AGENCY FOR INTERNATIONAL DEVELOPMENT
WASHINGTON, D. C. 20523

# BIBLIOGRAPHIC INPUT SHEET

FOR AID USE ONLY

1. SUBJECT CLASSIFICATION

A. PRIMARY
Economics

B. SECONDARY
General Economics

2. TITLE AND SUBTITLE
The international tin agreement: a reassessment

3. AUTHOR(S)
Smith, G.W.; Schink, G.R.

| 4. DOCUMENT DATE | 5. NUMBER OF PAGES | 6. ARC NUMBER |
|---|---|---|
| 1975 | 21p. | ARC |

7. REFERENCE ORGANIZATION NAME AND ADDRESS
Program of Development Studies, 121 Sewall Hall, William Marsh Rice University
Houston, Texas 77001

8. SUPPLEMENTARY NOTES (Sponsoring Organization, Publishers, Availability)
(In Program of Development Studies paper no. 69)

9. ABSTRACT

The International Tin Agreement is widely viewed as having provided a respectable and fairly successful mechanism for stabilizing the international tin market. This paper draws upon simulations of the Wharton EFA world tin model to argue three basic points: (1) the Tin Agreement has only marginally reduced the instability of prices and producer incomes. Of far greater importance in this respect have been United States government stockpile transactions of tin made outside of the International Tin Agreement; (2) the ITA has endured while other agreements have failed, partly because the United States strategic stockpile of tin has deprived it of the effective power to make the critical price decisions which would have intensified producer-consumer conflicts; (3) if the ITA had been designed from the beginning as an effective market stabilizer, along the lines currently envisaged for other products, there is a good chance the ITA would have fallen apart. A side implication of the analysis is that meaningful reductions in price fluctuations for the more volatile metals may require far larger buffer stocks than have been suggested up to this point.

| 10. CONTROL NUMBER | 11. PRICE OF DOCUMENT |
|---|---|
| PN-AAB-621 | |
| 12. DESCRIPTORS | 13. PROJECT NUMBER |
| | 14. CONTRACT NUMBER CSD-3302 Res. |
| | 15. TYPE OF DOCUMENT |

AID 590-1 (4-74)

# RICE UNIVERSITY

**Houston, Texas**

## Program of Development Studies

PROGRAM OF DEVELOPMENT STUDIES
121 Sewall Hall
WILLIAM MARSH RICE UNIVERSITY
Houston, Texas 77001

Paper No. 69

# The International Tin Agreement: A Reassessment

by

Gordon W. Smith
and
George R. Schink

Fall, 1975

The authors are Associate Professor of Economics at Rice University; and Executive Director of the Commodities Division, Wharton Econometric Forecasting Associates, respectively.

Program Discussion Papers are preliminary materials circulated to stimulate discussion and critical comment. References in publications to Discussion Papers should be cleared with the authors to protect the tentative character of these papers.

## Abstract

### The International Tin Agreement: A Reassessment

The International Tin Agreement is widely viewed as a qualified, but respectable success. This paper draws upon simulations of the Wharton EFA world tin model to argue three basic points. (1) The Tin Agreement has only marginally reduced the instability of prices and producer incomes. Of far greater importance in this respect have been U.S. government stockpile transactions of tin made outside of the Tin Agreement. (2) The ITA has endured while other agreements have failed, in part because the existence of the U.S. strategic stockpile of tin has deprived it of the effective power to make the critical price decisions which otherwise would have intensified producer-consumer conflicts. (3) If the ITA had been designed from the beginning as an effective market stabilizer along the lines currently envisaged for other products, there is a good chance it would have fallen apart. A side implication of our analysis is that meaningful reductions in price fluctuations for the more volatile metals may require far larger buffer stocks than have been suggested to this point.

The International Tin Agreement: A Reassessment

Sources as diverse as Prime Minister Wilson and the UNCTAD now have presented their outlines for a more "rational" and "equitable" system of world trade in raw materials.[1] While conflicting in many important aspects, the proposals all give their support in principle to international producer-consumer commodity agreements (ICAs). Unfortunately, experience with the operation of such devices has been quite limited.

This paper presents a reassessment of the most durable of commodity agreements, indeed the only one which has functioned thus far in a non-agricultural product. The International Tin Agreement[2] (ITA) is broadbased, bringing together several East European nations and all the major non-communist producing and consuming countries except the United States. In its twenty years the ITA has employed the conventionally recommended buffer stocks and export quotas in an attempt to reduce price fluctuations and secure fair and remunerative prices for tin. The ITA is widely viewed as a qualified, but respectable, success.[3]

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*This paper was written while Smith was a senior international economist at the U.S. Treasury--OASIA/Research. He would like to thank Ryan Amacher, John Bushnell, J. Michael Finger, and Thomas D. Willett for comments and encouragement. Sole responsibility for the views expressed here is the author's.

