo Grilli and Peter Pollak
Commodities and Export Projections Division
Economic Analysis & Projections Department
Development Policy Staff

This paper is prepared for staff use.
Views expressed are those of the authors; not necessarily those of the World Bank.
ACKNOWLEDGMENTS

In the preparation of this paper we have received advice and help from too many people to be able to mention all of them individually. Yet we are particularly indebted to Mrs. H. Hughes, Mr. S. Singh, Mr. K. Takeuchi and Mrs. S. Augusto (IBRD), Prof. J. Waelbroeck (University of Brussels), Prof. J. Adams (University of Pennsylvania), Mr. W.H. Allen and Mr. P. Lai (International Tin Council), Mr. P. Legoux (Conseil Generale des Mines), Mr. G. Dybalski (GSA), Mr. K.L. Harris (US Bureau of Mines), and Mr. W.C. Lenaham (US State Department) for their comments and suggestions.

We are also grateful to Ms. R. Weaving for her editorial help and to Mrs. B. Thompson for her typing and proofreading assistance.

However, the views expressed in the paper are ours and so is the responsibility for any omissions and remaining errors.
# TABLE OF CONTENTS

SUMMARY AND CONCLUSIONS ........................................ iv - v

I. THE BASIC STRUCTURE OF THE WORLD TIN ECONOMY ............. 1
   A. Production .................................................. 1
   B. Consumption ................................................ 1
   C. Trade ....................................................... 4

II. EVOLUTION OF THE WORLD TIN ECONOMY IN THE POST WORLD WAR II PERIOD: A BRIEF HISTORICAL REVIEW ............. 5

III. THE INTERNATIONAL TIN AGREEMENTS ........................... 6

IV. THE MODEL STRUCTURE ......................................... 9
   A. Overview of the Model ..................................... 9
   B. Supply ....................................................... 10
   C. Demand ..................................................... 16
   D. Prices and Inventories .................................... 23

V. VALIDATION OF THE MODEL; HISTORICAL POLICY SIMULATIONS AND PROJECTIONS ........................................... 27
   A. Ex Post Simulations of the Model .......................... 27
   B. Historical Policy Simulations: Price Stabilization for Tin ..................................................... 29

ANNEX I: Additional Equations used in the Ex Post Simulations of the Model

ANNEX II: Market Prospects for Tin
TEXT TABLES

1. World Production of Tin-in-Concentrates and Metal: 1972-74 (Average) ............................................... 2
2. World Consumption of Tin Metal: 1972-74 (Average)............... 3
3. World Consumption of Tin in 1974-76 by Major End Uses in Selected Countries.............................................. 4
4. Tin Supply Elasticities...................................................... 16
5. Tin Demand Elasticities...................................................... 23
6. Summary Results of Historical Simulations (Model Version I).... 27
7. Summary Results of Historical Simulations (Model Version II).... 31

CHARTS

2. Flow Chart of the World Tin Economy........................................ 10
4. Historical Simulations of Tin Model (Version II): 1966-75...... 30
SUMMARY AND CONCLUSIONS

i. Six developing countries—Malaysia, Bolivia, Indonesia, Thailand, Nigeria and Zaire—produce about 70 percent of world tin output. The remaining 30 percent is produced in a large number of developing countries and a few developed countries (Australia, the United Kingdom and South Africa).

ii. Consumption of tin is concentrated in developed countries. As a group, they absorb about 75 percent of world tin supplies; centrally planned economies account for about 20 percent, and the remainder is consumed in developing countries. The United States is the single most important tin consuming country with a share of about 25 percent of total world consumption, followed by Japan with 15 percent, and Germany and the United Kingdom each with about 6 percent.

iii. Slightly less than one half of tin output is processed into tinplate, which is the basic material for food and beverage containers. The use of aluminum and tin-free steel in the manufacture of cans and other containers has weakened the demand for tin in this end-use. In other end-uses, tin consumption has increased slowly or declined since World War II. There are two main reasons for the sluggish growth in tin consumption. First, the prices of many substitute products (aluminum, steel, glass etc.) have declined relative to the price of tin, and these materials have replaced tin in many of its traditional end-uses; second, technological innovations in the manufacture of tinplate have made it possible to thin the coating of tin applied to steel sheets, thus reducing the quantity of tin in manufacture of tinplate.

iv. Wide fluctuations in tin prices are caused largely by differences in the lag structure of tin consumption and tin mining. While tin consumption usually responds quickly to changes in income or economic activity, adjustments of mine output are costly and time-consuming. To stabilize the highly volatile tin market, major tin producing and consuming countries ratified the First International Tin Agreement in 1956. This agreement, which has been renewed four times since then, is generally regarded as the most successful example of an international commodity agreement. Its basic feature, the use of bufferstocks and export controls to keep prices within agreed limits, has become a model for similar commodity agreements.

v. Most of the behavior of the world tin economy is captured in the econometric model presented here, which consists of 23 behavioral equations. The model incorporates the two major institutional factors that influence the tin economy—the strategic tin stockpile in the United States and the International Tin Agreement. Eight supply equations describe tin production in major producing countries. The weighted average short-term price elasticity of supply was estimated at 0.42, the corresponding long-term elasticity at 1.07. Tin demand was analyzed on a regional basis (United States, Western Europe, Japan, South Africa, other developed
countries) as well as by end-use categories. Tin used in the manufacture of tinplate is treated separately from tin used for other end-uses. The estimated short-term price elasticities of demand varied between -0.1 and -0.5, supporting the argument that the demand for tin is highly price-inelastic in the short term.

vi. The simulation results of the model show that it is possible to capture most of the behavior of the world tin economy with a small model. To examine the impact of price stabilization on the tin economy, a bufferstock mechanism was incorporated into the tin model. The results of the bufferstock simulations provide some insight into the size of bufferstock—in terms of tin stocks and financial resources—necessary to stabilize prices within price bands of varying size, and also suggest the impact of price stabilization on export revenue stability and the size of export revenue. Price stabilization under rigid rules concerning the price band adjustment would bring about greater revenue stability, but at the cost of smaller total export revenues. The latter conclusions point to a serious policy dilemma concerning the trade-off between size and stability of export revenue.

vii. The tin model was also used to gain some insight into the likely prospects for the world tin economy. The projections show that the cyclical behavior of tin prices is likely to continue in the future. Different stockpile sale policies can alter the adjustment path of tin prices, but it seems unlikely that they will significantly affect their long-term growth trend. The model projections indicate that tin producers can look forward to a period of slow but steady growth in import demand and to a continued rise of tin prices (in real terms) along their long-run trend.
I. THE BASIC STRUCTURE OF THE WORLD TIN ECONOMY

A. Production

1. Tin is a typical primary product. Almost all the tin metal consumed outside the centrally planned economies originates in developing countries. Six of them—Malaysia, Bolivia, Indonesia, Thailand, Nigeria and Zaire—account for about 70 percent of world production of tin-in-concentrates. 1/ About 20 other small producers account for an additional 6 percent of world production. Only three developed countries—Australia, the United Kingdom and South Africa—contribute significantly to the supply of tin; they account jointly for 8 percent of world output of tin-in-concentrates. Little has been published about tin production in centrally planned economies, which account for about 16 percent of world production of tin-in-concentrates (Table 1).

2. Tin is mined by a variety of methods (dredging, gravel pumping, hydraulicing, opencast mining, deep lode mining and dulang washing). Different production methods prevail in different countries, according to the structure of the industry. Over 35 percent of the tin ore produced outside the centrally planned economies comes from gravel pump units that are often owned and operated by small producers. Gravel pump mining by small producers is predominant in both Malaysia and Thailand, where it accounts for over 50 percent of output. It is also important in Indonesia where it accounts for about 40 percent of total output. Dredges produce most of the remainder of tin ore in all these three countries. Dredging is a highly capital-intensive operation carried out by large (national or foreign) companies. Only in Bolivia—among the large producers of tin-in-concentrates—are large tin mines (mainly deep lode mines) predominant.

3. The main producing countries have domestic smelting capacity. Bolivia, Indonesia, Zaire and Australia, however, ship part of their mine output to foreign smelters for processing. Among these countries, Bolivia and Zaire depend most heavily on foreign smelting. The United Kingdom and Malaysia are the two leading tin-smelting countries (Table 1). 2/

B. Consumption

4. Developed countries consume about 75 percent of world tin production; centrally planned economies account for about 20 percent, and the remainder is consumed in developing countries.

1/ "Tin-in-concentrates" means tin content of tin concentrates established by chemical analysis. Production of tin-in-concentrates expresses, therefore, the metal content of tin ore.

2/ Bolivia is expanding her smelting capacity and is expected to become sufficient by the end of the current decade.

3/ Unless otherwise specified, only primary tin is considered in this paper.
Table 1: WORLD PRODUCTION OF TIN-IN-CONCENTRATES AND METAL: 1972-74 (AVERAGE)

<table>
<thead>
<tr>
<th></th>
<th>Tin-in-Concentrates ('000 m.t.)</th>
<th>World Total (percent)</th>
<th>Metal ('000 m.t.)</th>
<th>World Total (percent)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A. Developing Countries</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Malaysia</td>
<td>72.4</td>
<td>32.0</td>
<td>85.9</td>
<td>38.9</td>
</tr>
<tr>
<td>Bolivia</td>
<td>30.0</td>
<td>13.2</td>
<td>6.8</td>
<td>3.1</td>
</tr>
<tr>
<td>Thailand</td>
<td>21.1</td>
<td>9.3</td>
<td>21.6</td>
<td>9.8</td>
</tr>
<tr>
<td>Indonesia</td>
<td>23.3</td>
<td>10.3</td>
<td>13.9</td>
<td>6.3</td>
</tr>
<tr>
<td>Nigeria</td>
<td>6.0</td>
<td>2.6</td>
<td>0.6</td>
<td>0.3</td>
</tr>
<tr>
<td>Zaire</td>
<td>5.4</td>
<td>2.4</td>
<td>1.0</td>
<td>0.5</td>
</tr>
<tr>
<td>Others</td>
<td>13.3</td>
<td>5.9</td>
<td>11.6</td>
<td>5.2</td>
</tr>
<tr>
<td>Total:</td>
<td>171.5</td>
<td>75.7</td>
<td>141.4</td>
<td>64.1</td>
</tr>
<tr>
<td>B. Developed Countries</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Australia</td>
<td>11.0</td>
<td>4.9</td>
<td>6.9</td>
<td>3.1</td>
</tr>
<tr>
<td>South Africa</td>
<td>2.4</td>
<td>1.0</td>
<td>1.8</td>
<td>0.8</td>
</tr>
<tr>
<td>United Kingdom</td>
<td>3.4</td>
<td>1.5</td>
<td>17.9</td>
<td>8.1</td>
</tr>
<tr>
<td>Others</td>
<td>2.8</td>
<td>1.2</td>
<td>15.7</td>
<td>7.1</td>
</tr>
<tr>
<td>Total:</td>
<td>19.6</td>
<td>8.6</td>
<td>42.3</td>
<td>19.1</td>
</tr>
<tr>
<td>C. Centrally Planned Economies</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>USSR</td>
<td>12.0</td>
<td>5.3</td>
<td>14.0</td>
<td>6.3</td>
</tr>
<tr>
<td>China</td>
<td>22.0</td>
<td>9.7</td>
<td>22.0</td>
<td>10.0</td>
</tr>
<tr>
<td>Others</td>
<td>1.5</td>
<td>0.7</td>
<td>1.2</td>
<td>0.5</td>
</tr>
<tr>
<td>Total:</td>
<td>35.5</td>
<td>15.7</td>
<td>37.2</td>
<td>16.8</td>
</tr>
<tr>
<td>D. World Total</td>
<td>226.6</td>
<td>100.0</td>
<td>220.9</td>
<td>100.0</td>
</tr>
</tbody>
</table>