[1]See, for example, World Economic Interdependence and Trade in Commodities, presented to Parliament by the Prime Minister, May 1975, esp. pp. 1-15; UNCTAD, An Integrated Programme for Commodities, TD/B/C.1/166, 9 December 1974.

[2]Four five-year agreements have been negotiated, the last expiring in 1976. For simplicity we refer only to the Tin Agreement.

[3]See, for example, William A. Fox, Tin: the Working of a Commodity Agreement (London: 1974), which presents the most detailed description and appraisal of the Tin Agreement; T. Geer, "The Post-War Tin Agreements: A Case of Success Price Stabilization of Primary Commodities," Schweizerische Zeitschrift fur Volkwirtschaft und Statistik, no. 2, 1970.

Is the ITA an example pointing the way to successful agreements in other commodities? In what follows we draw upon simulations of the Wharton EFA world tin model to argue three basic points. (1) The Tin Agreement has only marginally reduced the instability of prices and producer incomes. Of far greater importance in this respect have been U.S. government stockpile transactions of tin made outside of the Tin Agreement. (2) The ITA has endured while other agreements have failed, in part because it has lacked effective power to make the critical price decisions which otherwise would have intensified producer-consumer conflicts. (3) If the ITA had been designed from the beginning as an effective market stabilizer along the lines currently envisaged for other products, there is a good chance it would have fallen apart. A side implication of our analysis is that meaningful reductions in price fluctuations for the more volatile metals may require far larger buffer stocks than have been suggested to this point.

We turn now to the simulation results. A brief description of the Wharton EFA tin model appears in the appendix.

## The effects of the ITA and the U. S. strategic stockpile

Since the Korean War the two major nonmarket forces in tin have been the ITA, which attempts to contain price fluctuations between announced ceiling and floor prices, and the U. S. strategic stockpile of the metal. Our first set of simulations attempts to disentangle the impact of each stockpile for the period 1956-73. Two counterfactuals are produced. In the first, both stockpiles are removed from the tin market.[1] The second counterfactual eliminates only U. S. stockpile transactions (hereafter referred to as GSA, after the initials of the administering agency). The difference

[1] The effects of export quotas are not removed, however,

between the first simulation and the second measures the impact of the ITC buffer stock, a comparison of the second simulation and actual market behavior shows the effect of the GSA.[1]

ITA buffer stock authorizations have been moderately small, ranging between one and two months consumption over the four tin agreements.[2] Actual stocks, however, have usually been much smaller, approaching authorized levels only in the late 1950s.[3] In 28 of the 74 quarters between July 1, 1956 and December 31, 1974, the International Tin Council (ITC)[4] held less than 1,000 tons of tin, an amount clearly inadequate to defend ceiling prices.[5] Indeed, during the 4 years of greatest excess demand pressure, 1964-66 and 1974, the ITC held no tin at all.

Not surprisingly, then, our simulations indicate that the buffer stock's impact on real prices and producer incomes has been minor (see Table 1 and Graph 1). Small stocks suffer from one or more of three limitations. The permissible price band will have to be wide, target prices will have to follow shorter-term market pressures fairly closely, or market prices will move outside the permissible band. In each case, considerable price instability will remain, as it did in the simulation of the ITC buffer stock.[6]

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[1]The pricing sector of the tin model is such that stock sales and purchases at the price extremes have a greater impact than in intermediate ranges. By removing first the ITA and then the GSA, when they are acting in the same year, we obtain an upperbound on the effectiveness of the ITA buffer stock.

[2]That is, 20,000-25,000 tons.

[3]Unless otherwise noted, all data on the operation of the ITA are taken from UNCTAD Secretariat, Review of the Operation of the Fourth International Tin Agreement Concluded at the United Nations Tin Conference, 1970, TD/TIN.5/4, 2 April 1975.

[4]The governing body of the Tin Agreement.

[5]One explanation, that floor prices have been too low, is presented below.

[6]The suboptimal size of the buffer stock has been recognized before. See, for example, Meghnad Desai, "An Econometric Model of the World Tin Economy, 1948-1961," Econometrica, 34, 1 (January 1966), pp. 105-134.

TABLE 1: Simulations of the Impact of the International Tin Council and GSA Stock Behavior upon the Tin Market, 1946-73

| Variable/Simulation | No Stock activity | ITC Activity only | ITC and GSA stock activity |
|---|---|---|---|
| Average percentage annual change in real prices (absolute value)[a] | 10.4% | 9.4% | 6.9[illegible] |
| Discounted total producer revenue[b] (million 1967 $) | 7789.8 | 7789.9 | [illegible]332.6 |
| Standard error of the natural log of producer revenues around simulated trends[c] | .281 | .268 | .178 |

[a]Annual average LME tin price deflated by U.N. index of dollar price of exports of developed countries, adjusted for changes in the £/$ exchange rate.