4. The United States is the single most important tin consuming country with a share of about 25 percent of total world consumption, followed by Japan with 15 percent, the Federal Republic of Germany and the United Kingdom, each with about 6 percent. Consumption of tin in the USSR and China is difficult to gauge precisely and can only be inferred from production and net trade estimates. Excluding the centrally planned economies, the following geographical distribution of world tin consumption emerges (Table 2).
Table 2: WORLD CONSUMPTION OF TIN METAL: 1972-74 (AVERAGE) /a

<table>
<thead>
<tr>
<th>Metal</th>
<th>World Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>('000 m.t.)</td>
<td>(percent)</td>
</tr>
</tbody>
</table>

A. Developed Countries

<table>
<thead>
<tr>
<th></th>
<th>Metal</th>
<th>World Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>North America</td>
<td>60.6</td>
<td>32.5</td>
</tr>
<tr>
<td>EEC</td>
<td>58.9</td>
<td>31.6</td>
</tr>
<tr>
<td>Japan</td>
<td>34.9</td>
<td>18.7</td>
</tr>
<tr>
<td>Oceania</td>
<td>4.4</td>
<td>2.4</td>
</tr>
<tr>
<td>Other Developed</td>
<td>11.3</td>
<td>6.1</td>
</tr>
<tr>
<td><strong>Total:</strong></td>
<td>170.1</td>
<td>91.3</td>
</tr>
</tbody>
</table>

B. Developing Countries

<table>
<thead>
<tr>
<th></th>
<th>Metal</th>
<th>World Total</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Total:</strong></td>
<td>16.2</td>
<td>8.7</td>
</tr>
</tbody>
</table>

C. World Total

<table>
<thead>
<tr>
<th></th>
<th>Metal</th>
<th>World Total</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Total:</strong></td>
<td>186.3</td>
<td>100.0</td>
</tr>
</tbody>
</table>

/a Excluding the Centrally Planned Economies.


5. About 95 percent of all tin is consumed in metallic form. The remainder is processed into various industrial chemicals. Its physical properties—low melting point, alloying and chemical compound-forming characteristics, resistance to corrosion, non-toxicity and good appearance—give tin an important position in modern industrial technology. Its main end-uses are tinplate, solders, bronze, whitemetal, chemicals and tinning. Tinplate and coating account for about one-half of all industrial uses (Table 3). Solder is the most important tin alloy, and it accounts for about 24 percent of tin consumption.

6. Tinplate is used mainly in food and beverage containers. Solders are used in a wide variety of products ranging from traditional plumbing to sophisticated mass-soldering for printed circuits. The heavy machinery and equipment industry is the main market for bronzes and bearing alloys (white-metals). The chemical industry uses tin in numerous compounds and in such diverse applications as wood preservatives, ceramics, toothpaste and pesticides. Pure tin is used in the form of foil by the electrical industry.
Table 3: CONSUMPTION OF TIN IN 1974-76
BY MAJOR END USES IN SELECTED COUNTRIES /a

<table>
<thead>
<tr>
<th>End-Use</th>
<th>Percent of Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tinplate</td>
<td>42</td>
</tr>
<tr>
<td>Solders</td>
<td>24</td>
</tr>
<tr>
<td>Bronze and Brass</td>
<td>7</td>
</tr>
<tr>
<td>Whitemetal and Babbit</td>
<td>9</td>
</tr>
<tr>
<td>Chemicals</td>
<td>6</td>
</tr>
<tr>
<td>Tinning</td>
<td>4</td>
</tr>
<tr>
<td>Others</td>
<td>8</td>
</tr>
</tbody>
</table>

/a Includes US, France, Germany, Italy, UK, Japan, Australia, Austria, Switzerland, Brazil and India.


7. Because of its many uses, tin faces competition from a variety of products, but aluminum remains the single most important substitute. Aluminum and tin-free steel are increasingly replacing tinplate in cans. Other substitutes for tinplate include glass, paper and plastics. Although satisfactory substitutes for tin in solders have not yet been found, aluminum alloys and other copper-based alloys and plastics can be substituted for bronze. Low-tin aluminum, copper and lead-base bearing alloys may also be used instead of whitemetals. 1/

C. Trade

8. Developing producing countries dominate the tin trade; they account for 92 percent of total world exports of tin-in-concentrates, 2/ and for almost 80 percent of world exports of tin metal. The importance of the trade in tin-in-concentrates has decreased drastically over the last 20 years as developing producing countries have expanded their smelting capacity.


2/ Exports of tin-in-concentrates largely reflect the imbalance between production and smelting capacity in the main producing countries.
9. Developed countries absorb about 85 percent of world tin metal imports, centrally planned economies about 10 percent and developing countries the remaining 5 percent. As a group the centrally planned economies are largely self-sufficient in tin, and their trade in tin is mostly intra-trade. 1/ However, the USSR and China have on occasions exported significant amounts of metal to developed countries. 2/

II. THE EVOLUTION OF THE WORLD TIN ECONOMY
IN THE POST WORLD WAR II PERIOD: A BRIEF REVIEW

10. World tin consumption in the post-war period has grown more slowly than that of other metals: at 1.7 percent per annum from 1955-74, compared to 4.8 percent per annum for copper, 8.3 percent per annum for aluminum and 4.6 percent per annum for zinc. The main reason for this slow growth was the increasing substitution of tin-free steel and aluminum for tinplate in can manufacturing. In addition, technical innovations have reduced the quantity of tin needed in tinplate. 3/ The use of tin in bronze and brass declined sharply during the post-war period, and the demand for solder expanded only slowly. The only significant growth in the demand for tin occurred in specialized industrial uses, particularly in chemical production, but considering the chemical industry's small share in the demand for tin, this had only a slight impact on the overall growth of tin consumption. During the post-war period demand for tin in developed countries grew steadily at 1.3 percent per annum, and at slightly higher rates in developing countries and centrally planned economies.

11. Unlike consumption, world tin production has fluctuated widely. The recovery of the tin industry after World War II lasted until the early 1950s and from 1953 to 1957 mine production virtually stagnated. World output of tin-in-concentrates fell drastically in 1958 and 1959 and then recovered again in 1960, remaining at that level until 1963. In 1964, production began to expand again, and the expansion lasted until 1968. Since then world mine production of tin has remained at a level of about 180,000 metric tons a year, except for a mild peak in 1972 and a small trough in 1975. Production of tin metal followed roughly the same path.

12. In the two decades after World War II, the tin economy experienced a series of shocks that severely affected the normal interaction between demand and supply. The first of these originated from the accumulation of strategic stocks in consuming countries—particularly the United States—which had

1/ Only the Eastern European countries rely on imports from outside the CPEs for a substantial amount of their tin requirements.

2/ For example, between 1957-60 and 1974-75.

3/ The introduction of electrolytic tinplating in the mid-1950s has led to a progressive reduction of the amount of tin needed to coat steel sheets.
begun in 1948 and was greatly accelerated by the outbreak of the Korean War. When in 1955 the United States discontinued purchases for its tin stockpile, a large over-supply situation began to develop which had to be corrected through stringent production control measures and through stockpiling in producing countries. While tin producers were trying to bring mine production into line with world consumption levels, a second shock occurred: the USSR began to sell large quantities of tin in the world market in 1957 and continued to do so until 1960-61. To prevent a further weakening of the market tin producers cut back mine production sharply. As a result, mine production lagged behind current consumption when the USSR stopped its sales of tin in the early 1960s. The United States alleviated the ensuing shortage of tin through sales from its stockpile. It was not until the late 1960s that the balance between world tin production and consumption was restored.

13. These outside disturbances greatly complicated the normally difficult demand/supply adjustment that characterizes metals markets. In general, the demand for metals responds quickly to changes in economic activity in industrialized countries. However, changes in mining output are costly and time consuming. The highly inelastic supply of metals leads to substantial price fluctuations whenever changes in demand occur. The delayed supply and demand reactions to price changes that normally follow prolong and complicate the adjustment process.

14. The failure of mine production of tin to adjust quickly to changes in market demand was the main determinant of the relatively large price fluctuations that characterized the post-World War II period despite the stabilizing action of the International Tin Agreement (ITA) that became effective in 1956 and was subsequently renewed in 1961, 1966, 1971 and 1976.

III. THE INTERNATIONAL TIN AGREEMENTS

15. The main purpose of all five International Tin Agreements has been the stabilization of tin prices in international markets. To achieve this purpose, two complementary types of action were envisaged: direct market intervention through bufferstock purchases and sales, and export supply controls through quotas. An international body—the International Tin Council (ITC)—consisting of both producers and consumers of tin was set up to administer the agreements. The ITC determined floor and ceiling prices between which tin prices were left to fluctuate freely; it tried to maintain market prices within these limits by buying for and selling from its bufferstock and by imposing export controls on member countries when its financial resources

1/ These control measures were implemented in the framework of the First International Tin Agreement.
were insufficient to maintain the agreed floor prices. The bufferstock began to function in 1957 and remained operative under all the five agreements. 1/

16. Floor and ceiling prices were revised regularly and the revisions reflected trends in market prices. Because of the small size of the tin bufferstock—25,000 metric tons equivalent under the first ITA and 20,000 metric tons under the following three agreements 2/—the ITC was better able to defend floor prices with the additional help of export controls at times of low demand, than to defend the ceiling price at times of high demand. The ITC imposed export restrictions during the periods 1958-60, 1968-69, in 1973 and again in 1975-76. While market prices fell below the ITC floor only briefly in 1958, they broke through the ceiling in 1961, 1964-65, 1966, 1973-74 and 1976 (Chart 1). Although the United States was not a member of the first four Tin Agreements (ITA), 3/ sales from the US strategic stockpile were to a considerable extent used by the US Government to cut market price peaks 4/ when market prices exceeded the ITC ceiling (1964-66 and 1973-74).


2/ The Fifth ITA which entered into force on July 1, 1976, envisages a bufferstock of 40,000 metric tons of tin. However, while producers are under binding obligation to contribute the equivalent of 20,000 metric tons of tin to the bufferstock, consumers have not assumed a formal obligation to contribute the other half. Several consuming countries have announced their willingness to make voluntary contributions, but unless the United States decides to contribute to the bufferstock, it is doubtful whether total consumers' contributions will approach 20,000 metric tons.

3/ The United States has become a member of the Fifth ITA.

IV. THE MODEL STRUCTURE

A. Overview of the Model

17. The tin model developed here is a disaggregated supply/demand model with a market clearing equation for prices. All the 23 behavioral equations were estimated using ordinary least squares' regressions on annual data. The period covered is usually 1955-75. The inclusion of the years 1973-75 is particularly important, since most of the previous models were estimated before the changes in production and consumption conditions that took place in the aftermath of the oil crisis and in the subsequent period of recession-cum-inflation in the world economy. The model is described in Chart 2.

18. The form of model used here captures the competitive nature of the tin market. The two major institutional constraints—the US strategic stockpile and the International Tin Agreements—were built into the model. Purchases and sales by the US stockpile and ITC were entered directly into the stream of tin becoming available in any given year to commercial users (purchases were subtracted from "world availability" of tin and sales were added to it). Dummy variables were used in the estimation of supply equations to account for export controls imposed by ITC.

19. The model covers production and consumption in developed and developing countries. Lack of reliable data made it impossible to estimate supply and demand equations for centrally planned economies, although since these economies are largely self-sufficient in tin, they have only a slight impact on international tin market conditions. Nevertheless, to account for the possible effects on tin prices of abnormal trade years (e.g. 1957-60 and 1974-75) annual exports from the "rest of the world" to CPEs were subtracted from the "world availability" of tin, and annual exports from CPEs to the rest of the world were added to it.

1/ In devising the model structure an attempt was made to build upon and improve existing tin models, such as the Desai, the Wharton/GSA model as well as mini-models built by the World Bank and UNCTAD. For a detailed description of these models see: M. Desai, "An Econometric Model of the World Tin Economy", Econometrica, Vol. 34, No. 1 (January 1966), pp. 105-134 and Wharton Econometric Forecasting Associates, Inc., "Forecasts and Analysis of the Tin Market", Report submitted to the US General Services Administration, September 1974; F. Pinto "Tin Model", in: The Simlink Model of Trade and Growth for the Developing World, IBRD Staff Working Paper No. 220, October 1975, Appendix 11-17; and E. Grilli, "A Revised Tin Model", A System of Linked Models For Commodity Market Analysis, IBRD Report, March 1976, pp. 31-34; B. Shaw, "Tin Model (mimeo), 1975.
B. Supply

20. The diversity in production methods, industry structure and degree of government controls that exists in the various producing countries makes any general hypothesis about the behavior of tin producers highly tentative. The estimated supply equations rest on the following two major assumptions. First, it was assumed that tin producers adjust their output in response to changes in market prices and mining costs. The prices used were international market prices of tin, such as those quoted at the London Metals Exchange. These prices were deflated by an index of mining costs which considers the costs of fuel, machinery, equipment and labor. The weights of these cost components differ from country to country reflecting the different relative shares of fuel, capital equipment and labor in total costs. ITC cost surveys for 1973-75 were used to develop the production cost weights for individual producing countries. Since the structure of tin mining costs depends largely on the method of mining (dredging, gravel pumping, open cast mining, etc), weights were first derived for the various production modes and then averaged on the basis of the relative importance of the various types of tin production in each country. The prices were included with appropriate lags in the estimated supply equations. The results indicate an average time lag of two to three years in the response of supply to price changes.

21. It was further assumed that tin producers adjust their production to meet the global export goals set by the ITC whenever necessary. In addition to prices, costs and production targets, a host of other factors (a country's labor situation, government policies, the availability of credit, taxation, etc) influence tin supply. The impact of these factors could not be taken into account in the formulation of the supply models mostly because of lack of consistent information.

22. The supply of secondary tin was not included in the model, since many countries do not publish data on their production of secondary tin. For countries for which such data could be obtained, (e.g. the United States), they indicate little variation in total supply. Secondary tin production in the United States failed even to respond to the high tin prices of 1973 and 1974. An explanation for this apparent lack of price responsiveness can probably be found in the increase in recovery costs that took place over the same period. Attempts to capture the price response of US supply of secondary tin statistically were largely unsatisfactory.

23. Individual supply equations for tin-in-concentrates were estimated for Malaysia, Indonesia, Thailand, Bolivia, Nigeria and Zaire (which together account for about 83 percent of world production outside the CPEs), the developed countries as a group (which account for another 10 percent of the world total) and the "rest of the world" (which accounts for the remaining 7 percent of world production). The estimated supply equations are described below. The estimated supply elasticities are compared at the end of this section. The values in parentheses below the estimated coefficients are t-values.
Malaysia: 1955-75

\[(1.1) \quad STCMAL_t = 10.09817 + 0.54656 STCMAL_{t-1} \]
\[\quad + 0.00643 \left( \frac{PTLME}{MLCOST} \right)_{t-1} - 8.54375 DMYXC_t \]
\[\quad R^2 = 0.88 \quad S.E.E. = 4.21 \quad D.W. = 1.65 \]

where:
- \(STCMAL\) = Production of tin-in-concentrates in Malaysia ('000 mt)
- \(PTLME\) = LME tin price (US$/mt)
- \(MLCOST\) = Index of tin mining cost in Malaysia (1970=100)
- \(DMYXC\) = Dummy variable for ITC export control periods (set to 1 for 1958, 1959, 1969, 1973, 1975 and to 0 for all other years)

Indonesia: 1948-75

\[(1.2) \quad STCIND_t = 6.40869 + 0.77249 STCIND_{t-1} + 0.00154 \left( \frac{PTLME}{INCOST} \right)_{t-3} \]
\[\quad - 1.65520 DMYXC_t - 1.01641 TIME_t + 0.03345 TIME^2_t \]
\[\quad R^2 = 0.94 \quad S.E.E. = 1.97 \quad D.W. = 2.51 \]

where:
- \(STCIND\) = Production of tin-in-concentrates in Indonesia ('000 mt)
- \(PTLME\) = LME tin price (US$/mt)
- \(INCOST\) = Index of mining costs in Indonesia (1970=100)
- \(TIME\) = Time trend (1948=1)

Thailand: 1955-75

\[(1.3) \quad STCTHA_t = -2.138233 + 0.488082 STCTHA_{t-1} \]
\[\quad + 0.003681 \left( \frac{PTLME}{TLCOST} \right)_{t-1} - 1.46190 DMYXC_t \]
\[\quad R^2 = 0.90 \quad S.E.E. = 1.28 \quad D.W. = 1.65 \]
where:

STCTHA = Production of tin-in-concentrates in Thailand ('000 mt)
PTLME = LME Tin Price (US$/mt)
TLCOST = Index of tin mining costs in Thailand (1970=100)

**Bolivia: 1955-75**

\[
(1.4) \ln \text{STCBOL}_t = 0.2195 + 0.2915 \ln \text{STCBOL}_{t-1} + 0.2395 \ln \left[ \frac{\text{PTLME}_{t-3}}{\text{BOCOST}_{t-3}} \right] + 0.01186 \text{TIME}_t \\
R^2 = 0.88 \quad \text{S.E.E.} = 0.06 \quad \text{D.W.} = 1.94
\]

where:

STCBOL = Production of tin-in-concentrates in Bolivia ('000 mt)
PTLME = LME Tin Price (US$/mt)
BOCOST = Index of tin mining costs in Bolivia (1970=100)
TIME = Time trend (1955=1)

**Nigeria 1/: 1955-75**

\[
(1.5) \ln \text{STCNIG}_t = 0.15404 + 0.92165 \ln \text{STCNIG}_{t-1} - 0.45046 \text{DMYXC}_t \\
R^2 = 0.87 \quad \text{S.E.E.} = 0.17 \quad \text{D.W.} = 1.27
\]

1/ An alternative production equation for Nigeria was estimated using a priori information about supply elasticities with respect to price. The following results were obtained:

\[
(1.5.1) \text{STCNIG}_t = -0.04702 + 0.75320 \text{STCNIG}_{t-1} + 0.000084 \left[ \frac{\text{PTLME}_{t-1}}{\text{AFCOST}} \right] - 2.03240 \text{DMYXC}_t \\
R^2 = 0.68 \quad \text{S.E.E.} = 1.07 \quad \text{D.W.} = 1.09
\]

where

AFCOST = Index of tin mining costs in Africa

The definition of the other variables is identical to that given in equation (1.5) and (1.6).
where:

\( STCNIG_t = \) Production of tin-in-concentrates in Nigeria ('000 mt)

\( Zaire \quad 1/ \): 1955-75

\( \ln STCZAI_t = 0.26437 + 0.85167 \ln STCZAI_{t-1} - 0.09493 \text{DMYXC}_t \)  

\( R^2 = 0.74 \quad \text{S.E.E.} = 0.15 \quad \text{D.W.} = 2.66 \)

where:

\( STCZAI = \) Production of tin-in-concentrates in Zaire ('000 mt)

Developed Countries: 1955-75

\( \ln STCDC_t = -1.6334 + 0.5738 \ln STCDC_{t-1} + 0.3044 \ln \left[ \frac{PTLME}{IPI} \right]_{t-3} + 0.0203 \text{TIME}_t \)  

\( R^2 = 0.97 \quad \text{S.E.E.} = 0.07 \quad \text{D.W.} = 2.11 \)

\( STCDC = \) Production of tin-in-concentrates in developed countries ('000 mt)

\( PTLME = \) LME Tin Price (US$/mt)

\( IPI = \) World Bank index of international inflation (1970=100)

\( \text{TIME} = \) Time trend (1955=1)

1/ An alternative production equation for Zaire estimated using **a priori** information about supply elasticities with respect to price. The following results were obtained:

\( STCZAI_t = -2.33459 + 0.96882 \ln \left[ \frac{PTLME}{IPI} \right]_{t-1} + 0.000858 \text{AFCOST}_j - 0.97657 \text{DMYXC}_t \)  

\( R^2 = 0.82 \quad \text{S.E.E.} = 1.39 \quad \text{D.W.} = 2.53 \)

The definition of the variables is identical to that given in equations (1.5) and (1.6)
"Rest of the World": 1955-75

(1.8) \[ \text{STCROW}_t = 3.33536 + 0.46836 \text{STCROW}_{t-1} + 0.00215 \left( \frac{\text{PTLME}}{\text{IPI}} \right)_{t-1} + \text{R}^2 = 0.82 \]

\( \text{S.E.E.} = 1.11 \)

\( \text{D.W.} = 1.66 \)

where:

\( \text{STCROW} = \) Production of tin-in-concentrates in the rest of the world ('000 mt)

\( \text{PTLME} = \) LME Tin Price (US$/mt)

\( \text{IPI} = \) World Bank index of international inflation (1970=100)

**World Production**

24. The following equation (1.9) summarizes the variables which were used in the model to compute world production of tin. Supplies generated by the equations for the eight tin producing countries and regions described above enter the world supply equation as endogenous variables. Transactions by the ITC bufferstock and the US strategic stockpile for tin as well as imports from centrally planned economies enter the equation exogenously, i.e. the values of these variables are not generated by the model. These variables transform world production of tin-in-concentrates into world availability.