[b]Total revenues were discounted back to 1956, using a 2 percent real discount rate.

[c]Trend estimated for each simulation by ordinary least squares in semi-log form, 1956-73.

The ITC was notably unable to defend its price ceilings. In fully 50 of the 222 months between the inception of the Agreement and December 31, 1974 average monthly had soared above ceiling levels.

Export quotas have been the other tool available to the ITC. During control periods maximum permissible levels of producer stocks are also specified.[1] Thus when controls are severe or prolonged, so that the upper stock limit is reached, export quotas become identical in effect to production controls. Severe quotas have been imposed in only one period, 1958-60, mainly

[1]See IMF-IBRD, "The Problem of Stabilization of Prices of Primary Products (Part I)," (Washington: 1969), p. 88. This provision appears in Article 39 of the new Fifth Agreement.

to offset the large sales Russia was making at that time in western markets. Subsequently when they were invoked, in late 1968, 1969 and 1973, quotas were so mild and/or evasion was sufficiently widespread that large effects on market prices were precluded.[1] It is impossible to determine within the Wharton model the exact impact of these mild export quotas on total producer and consumer stocks of tin and upon tin prices after controls were lifted (see Table 2 for the simulated effect of quotas on production). It should be pointed out, however, that these later quotas were somewhat misguided, in that they were imposed in times of incipient market shortages.[2] To the extent they were effective they may have increased rather than reduced market instability.[3]

TABLE 2: Simulated Effects of ITA Export Quotas on Tin Production (th. metric tons)

| | |
|---|---|
| 1968[a] | - .76 |
| 1969 | - 1.99 |
| 1973 | - .87 |

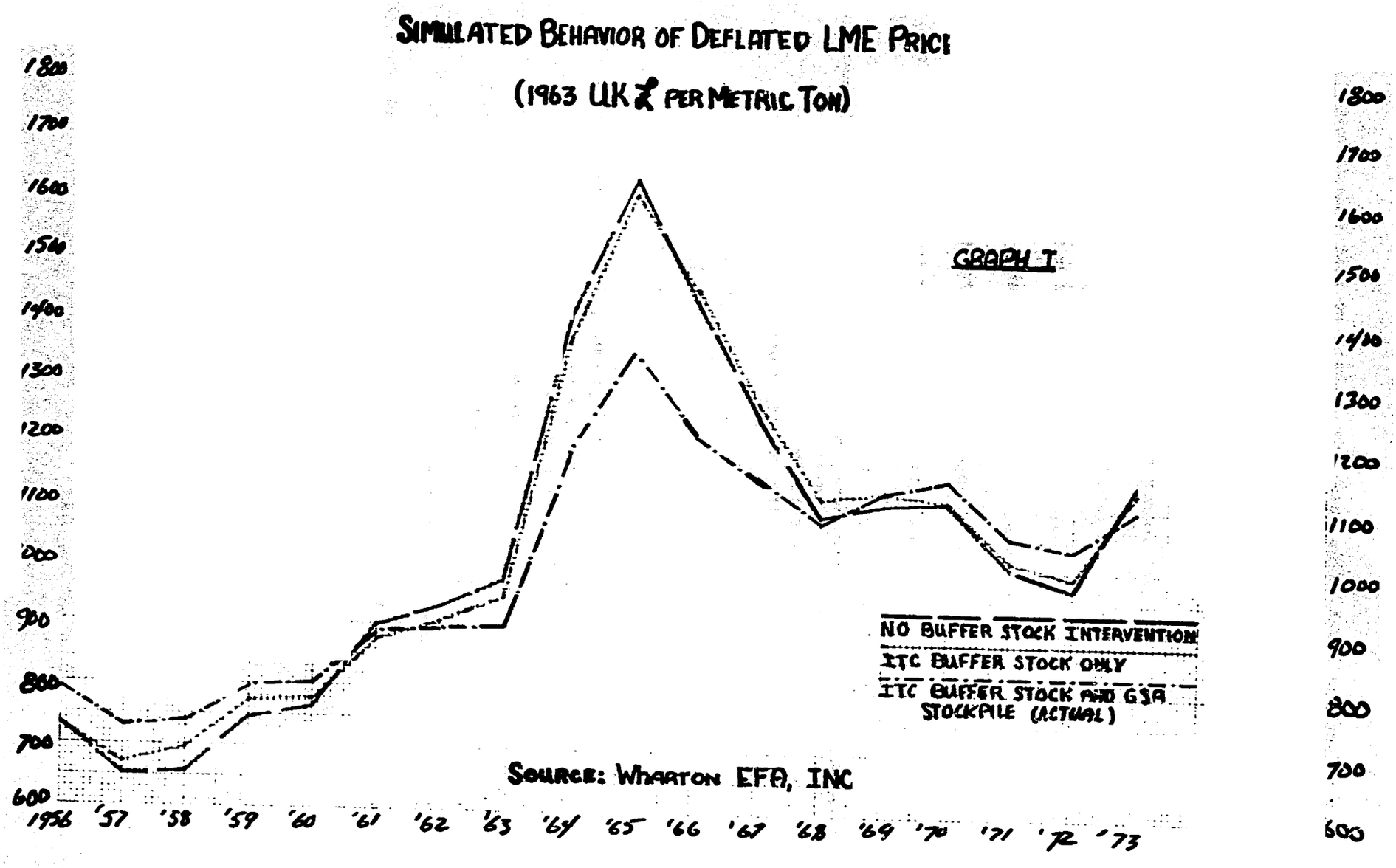
[a]Quotas were imposed in September, 1968. Figure shown is 1/4 of the annual effect of such quotas.
SOURCE: Simulations of the Wharton EFA world tin model.