(1.9) \[ \text{TCWAV}_t = \text{STCMAL}_t + \text{STCIND}_t + \text{STCTHA}_t + \text{STCBOL}_t + \text{STCNIG}_t + \text{STCZAI}_t + \text{STCDC}_t + \text{STCROW}_t + \text{GSPSAL}_t + \text{ITCSAL}_t + \text{MFCPE}_t \]

where:

\( \text{TCWAV} = \) World availabilities of tin-in-concentrates ('000 mt)

\( \text{GSPSAL} = \) Government stockpile sales ('000 mt)

\( \text{ITCSAL} = \) ITC bufferstock sales ('000 mt)

\( \text{MFCPE} = \) Imports from CPEs ('000 mt)

**Supply Elasticities**

Table 4 below summarizes the results of the supply analysis in terms of price elasticities and adjustment coefficients.

\[ 1/ \text{ This variable includes the tin-in-concentrates from "unspecified origin": 1,500 mt in 1974, 5,900 mt in 1975 and 5,200 mt in 1976. The figure for 1976 was entered in the forecast runs of the model.} \]
Table 4: TIN SUPPLY ELASTICITIES

<table>
<thead>
<tr>
<th>Country or Area</th>
<th>Coefficient of Adjustment</th>
<th>Price Elasticity of Supply</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Short-Term /a</td>
</tr>
<tr>
<td>Malaysia</td>
<td>0.45</td>
<td>0.31*</td>
</tr>
<tr>
<td>Indonesia</td>
<td>0.23</td>
<td>0.21</td>
</tr>
<tr>
<td>Thailand</td>
<td>0.48</td>
<td>0.60*</td>
</tr>
<tr>
<td>Bolivia</td>
<td>0.71</td>
<td>0.24*</td>
</tr>
<tr>
<td>Developed Countries</td>
<td>0.43</td>
<td>0.30*</td>
</tr>
<tr>
<td>Rest of the World</td>
<td>0.53</td>
<td>1.11*</td>
</tr>
</tbody>
</table>

* Significant at the 95 percent confidence level.

/a The elasticities were estimated at the means of production and prices using the results of linear statistical models.

25. The estimated supply equations show that all producers (with the exception of Zaire and Nigeria) adjusted their production when real prices of tin changed. All the estimated short- and long-term supply elasticities (except for Indonesia) are significant at the 95 percent confidence level or above. The lag with which supply reacts to real price changes varies among producers: Malaysia, Thailand and the small producers (lumped together in "Rest of the World") respond to price changes with a one-year lag; Bolivia, Indonesia and the developed producers with a three-year lag. Short-term price elasticities of supply range from 0.2 for Indonesia to 1.1 for the small producers; the weighted average—that closely approximates the world supply elasticity—is 0.42. Long-term price elasticities range from 0.7 to 2.09. The weighted average is 1.07.

C. Demand

26. Tin is consumed in a variety of end-uses of which tinplate is by far the most important. Demand for tin in this end-use is determined by the production of tinplate, tin prices, prices of complements and substitutes (e.g. hot rolled steel strips, which are the major components of tinplate, and aluminum which is the most important substitute for tinplate) and tech-
nological factors (such as the evolution of electrolytic tinplating). Production of tinplate, in turn, is determined by the production of food and beverages, the price of tin cans in relation to those made of aluminum and plastic, and technical factors affecting the mode of containerization of food and beverages.

27. The large number and great variety of uses for tin, other than the production of tinplate, make it difficult to capture the economic forces which determine the demand for tin in these end-uses in econometric relationships. Industrial production emerged as the strongest explanatory variable. The price of tin was another variable which was statistically significant in almost all of the estimated demand equations for non-tinplate end-uses.

28. As in production, it was assumed that consumer response to changes in tin prices will extend over several periods. Various institutional and technological rigidities prevent an immediate adjustment of the demand for tin to changes in both prices and demand for final products. Institutional rigidities have to do with the market structure of the final products, while technical constraints stem from the fact that production processes are difficult to change in the short term. The tin demand equations incorporate this dynamic adjustment process.

29. The demand equations include tin prices, prices of complements and substitutes and variables indicating economic activity. The activity variables used were generally indexes of industrial production. Tin prices were generally LME prices expressed in US dollars or local currency and deflated by wholesale price indexes. Prices of complements and substitutes (e.g. hot rolled steel sheets and aluminum) were similarly expressed. Where appropriate, variables that represent the effects of technical changes on tin demand were also included. To capture the effects of technical substitution for tin, variables such as the percentage share of electrolytic tinplate in total tinplate production and the percentage share of tin cans in total production of cans were included in the demand equations.

30. Tin demand was analyzed on a regional basis (United States, Western Europe, Japan, South Africa, other developed countries and developing countries) as well as on an end-use basis (tin in tinplate uses and tin in non-tinplate uses). Disaggregated end-use demand equations were estimated for the United States, Western Europe and Japan which together account for about 80 percent of world tin consumption outside the CPEs. Tinplate production—which is the main explanatory variable for consumption of tin in tinplate—was also modeled for the United States, Western Europe and Japan.1/ The estimated demand equations for major consuming countries and tin end-uses are described below.

1/ See Annex I.
United States

(a) Tinplate Uses: 1953-75

\[ DTNUS_t = 59.80189 + 0.00357 \ STPUS_t - 10.56827 \ ETPRAT_t \\
- 0.00211 \left( \frac{PTNY}{WPIUSI} \right)_t - 5.66929 \left( \frac{PSTEEL}{WPIUSI} \right)_{t-1} - 2.35658 \ DMYUSI_t \]

\[ R^2 = 0.92 \quad S.E.E. = 1.46 \quad D.W. = 1.37 \]

where:

DTNUS = Consumption of primary tin in tinplate uses in the United States ('000 mt)

STPUS = Production of tinplate in the United States ('000 mt)

ETPRAT = Ratio of electrolytic to total tinplate production in the United States

PTNY = Price of tin in New York (US$/mt)

WPIUSI = US wholesale price index (1967=100)

PSTEEL = Price of hot rolled steel strips (US$/mt) in the United States

DMYUSI = Dummy variable for strikes in the fabricated metals' industry, (set to 1 for 1959 and 1969 and to 0 for all other years)

(b) Non-Tinplate Uses: 1955-75

\[ DTNOUS_t = 4.70055 + 0.17063 \ IIPUS_t + 0.291766 \ ICONUS_t \\
- 0.0011 \left( \frac{PTNY}{WPIUSI} \right)_t - 0.88046 \ TIME - 4.64169 \ JCDMM1_t \]

\[ R^2 = 0.95 \quad S.E.E. = 1.23 \quad D.W. = 2.61 \]

where:

DTNOUS = Consumption of primary tin in non-tinplate uses in the United States ('000 mt)

IIPUS = US index of production of machinery and equipment (1967=100)

ICONUS = US index of real value of total new constructions (1972=100)

JCDMM1 = Dummy variable for steel strikes in the US.
Western Europe

(a) Tinplate Uses: 1955-75

\[ DTNEUR_t = 22.082520 + 0.004113 \text{STPEUR}_t - 0.000933 \left( \frac{\text{PTLME}}{\text{WPIEUR}} \right)_t - 9.131836 \text{ETPRAT1}_t \]

\[ (4.91) \quad (1.35) \quad (2.41) \]

\[ R^2 = 0.78 \quad \text{S.E.E.} = 0.90 \quad \text{D.W.} = 1.91 \]

where:

DTNEUR = Consumption of primary tin in tinplate uses in Western Europe ('000 mt)

STPEUR = Production of tinplate in Western Europe ('000 mt)

PTLME = LME tin price (US$/mt)

WPIEUR = Wholesale Price Index (1963=100), with tin consumption shares used as weights

ETPRAT1 = Ratio of electrolytic to total tinplate production in Western Europe

(b) Non-Tinplate Uses: 1955-75

\[ DTNOEU_t = 33.0800 + 0.26664 DTNOEU_{t-1} + 0.03819 \text{IPOECD}_t - 0.00330 \left( \frac{\text{PTLME}}{\text{WPIEUR}} \right)_{t-1} + 3.60538 \text{DMY73}_t \]

\[ (1.95) \quad (2.73) \quad (4.42) \quad (2.40) \]

\[ R^2 = 0.77 \quad \text{S.E.E.} = 1.27 \quad \text{D.W.} = 2.43 \]

where:

DTNOEU = Consumption of primary tin in non-tinplate uses in Western Europe ('000 mt)

IPOECD = Index of industrial production in OECD Europe (1970=100)

DMY73 = Dummy variable for unexplained large increments in official consumption statistics in 1973 (set to 1 for 1973 and to 0 for all other years).

---

1/ The extremely large increments in the use of tin in non-tinplate applications shown by official apparent consumption statistics for Western Europe and Japan is probably due to industry stock piling of tin.
Japan

(a) Tinplate Uses: 1955-75

(2.5) \begin{align*}
\text{DTNJAP}_t &= -0.813751 + 0.004451 \text{STPJAP}_t - 8.867310 \text{ETPJAP}_t \\
&\quad - 0.000132 \frac{\text{PTJAP}}{\text{WPIJAP}}_{t-1} \\
R^2 &= 0.98 \\
\text{S.E.E.} &= 0.64 \\
\text{D.W.} &= 2.41
\end{align*}

where:

\text{DTNJAP} = \text{Consumption of primary tin in tinplate uses in Japan (1000 mt)}

\text{STPJAP} = \text{Production of tinplate in Japan ('000 mt)}

\text{ETPJAP} = \text{Ratio of electrolytic to total tinplate production in Japan}

\text{PTJAP} = \text{LME tin price (¥/mt)}

\text{WPIJAP} = \text{Wholesale price index (1970=100) for Japan}

(b) Non-Tinplate Uses: 1955-75

(2.6) \begin{align*}
\text{DTNOJP}_t &= 8.96771 + 0.09763 \text{IIPJAP}_t - 0.66498 \left[ \frac{\text{PTJAP}}{\text{PAJAP}} \right]_{t-1} \\
&\quad + 4.66871 \text{DMY73} \\
R^2 &= 0.96 \\
\text{S.E.E.} &= 1.00 \\
\text{D.W.} &= 1.43
\end{align*}

where:

\text{DTNOJP} = \text{Consumption of primary tin in non-tinplate uses in Japan ('000 mt)}

\text{IIPJAP} = \text{Index of production of transport and equipment (1970=100) for Japan}

\text{PAJAP} = \text{Aluminum price in Japan (¥/mt)}
South Africa: 1955-75

(2.7) \[ \text{DTNSAF}_t = 1.32857 + 0.03896 \text{TIME}_t \]

\[ R^2 = 0.52 \quad \text{S.E.E.} = 0.23 \quad \text{D.W.} = 0.51 \]

where:

\( \text{DTNSAF} \) = Total consumption of primary tin in South Africa ('000 mt)

\( \text{TIME} \) = Time trend (1955=1)

Other Developed Countries: 1955-75

(2.8) \[ \text{DTNDC}_t = 3.63795 + 0.76786 \text{DTNDC}_{t-1} + 0.01770 \text{IIPODC}_t \\
- 0.55960 \text{PAUK}_{t-2} \]

\[ R^2 = 0.51 \quad \text{S.E.E.} = 0.68 \quad \text{D.W.} = 1.87 \]

where:

\( \text{DTNDC} \) = Total consumption of primary tin in other developed countries ('000 mt)

\( \text{IIPODC} \) = UN Index of industrial production (1970=100) weighted by GNP shares for other developed countries

\( \text{PAUK} \) = Aluminum price in UK (US$/mt)

Developing Countries: 1955-75

(2.9) \[ \text{DTNLDC}_t = 8.51783 + 0.28702 \text{DTNLDC}_{t-1} + 0.04526 \text{IIPLDC}_t \\
- 0.00048 \text{IPI}_{t-1} \]

\[ R^2 = 0.81 \quad \text{S.E.E.} = 0.90 \quad \text{D.W.} = 2.05 \]
where:

\[
\text{DTNLDC} = \text{Total consumption of primary tin in developing countries ('000 mt)}
\]

\[
\text{IPI}_{\text{LDC}} = \text{UN index for industrial production (1970=100)}
\]

\[
\text{IPI} = \text{World Bank index of international inflation (1970=100)}
\]

**World Demand**

31. The following equation (2.10) summarizes the variables which were used to obtain world demand for tin. As in the corresponding equation for world production (1.9) the demand equation consists of endogenous and exogenous variables. The demand for tin in the United States, Western Europe, Japan, South Africa and other developed and developing countries is generated within the model by equations (2.1) to (2.9). Purchases for the US strategic tin stockpile, for the ITC tin bufferstock and exports to centrally planned economies constitute "outflows" of tin for which it was not possible to estimate behavioral equations. Values for these variables enter the model exogenously.

\[
(2.10) \quad \text{TMWDS}_t = \text{DTNUS}_t + \text{DTNOUS}_t + \text{DTNEUR}_t + \text{DTNOEU}_t + \text{DTNJAP}_t + \text{DTNOJP}_t + \text{DTNASAF}_t + \text{DTNDC}_t + \text{DTNLDC}_t + \text{GSPPCS}_t + \text{ITCPCS}_t + \text{XTCPE}_t
\]

where:

\[
\text{TMWDS} = \text{World disappearance of primary tin metal}
\]

\[
\text{GSPPCS} = \text{Government stockpile purchases ('000 mt)}
\]

\[
\text{ITCPCS} = \text{ITC bufferstock purchases ('000 mt)}
\]

\[
\text{XTCPE} = \text{Exports to CPEs ('000 mt)}
\]

Abbreviations for the other variables are identical to those used above.

**Demand Elasticities**

32. The price elasticities implied in the coefficients of the estimated demand equations are summarized in Table 5.
### Table 5: TIN DEMAND ELASTICITIES

<table>
<thead>
<tr>
<th>Country or Area</th>
<th>Coefficient of Adjustment</th>
<th>Price Elasticity of Demand</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Short-Term /a</td>
<td>Long-Term</td>
</tr>
<tr>
<td>United States</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tinplate uses</td>
<td>n.a.</td>
<td>0.24*</td>
<td>n.a.</td>
<td></td>
</tr>
<tr>
<td>Non-tinplate uses</td>
<td>n.a.</td>
<td>0.13</td>
<td>n.a.</td>
<td></td>
</tr>
<tr>
<td>Western Europe</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tinplate uses</td>
<td>n.a.</td>
<td>0.11</td>
<td>n.a.</td>
<td></td>
</tr>
<tr>
<td>Non-tinplate uses</td>
<td>0.74</td>
<td>0.30*</td>
<td>0.41*</td>
<td></td>
</tr>
<tr>
<td>Japan</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tinplate uses</td>
<td>n.a.</td>
<td>0.18</td>
<td>n.a.</td>
<td></td>
</tr>
<tr>
<td>Non-tinplate uses</td>
<td>n.a.</td>
<td>0.49*</td>
<td>n.a.</td>
<td></td>
</tr>
<tr>
<td>Other Developed Countries</td>
<td>0.23</td>
<td>0.37</td>
<td>1.60</td>
<td></td>
</tr>
<tr>
<td>Developing Countries</td>
<td>0.71</td>
<td>0.11</td>
<td>0.15</td>
<td></td>
</tr>
</tbody>
</table>

/a Estimated at the mean values of consumption and prices.

* = Significant at the 95 percent confidence level.

n.a. = Not available.

33. The estimated price elasticities of the demand for tin are statistically less significant than the supply elasticities (Table 4). However, all had the correct sign and their values fell within a fairly narrow range—from −0.1 to −0.5. These estimates support the argument that the demand for tin is highly price-elastic in the short term. The long-term elasticities vary widely and it is therefore difficult to draw any conclusions from the estimates in Table 5.

D. Prices and Inventories

34. Tin prices are quoted for the three major markets: London (London Metals Exchange), New York and Penang (Malaysia). The highly competitive nature of the world tin economy ties these markets closely together. Although
differences in the price quotations 1/ between these three markets occur occasionally, they are usually short-lived. Chart I shows that tin prices at the London Metals Exchange have drifted upwards steadily until about the middle of 1973, when prices more than doubled within a few months. Although prices dropped towards the end of 1974 and also during 1975, they climbed again steeply during the early part of 1976. Among the many market forces which affect the price of tin, two factors, namely changes in tin inventories and inflation, explain most of the variation in tin prices.

35. Inventories are maintained by producers, traders, consumers and some governments for security reasons. In terms of its impact on tin prices, the strategic tin stockpile held by the US government is the most important of these governmental stockpiles. A certain quantity of tin is also held by the International Tin Council. Accurate information on industry and trade inventories has not been published and it was impossible therefore to analyze in detail the behavior of tin inventories. To capture the effect of inventory changes on tin prices, "implied stocks" 2/ were computed. Inventory levels by themselves have little economic meaning, but when related to demand or supply, they indicate the length of time for which reserves are available. The shorter the time period, the greater is the urgency to increase supply (or reduce consumption), and thus the higher is the pressure on prices. One would expect, therefore, an inverse relationship between prices and the ratio of inventories to demand or supply. The results of the estimated price equations confirm this expectation. In interpreting the estimated coefficients of the price equation, it may be useful to view it as a price-dependent demand equation for tin stocks. 3/ The coefficient associated with the ratio of stocks to world demand (IMSW/DTNW) becomes then the price flexibility of the demand for stocks. 4/ The size of the coefficient indicates the impact of a change in stocks (relative to demand) on the price of tin, and it affects significantly the results of the simulated bufferstock operations. 5/

36. In addition to changes in inventories, prices of tin (as well as those of other metals) are highly sensitive to changes in world inflation. The sudden increase of world inflation that began in 1973 coincided with

---

1/ Adjusted for transfer cost (transport cost, commissions, taxes, etc.).

2/ The stocks used are "implied" stocks, i.e. stocks in the previous period, plus total market availabilities minus total market disappearance in the current period; the computation of "implied" stocks was started in 1946.

3/ Equation (3.4) is equivalent to a supply equation for stocks.

4/ A price flexibility is the inverse of a price elasticity; it indicates the percent change in prices associated with a one percent change in some quantity (demand, supply, stocks, etc.).

5/ Price equation (3.3) which was used to test and verify the model was re-estimated and replaced by equation (4.1).
the steep rise in tin prices. In nominal terms LME tin prices climbed from $3,500 per ton in 1972 to US$8,200 in 1974—a 134 percent jump in prices within two years. Tin prices dropped slightly in 1975—to US$6,869—but increased again during 1976 to US$7,582 per ton. To account for the effect of inflationary conditions on tin prices, the US wholesale price index was included in the price equation as a proxy for world inflation. The estimated coefficient indicates an inflation elasticity of about 1.5 percent. Thus a one percent increase in the rate of inflation (measured by the US wholesale price index) was associated with a 1.5 percent rise in tin prices.

37. Tin has also become one of the key metals used as a "hedge" against fluctuations in exchange rates. However, it has been difficult to capture the influence of exchange rate movements on annual tin prices. 1/

38. The following price equation for tin has been estimated for the period 1957 to 1976.

\[ \ln P_{\text{TLM}} = 4.061157 + 0.436714 \ln P_{\text{TLM}} - 0.614975 \ln M_{\text{SW}} + 1.458252 \ln W_{\text{PIUSI}} \]

\[ R^2 = 0.93 \quad \text{S.E.E.} = 0.118 \quad \text{D.W.} = 1.65 \]

where:

- \( P_{\text{TLM}} \) = LME (cash) tin price (US$/mt)
- \( M_{\text{SW}} \) = Implied world stocks of primary tin metal ('000 mt)
- \( D_{\text{TNW}} \) = World consumption of primary tin ('000 mt)
- \( W_{\text{PIUSI}} \) = US wholesale price index (1967=100)

39. Although the price equation contains the key variables that determine tin prices, it failed to capture the price boom of 1964-65. Since this boom coincided with the Malaysian-Indonesian confrontation, it could be argued that it was caused largely by the uncertainty about tin supplies. Similarly, the sharp increase in tin prices in 1974 was also due more to consumers' expectations of possible shortages fostered by the oil crisis and the boom in all metal prices, than to changes in the underlying forces of supply and demand. Separate dummy variables were used to capture the price effect of these exogenous factors. 2/ Two additional price equations were estimated for the same period, the first including a dummy variable for 1974 and the second including an additional dummy variable for 1964 and 1965.

1/ A quarterly model could probably reflect the impact of exchange rate uncertainties—actual or anticipated—on tin prices.

2/ The effects could probably be explained endogenously by changes in industry stocks. As explained before, however, reliable industry stock figures were not available for the period under consideration.
(3.2) \[ \ln PTLME_t = 3.13888 + 0.608734 \ln PTLME_{t-1} - 0.482727 \ln \left( \frac{IMSW}{DTNW} \right)_t + 0.971008 \ln WPIUSI_t + 0.354248 DMY74 \]
\[ R^2 = 0.96 \quad \text{S.E.E.} = 0.097 \quad \text{D.W.} = 1.81 \]

and

(3.3) \[ \ln PTLME_t = 3.54702 + 0.526141 \ln PTLME_{t-1} - 0.302055 \ln \left( \frac{IMSW}{DTNW} \right)_t + 0.990231 \ln WPIUSI_t + 0.350041 DMY74 + 0.222109 DMYIND \]
\[ R^2 = 0.98 \quad \text{S.E.E.} = 0.071 \quad \text{D.W.} = 1.85 \]

where:

DMY74 = Dummy variable for 1974 oil crisis (set to 1 for 1974 and to 0 for all other years)
DMYIND = Dummy variable for Malaysian-Indonesian confrontation (set to 1 for 1964 and 1965, and to 0 for all other years)

40. The two dummy variables (DMY74 and DMYIND) improved not only the statistical properties of the price equation, but also its usefulness in model simulations. Equations (3.2) and (3.3) show that changes in the inventory-demand ratio have a significant impact on tin prices. Equation (3.3) was finally incorporated into the tin model.

41. The following market clearing equation closes the model:

(3.4) \[ IMSW_t = IMSW_{t-1} + TCWAV_t - TMWDS_t \]

where:

IMSW = Implied world stocks of primary tin metal ('000 mt)
TCWAV = World availability of primary tin metal ('000 mt)
TMWDS = World disappearance of primary tin metal ('000 mt)
V. VALIDATION OF THE MODEL, HISTORICAL POLICY SIMULATIONS AND PROJECTIONS

A. Ex-Post Simulations of the Model

42. To test and evaluate the model, ex-post simulations were conducted for different periods. The choice of periods was dictated not only by the need to test the model performance over different time spans, but also by the desire to use the simulations for historical policy analysis. In all the simulations, production of tinplate in the US, Western Europe and Japan as well as the New York tin price and the ratio of tin can shipments to total shipments of cans in the US (STPUS, STPEUR, STPJAP, PTNY, CANRAT) were endogenized. The additional behavioral equations that were used in the historical simulations are contained in Annex I.

43. The results of historical simulations for the key endogenous variables during the periods 1961-75 and 1966-75 are summarized in Table 6. Chart 3 shows the simulation results for the 1966-75 period. "Version I" refers to the model as specified so far.

<table>
<thead>
<tr>
<th>Year</th>
<th>PTLMN (Price)</th>
<th>DTNWN (Consumption)</th>
<th>STCNW (Production)</th>
<th>TMSNW (Stocks)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1961-1975</td>
<td>3934</td>
<td>170.4</td>
<td>168.6</td>
<td>88.6</td>
</tr>
<tr>
<td>(actual data)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean (simulated)</td>
<td>3884</td>
<td>171.0</td>
<td>168.5</td>
<td>86.5</td>
</tr>
<tr>
<td>RMS /a Error</td>
<td>404</td>
<td>4.6</td>
<td>5.3</td>
<td>16.1</td>
</tr>
<tr>
<td>RMS Error (in %)</td>
<td>0.098</td>
<td>0.026</td>
<td>0.031</td>
<td>0.191</td>
</tr>
<tr>
<td>1966-1975</td>
<td>4429</td>
<td>175.2</td>
<td>180.4</td>
<td>101.5</td>
</tr>
<tr>
<td>(actual data)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean (simulated)</td>
<td>4184</td>
<td>177.2</td>
<td>182.2</td>
<td>103.3</td>
</tr>
<tr>
<td>RMS /a Error</td>
<td>425</td>
<td>4.3</td>
<td>6.9</td>
<td>7.5</td>
</tr>
<tr>
<td>RMS Error (in %)</td>
<td>0.089</td>
<td>0.025</td>
<td>0.038</td>
<td>0.079</td>
</tr>
</tbody>
</table>

/a RMS is the Root-Mean-Square simulation error.

44. The simulation results indicate that it is possible to capture most of the behavior of the world tin economy with a small model (containing only 23 behavioral equations). The performance of the model in simulating tin prices—both their long-term trend as well as short-term changes—is quite remarkable. The root-mean-square percent error of the simulated prices is
CHART 3


A. WORLD PRODUCTION OF TIN

B. WORLD CONSUMPTION OF TIN

C. WORLD TIN PRICE (LME, CASH)

D. WORLD (IMPLIED) STOCKS OF TIN

World Bank – 1980
0.098 over the 1961–75 period simulation and 0.089 over the 1966–75 simulation period. The model also simulates very well the turning points in the historical price series: the peaks of 1965 and 1974 as well as the 1968 and 1975 troughs.(see Chart 3).

45. The good price simulation performance of the model was due mainly to price equation 3.3. However, compared to the other estimated price equations (3.1 and 3.2), its coefficient on the stock/consumption variable was considerably lower. Thus, for identical levels of tin consumption, this equation required larger changes in stocks to achieve similar changes in simulated prices than the other price equations. Since one of the purposes of the tin model is to simulate the impact of price stabilization through buffer stock operations, this drawback was quite serious.

46. To test the responsiveness of prices to changes of stocks (relative to consumption), the price equation was reestimated for different periods. Since it was observed that fewer observations tended to yield statistically significant coefficients for the stock/consumption variables that tended towards 1, three new price equations for the 1956–76 period were estimated using respectively 0.65, 0.85 and 0.95 as a priori coefficients for the stock/consumption variable. The following equation was selected because of its fit and statistically significant estimates.

\[
\begin{align*}
\ln PTLME_t &= 3.195038 + 0.514138 \ln PTLME_{t-1} \\
&\quad - 0.95 \left[ \frac{TMSW}{DTNW} \right]_t + 1.526318 \text{WPIUSI} + 0.279531 \text{DMY74} \\
R^2 &= 0.97 \\
\text{S.E.E.} &= 0.112 \\
\text{D.W.} &= 1.46
\end{align*}
\]

47. This equation was used to simulate the model again for the 1966–75 period (Version II). The results of the new ex-post simulations are summarized in Table 7 and shown in Chart 4. This second version of the model performs almost as well as Version I in simulating consumption and market price, and better in simulating the behavior of world production and stocks. Version II was therefore used for the historical policy simulations as well as for projections.

B. Historical Policy Simulations: Price Stabilization for Tin

48. Wide fluctuations in prices for primary commodities have rekindled interest in the various means of price stabilization. Since tin is the only commodity for which a price stabilization scheme has been in operation for more than two decades, the International Tin Agreement became the model for a host of proposals aimed at stabilizing the markets of primary commodities. All of these proposed schemes have several features in common: a bufferstock (or bufferfund) mechanism which takes some stabilizing action (e.g. by changing the level of stocks or funds under the control of the stabilizing authority) whenever prices rise or fall below agreed price levels; they also contain some rationing mechanism that allocates exports or production among producers in times of persistent excess supplies.
Table 7: SUMMARY RESULTS OF HISTORICAL SIMULATIONS (MODEL VERSION II)

<table>
<thead>
<tr>
<th></th>
<th>PTLME (Price)</th>
<th>DTNW (Consumption)</th>
<th>STCW (Production)</th>
<th>IMSW (Stocks)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1966-1975</td>
<td>Mean (actual)</td>
<td>4429</td>
<td>175.2</td>
<td>180.4</td>
</tr>
<tr>
<td></td>
<td>Mean (simulated)</td>
<td>4333</td>
<td>175.1</td>
<td>180.8</td>
</tr>
<tr>
<td></td>
<td>RMS /a Error</td>
<td>414</td>
<td>5.1</td>
<td>3.4</td>
</tr>
<tr>
<td></td>
<td>RMS Error (in %)</td>
<td>0.095</td>
<td>0.029</td>
<td>0.018</td>
</tr>
</tbody>
</table>

/a RMS is the Root-Mean-Square simulation error.

49. These proposals, and in particular the UNCTAD Integrated Program for Commodities, 1/ have sparked a lively debate about the advantages and disadvantages of market price stabilization. Most of the discussion has centered around the fundamental question of whether benefits associated with price stabilization outweigh its costs. 2/ Another equally important question from the policy standpoint refers to the distribution of benefits and costs. 3/

50. The fundamental question of whether for a particular group of countries (producers or consumers) benefits outweigh costs in commodity price stabilization is very difficult to answer, even on a case by case basis. The definition of costs and benefits is critical to the exercise. While "direct" costs (size of the stock and operational expenditures) and "direct" benefits (impact of price stabilization on total revenue and on revenue stability) can be gauged with some confidence using appropriately


3/ The question of distribution of gains is dealt with in E. Brook, E. Grilli, J. Waelbroeck, "Commodity Price Stabilization and the Developing Countries: The Problem of Choice," IBRD Staff W.P. No. 262, July 1977. The paper also examines the effects of commodity price stabilization on export revenue and on export revenue stability.
constructed and hopefully well estimated models of the commodities in question, the "indirect" costs and benefits are vastly more difficult to conceptualize and measure with any degree of confidence. Improvements in the investment climate, better planning of production and processing of raw materials due to stable market prices could result in important welfare gains. Similarly if commodity price stabilization were to contribute significantly to a reduction of inflationary trends in the world economy, the benefits in terms of averted output losses, even if short-term, could be quite large.

51. Any attempt to provide an answer—however tentative—to all these questions would exceed the scope of this paper. However, with the help of the estimated tin model (Version II), it is possible to shed some light on the question of the "direct" costs and benefits of price stabilization in tin. The following analysis, therefore, focuses only on the impact of a tin bufferstock on three variables: the initial endowment necessary to maintain a bufferstock in full operation during the simulation periods, and to achieve the desired degree of price stability (maximum stock), 1/ the impact of price stabilization on export unit values and the impact on export revenues. The first variable, the maximum stock, provides some indication of the magnitude of the resources required—and thus the "direct" cost—of a tin bufferstock. The second and third variables, export prices and revenues, serve as indicators of the "direct" benefits. 2/

52. To examine the impact of price stabilization on the tin economy, a bufferstock mechanism was incorporated into the tin model (Version II). Three different methods were used to determine price floors and ceilings. The first method uses price bands as they were defined in the International Tin Agreements. (The results of these simulations were labeled ITA.) 3/ The second

1/ It is clear that the desired degree of price stability is a policy target on which the size of the stock depends.

2/ Since this analysis considers by no means all the most significant benefits and costs, the results should be interpreted with some caution. Although other studies have obtained similar results (see G.W. Smith and G.R. Schink, "The International Tin Agreement: A Reassessment," op. cit.) definite conclusions about the economic usefulness of the tin bufferstock would have to be based on a more complete analysis.

3/ Under the various tin agreements, the bufferstock manager was given the flexibility to buy for or sell from the bufferstock when prices were within certain limits above the floor and below the ceiling. Since this discretionary power cannot be introduced in the bufferstock model, the results shown here under the ITA label do not correspond precisely to the ITA procedures and rules of behavior. They would in fact represent the results of a more rigid rule of behavior that would allow the bufferstock manager to buy only when prices dropped below the floor and to sell only when they climbed above the ceiling without any action in between.
method determines the price ceiling and floor as a departure by a fixed percentage from a weighted 3 year price moving average. 1/ In the third method, the weighted average price is replaced by a price computed from the percent change of prices during the previous three years applied to the average price during the previous two years. In all cases two price stabilization bands (+ 10 and + 15 percent) were used. If actual market prices stayed within the price stabilization band the bufferstock mechanism was not activated. Only if prices exceeded the ceiling (or dropped through the floor), did the bufferstock release (or absorb) tin into (or from) the market. Any transaction by the bufferstock affects the inventory/demand ratio (TMSW/TMWDS) and through it tin prices.

53. The use of ceilings and floors based on some past average prices has the advantage that they reflect, to some extent, changes in the relative strength of demand and supply for tin. However, it could be argued that the price bands contained in the various International Tin Agreements also mirror the prevailing and anticipated market conditions as they were perceived by the negotiating parties. The ex-post simulations of the tin bufferstock (Table 8) show quite clearly that the results concerning the size of the stock necessary to keep the market price within the predetermined bands at all times, the average size of the stockholding by the stabilization agency and, therefore, the costs of stabilization are quite sensitive to the price setting rule chosen by the stabilization agency. Simulations conducted using more mechanical determinations of ceiling and floors based on past prices (e.g. simple or weighted averages 2/) also show quite conclusively that such rules imply much larger stocks of tin than indicated under the rules chosen here.

54. The bufferstock simulations that were conducted using Version II of the model also indicate that the inclusion of the years 1974 and 1975 in the simulation period raises quite substantially the estimates of maximum and average stocks to be held by the stabilization agency. This is not surprising, given the sharp changes in tin market prices that took place since late 1973. Such price changes would have put extreme strain on the resources of any price stabilization scheme in operation during that period. Excluding, therefore, the years 1974 and 1975, it would appear that a bufferstock of about 40,000 metric tons could have been sufficient to maintain prices within the "ITA" limits. Similar results are obtained under the - 10% trend rule. The results

1/ The weights are as follows: 0.7 for price at t-1, 0.2 for price at t-2 and 0.1 for price at t-3. The average is then adjusted for expected inflation, using the percentage change in the US WPI at t-1.

2/ Not adjusted for expected inflation.
### Table 8: Bufferstock Simulations for Selected Tin Price Ranges, 1961-73 and 1961-75

<table>
<thead>
<tr>
<th></th>
<th>ITA /a ITA Ranges</th>
<th>Deviations from Trend /b 10%</th>
<th>Deviations from Trend /b 15%</th>
<th>Deviations from Weighted 3 Year Moving Average /c 10%</th>
<th>Deviations from Weighted 3 Year Moving Average /c 15%</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>1961-73</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>STOCKS (’000 m.t.)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maximum</td>
<td>41.0</td>
<td>34.0</td>
<td>26.0</td>
<td>117.0</td>
<td>21.0</td>
</tr>
<tr>
<td>Average</td>
<td>29.5</td>
<td>17.4</td>
<td>12.1</td>
<td>73.7</td>
<td>17.8</td>
</tr>
<tr>
<td>(Standard Deviation)</td>
<td>12.4</td>
<td>7.9</td>
<td>5.7</td>
<td>44.0</td>
<td>5.1</td>
</tr>
<tr>
<td>Average Absolute Change</td>
<td>3.1</td>
<td>4.2</td>
<td>1.9</td>
<td>9.1</td>
<td>1.3</td>
</tr>
<tr>
<td><strong>FUND (Million US$)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maximum</td>
<td>127.7</td>
<td>107.6</td>
<td>90.6</td>
<td>366.4</td>
<td>60.4</td>
</tr>
<tr>
<td>Average</td>
<td>87.4</td>
<td>49.1</td>
<td>35.7</td>
<td>221.0</td>
<td>49.6</td>
</tr>
<tr>
<td>(Standard Deviation)</td>
<td>41.3</td>
<td>26.0</td>
<td>20.0</td>
<td>142.8</td>
<td>15.3</td>
</tr>
<tr>
<td>Average Absolute Change</td>
<td>10.9</td>
<td>14.2</td>
<td>6.8</td>
<td>29.0</td>
<td>4.0</td>
</tr>
</tbody>
</table>

| **1961-75**      |                    |                             |                             |                                                      |                                                      |
| **STOCKS (’000 m.t.)** |                    |                             |                             |                                                      |                                                      |
| Maximum          | 51.0               | 140.0                       | 103.0                       | 153.0                                                | 62.0                                                 |
| Average          | 32.0               | 33.7                        | 24.1                        | 84.3                                                 | 23.7                                                 |
| (Standard Deviation) | 13.5              | 43.6                        | 32.2                        | 49.3                                                 | 16.2                                                 |
| Average Absolute Change | 3.9                | 11.2                        | 7.2                         | 10.5                                                 | 4.1                                                  |
| **FUND (Million US$)** |                    |                             |                             |                                                      |                                                      |
| Maximum          | 206.6              | 536.0                       | 472.1                       | 579.3                                                | 315.0                                                |
| Average          | 102.1              | 113.8                       | 93.6                        | 268.8                                                | 85.0                                                 |
| (Standard Deviation) | 54.5              | 172.4                       | 153.9                       | 182.7                                                | 94.5                                                 |
| Average Absolute Change | 16.4              | 43.0                        | 33.4                        | 40.6                                                 | 21.6                                                 |

/a Price ranges as set by the International Tin Council.

/b The mid-point of the price range was projected on the basis of the percent change in prices during the previous three years. This percent change was then applied to the average price of the previous two years. Price ceilings and floors were then expressed in terms of a fixed percentage (+ 10% or + 15%) from the projected mid-point. The following formula was used to determine the mid-point:

\[
\text{Pt} = \left( \left( \frac{\text{Pt}_1 - \text{Pt}_3}{2} \right) \right)
\]

/c The weights selected were 0.7, 0.2 and 0.1 for the years (t-1), (t-2) and (t-3); the weighted average was adjusted by the US Wholesale Price Index (t-1).
of the weighted 3-year moving average rule (adjusted for inflation) show, on
the other hand, a much larger spread than those of the trend rule depending
on whether $\pm 10\%$ or $\pm 15\%$ is chosen as margin. 1/ The results in Table 9 show clearly that price stabilization in
tin under the intervention rules postulated in this paper would reduce the
instability of export revenue to a much greater extent than under tradi-
tional "ITA" rules: the coefficient of variation of export revenue for the
1961-75 bufferstock simulation is 41.13 without stabilization, 40.05 under
the "ITA" type of stabilization, an average of 25.0 under the trend price
intervention rule and of 34.4 under the weighted 3-year moving average price
intervention rule. However, greater price and revenue stability is achieved
at the expense of lower total export revenue over the simulation period. The
present value of export revenues 2/ (in constant 1967 US$) is somewhat
lower under the intervention rules with fixed price bands ($\pm 10\%$ and $\pm 15\%$) than
under the more flexible price ceilings and floors contained in the Inter-
national Tin Agreements.

56. These results are not surprising. Between 1961 and 1975, tin prices
and export revenues had reached their historical peak. Any effective mecha-
nism to stabilize prices would have cut peak prices and thereby revenues. Yet,
the results pinpoint a serious policy dilemma: the achievement of greater
price stability implies a cost in terms of lower revenues. This dilemma
arises—probably in all metals—whenever price stabilization is enforced
rigidly along predetermined rules of market price intervention. Obviously,
the choice between stable prices and higher revenues is a difficult one.
The answer depends inter alia on the attitude of policy makers towards risk,
the importance of the revenues from a certain commodity to a given country,
the policy instruments available to control the effects of revenue fluctua-
tions on the national economies and access to international credit.

C. Price Scenarios: 1978-85

57. The tin model (Version II) was also used to gain some insight into
the likely prospects for the world tin economy. In general, the projections
of an econometric model reflect its structure and the assumptions made about
its exogenous variables. Assumptions about the future value of an economic
variable are always somewhat arbitrary. To stake out the boundaries for the
future development of the tin economy, the projections were based on three
different sets of assumptions for the exogenous variables (1978-85): (i) a
high rate of inflation (6.5 percent a year), high GNP growth rates (5 percent
a year) in industrialized countries and heavy US government stockpile sales;

1/ It should be pointed out that all the results shown in Table 8 are probably
on the low side since all the simulations are deterministic in nature.
Stochastic simulations would tend to show higher figures for both stocks
and fund.

2/ Export revenues for the period 1961-75 were discounted at the rate of 3
percent per year to compute their present value in 1966.
### Table 9: EFFECT OF PRICE STABILIZATION ON SIZE AND STABILITY OF EXPORT REVENUES

<table>
<thead>
<tr>
<th>Year</th>
<th>ITA /a</th>
<th>ITA Ranges</th>
<th>Deviations from Trend /b ± 10%</th>
<th>Deviations from Weighted 3 Year Moving Average /c ± 10%</th>
<th>Actual Revenue /d</th>
</tr>
</thead>
<tbody>
<tr>
<td>1961</td>
<td>261.1</td>
<td>267.1</td>
<td>276.7</td>
<td>255.4</td>
<td>264.1</td>
</tr>
<tr>
<td>1962</td>
<td>260.2</td>
<td>267.1</td>
<td>271.1</td>
<td>251.0</td>
<td>259.7</td>
</tr>
<tr>
<td>1963</td>
<td>286.4</td>
<td>294.4</td>
<td>293.4</td>
<td>267.2</td>
<td>287.1</td>
</tr>
<tr>
<td>1964</td>
<td>307.0</td>
<td>318.5</td>
<td>324.8</td>
<td>289.6</td>
<td>325.7</td>
</tr>
<tr>
<td>1965</td>
<td>353.6</td>
<td>356.2</td>
<td>261.9</td>
<td>315.1</td>
<td>371.1</td>
</tr>
<tr>
<td>1966</td>
<td>423.4</td>
<td>411.5</td>
<td>430.7</td>
<td>349.0</td>
<td>433.3</td>
</tr>
<tr>
<td>1967</td>
<td>484.4</td>
<td>488.0</td>
<td>504.3</td>
<td>385.4</td>
<td>495.6</td>
</tr>
<tr>
<td>1968</td>
<td>518.7</td>
<td>556.5</td>
<td>551.2</td>
<td>432.3</td>
<td>543.4</td>
</tr>
<tr>
<td>1969</td>
<td>519.4</td>
<td>566.0</td>
<td>528.8</td>
<td>494.9</td>
<td>530.4</td>
</tr>
<tr>
<td>1970</td>
<td>519.5</td>
<td>554.3</td>
<td>507.2</td>
<td>581.1</td>
<td>519.0</td>
</tr>
<tr>
<td>1971</td>
<td>502.6</td>
<td>500.2</td>
<td>479.1</td>
<td>571.9</td>
<td>490.0</td>
</tr>
<tr>
<td>1972</td>
<td>535.7</td>
<td>493.3</td>
<td>502.1</td>
<td>558.1</td>
<td>510.1</td>
</tr>
<tr>
<td>1973</td>
<td>594.2</td>
<td>479.1</td>
<td>533.6</td>
<td>578.5</td>
<td>579.2</td>
</tr>
<tr>
<td>1974</td>
<td>936.6</td>
<td>500.9</td>
<td>621.4</td>
<td>761.2</td>
<td>790.8</td>
</tr>
<tr>
<td>1975</td>
<td>835.0</td>
<td>430.7</td>
<td>543.1</td>
<td>662.9</td>
<td>693.4</td>
</tr>
</tbody>
</table>

**TOTAL** | **7,337.8** | **6,488.8** | **6,729.4** | **6,753.4** | **7,092.9** | **7,576.4** |

**Coefficient of Variation** | 40.05 | 24.67 | 25.39 | 36.30 | 32.51 | 41.13 |

**Total Present Value** | 4,998 | 4,625 | 4,724 | 4,651 | 4,902 | 5,144 |

/a Price ranges as set by the International Tin Council.

/b The midpoint of the price range was projected on the basis of the percent change in prices during the previous three years. This percent change was then applied to the average price of the previous two years. Price ceilings and floors were then expressed in terms of a fixed percent (+10% or +15%) from the projected midpoint. The following formula was used to determine the midpoint:

\[
\frac{(P_{t-1} - P_{t-2})}{2} = \frac{P_{t-1}}{2} + \frac{P_{t-2}}{2}
\]

/c The weights selected were 0.7, 0.2 and 0.1 for the Year \((t-1), (t-2)\) and \((t-3)\). This weighted average was adjusted by the US Wholesale Price Index \((t-1)\).

/d Simulated revenues.

/e Coefficient of variation (standard deviation divided by mean) multiplied by 100.

/f Present value of export revenues (1961-75) in terms of 1967 constant US dollars and discounted 3 percent per year.
(ii) a 5.5 percent rate of inflation, medium GNP growth rates (4 percent a year) moderate US government stockpile sales; (iii) a 4.5 percent rate of inflation, low GNP growth rates (3 percent a year) and no government stockpile sales.

58. The projected values for the key variables—supply, demand, stocks and prices—for the medium GNP growth and inflation assumption are summarized in Annex Table II.1. Projected prices for 1985, in constant 1975 US$ terms, vary between $13,105 per metric ton (under the assumptions of high economic growth and high inflation) and $9,740 per metric ton (under the assumption of low economic growth and low inflation). Under the current World Bank assumptions regarding GNP growth and inflation (reflected by the medium growth and medium inflation assumption) tin prices in 1985 are projected to be in the $11,300-$11,900 per metric ton range.

59. Table 10 shows these projected prices (in 1975 constant US$) for the period 1978-85 under three alternative hypotheses regarding US government stockpile sales. For this exercise medium inflation and medium GNP growth rates in industrial countries were assumed. The year by year results clearly show the impact of the lags in supply and demand on prices. Heavy stockpile sales (Scenario III) can keep prices relatively low for as long as they last (until 1981), but because of the adjustment lags, in both demand and supply, the market prices in the three ensuing years can be seen to increase faster than under the medium or no stockpile sale scenarios. Medium stockpile sales (Scenario II) have a similar, if less pronounced, effect on the path of adjustment of tin prices. With no stockpile sales (Scenario I) tin prices remain fairly stable at around $10,500 per metric ton during the entire projections period (1978-85). 1/

60. The time path of tin market prices from 1978 to 1985 in constant 1975 US$ terms is shown in Chart 5. The projections show that the cyclical behavior of tin prices is likely to continue in the future in the absence of a strong price stabilization effort (all these projections were worked out on the assumption of no bufferstock action). It also shows that tin prices are likely to maintain their long-term trend growth in real terms. Different stockpile sale policies can alter the adjustment path of tin prices, but cannot modify their long-term trend growth.

61. On the whole it would appear from the projections that tin producers can look forward to a period of slow, but steady rise in import demand for this metal as well as to prices that will continue to rise in real terms along their long-run trend. However, as a result of the lags that characterize the response of demand and supply to changing market conditions, the current price boom will be followed by a period of much lower real prices which is likely to begin in the early 1980s and to last until the mid-1980s.

1/ Heavy stockpile sales imply a disposal of 15,000 m.t. in 1978, 1979, 1980 and 1981 and 5,000 m.t. a year thereafter. Moderate stockpile sales imply disposal of 15,000 m.t. in 1978, 1979 and 5,000 m.t. a year thereafter.
Table 10: PRICE PROSPECTS FOR TIN UNDER VARIOUS ASSUMPTIONS
OF GOVERNMENT STOCKPILE SALES: 1978-1985
(1975 US$/mt)

<table>
<thead>
<tr>
<th>Year</th>
<th>Assumptions</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>I</td>
<td>II</td>
<td>III</td>
</tr>
<tr>
<td>1978</td>
<td>9,243</td>
<td></td>
<td>8,399</td>
<td>8,399</td>
</tr>
<tr>
<td>1979</td>
<td>10,959</td>
<td></td>
<td>9,355</td>
<td>9,335</td>
</tr>
<tr>
<td>1980</td>
<td>11,005</td>
<td></td>
<td>10,344</td>
<td>9,753</td>
</tr>
<tr>
<td>1981</td>
<td>10,269</td>
<td></td>
<td>10,573</td>
<td>9,702</td>
</tr>
<tr>
<td>1982</td>
<td>10,057</td>
<td></td>
<td>10,512</td>
<td>10,256</td>
</tr>
<tr>
<td>1983</td>
<td>10,269</td>
<td></td>
<td>10,406</td>
<td>10,722</td>
</tr>
<tr>
<td>1984</td>
<td>10,856</td>
<td></td>
<td>10,597</td>
<td>11,060</td>
</tr>
<tr>
<td>1985</td>
<td>11,908</td>
<td></td>
<td>11,394</td>
<td>11,681</td>
</tr>
</tbody>
</table>

Note: Assumption I: No government stockpile sales.
Assumption II: Moderate government stockpile sales.
Assumption III: Heavy government stockpile sales.

These three price scenarios are based on the assumption of medium rates for GNP and inflation.

$Per (1975 US$)

- No Stockpile Sales
- Heavy Stockpile Sales
- Moderate Stockpile Sales

1/ Medium GNP growth and medium inflation

World Bank – 18499
ADDITIONAL EQUATIONS USED IN THE EX-POST SIMULATIONS OF THE MODEL

UNITED STATES

TINPLATE PRODUCTION: 1955-75

(22) \[ \text{STPUS}_t = -18055.86 + 63.24198 \text{IMFBUS}^*_t + 17740.05859 \text{CANRAT}_t - 666.43 \text{DMYUSI} \]

\[ (6.32) \quad (6.31) \quad (2.94) \]

\[ R^2 = 0.71 \quad \text{S.E.E.} = 296.1 \quad \text{D.W.} = 2.05 \]

where: \( \text{STPUS} \) = Tinplate production (1000 MT)
\( \text{IMFBUS}^* \) = Index of Industrial Production for Manufactured Food Beverages and Tobacco (1970=100)
\( \text{CANRAT} \) = Ratio of shipments of tin cans to total cans' shipments
\( \text{DMYUSI} \) = Dummy variable for strikes in the fabricated metal industry

(23) \[ \log \text{CANRAT} = -0.11735 + 0.01559 \text{TIME} \]

\[ (11.64) \]

\[ R^2 = 0.91 \quad \text{S.E.E.} = 0.024 \]

WESTERN EUROPE

TINPLATE PRODUCTION: 1955-75

(24) \[ \text{STPEUR} = -225.93 + 50.30054 \text{IIPEUR}^*_t - 128.60156 \left( \frac{\text{PTIME}}{\text{PAUK}^*_t} \right) \]

\[ (3.39) \quad (2.87) \]

\[ R^2 = 0.97 \quad \text{S.E.E.} = 174.1 \quad \text{D.W.} = 1.33 \]

where: \( \text{STPEUR} \) = Tinplate production (1000 MT)
\( \text{IIPEUR}^* \) = Index of Industrial Production for Food, Beverages and Tobacco OECD Europe, 1970=100
\( \text{PAUK} \) = Aluminum price in UK ($/MT)

JAPAN

PRODUCTION OF TINPLATE: 1955-75

(25) \[ \text{STPJAP}_t = -402.875 + 23.29974 \text{IIPJAP}^*_t - 0.00389 \left( \frac{\text{PTJAP}}{\text{WPIJAP}^*_t} \right) \]

\[ (17.23) \quad (2.09) \]

\[ R^2 = 0.97 \quad \text{S.E.E.} = 112.3 \quad \text{D.W.} = 1.19 \]

where: \( \text{STPJAP} \) = Tinplate production (1000 MT)
\( \text{IIPJAP} \) = Index of Industrial Production for Food, Beverages and Tobacco (1970=100)
\( \text{WPIJAP} \) = Wholesale Price Index (1970=100)
\( \text{PIJAP} \) = LME tin price expressed in ¥/MT
Table II.1: MARKET PROSPECTS FOR TIN
(Prices in 1975 US$/mt; quantities in '000 mt)

<table>
<thead>
<tr>
<th>Year</th>
<th>No GSA Sales</th>
<th>Moderate GSA Sales</th>
<th>Heavy GSA Sales</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Price</td>
<td>Supply</td>
<td>Demand</td>
</tr>
<tr>
<td>1978</td>
<td>9,243</td>
<td>165</td>
<td>181</td>
</tr>
<tr>
<td>1979</td>
<td>10,959</td>
<td>174</td>
<td>176</td>
</tr>
<tr>
<td>1980</td>
<td>11,005</td>
<td>190</td>
<td>170</td>
</tr>
<tr>
<td>1981</td>
<td>10,269</td>
<td>204</td>
<td>174</td>
</tr>
<tr>
<td>1982</td>
<td>10,057</td>
<td>213</td>
<td>185</td>
</tr>
<tr>
<td>1984</td>
<td>10,856</td>
<td>222</td>
<td>200</td>
</tr>
<tr>
<td>1985</td>
<td>11,908</td>
<td>230</td>
<td>204</td>
</tr>
</tbody>
</table>

Assumptions

/a For a definition of stocks see equation (3.4).
/b 15,000 mt a year in 1978 and 1979, followed by 5,000 mt a year from 1980 to 1985.
/c 15,000 mt a year from 1978 to 1981, followed by 5,000 mt a year from 1982 to 1985.

These three price scenarios are based on medium GNP growth and inflation assumptions.