Although the ITA has consistently failed to defend its ceiling prices, floor prices have been penetrated only once (September, 1958). Two factors probably explain this asymmetrical success. First, the ITC had the instrument, export quotas, which could (and did in the late 1950s) defend prices

[1]A short-term price run-up was provoked by the 1969 quotas, however. On the non-observance of quotas see William S. Fox, op. cit., p. 269.

[2]On this see William A. Fox, op. cit., pp. 372-73.

[3]For example, export quotas were in effect throughout 1969, even though the buffer stock sold almost 7.000 tons of tin that year.


SIMULATED BEHAVIOR OF DEFLATED LME PRICE
(1963 UK £ PER METRIC TON)
GRAPH I
NO BUFFER STOCK INTERVENTION
ITC BUFFER STOCK ONLY
ITC BUFFER STOCK AND GSA STOCKPILE (ACTUAL)
SOURCE: WHARTON EFA, INC
1800
1700
1600
1500
1400
1300
1200
1100
1000
900
800
700
600
1956
'57
'58
'59
'60
'61
'62
'63
'64
'65
'66
'67
'68
'69
'70
'71
'72
'73

against massive downward pressure. No doubt market participants recognized this power, so that destabilizing speculation against the floor was precluded.

More importantly, the ITC was usually defending a fairly low price band. Real average floor prices were more than 15 percent below ex post trend prices in 14 of 19 years, while ceiling prices were less than 15 percent above ex post trend prices in all but 3 of the years under consideration.[1]

TABLE 3: Relation of ITC Ceiling and Floor Price to Long-Run Trends[a] (Real 1967$)

| | Percentage that Average floor prices were below trend price | Percentage that average ceiling prices were above trend price |
|---|---|---|
| 1956 | 25.2 | 2.9 |
| 1957 | 21.3 | -2.5 |
| 1958 | 18.0 | -1.2 |
| 1959 | 19.0 | -2.5 |
| 1960 | 21.7 | -5.6 |
| 1961 | 24.4 | -8.8 |
| 1962 | 20.0 | -2.4 |
| 1963 | 22.2 | -5.2 |
| 1964 | 18.5 | -3.9 |
| 1965 | 9.3 | 8.9 |
| 1966 | 8.8 | 12.8 |
| 1967 | 6.6 | 19.4 |
| 1968 | 8.0 | 17.1 |
| 1969 | 13.5 | 15.2 |
| 1970 | 18.6 | 2.8 |
| 1971 | 17.8 | .4 |
| 1972[2] | 22.8 | -4.6 |
| 1973[2] | 26.5 | -10.2 |
| 1974[2] | 26.8 | -9.3 |

[a]Trend was estimated for 1961-73 in semi-log form, using real dollar prices calculated as explained in note (a) of Table 1.

[b]Years in which market price was above ITC ceiling during one or more quarters.

[1]See Table 3.

This suggests that the price band was generally below the levels warranted by long-run (upward) trends and is consistent with Fox's observation that the ITC followed rather than anticipated market forces in fixing its prices.[1] The low price band helps explain the usually small actual size of the buffer stock, the frequent penetrations of ceiling prices and, excluding the late 1950s, the generally minor pressures on the floor price.

In toto, then, it seems that except in the late 1950s the combined buffer stock operations and export controls have been relatively minor factors in the tin market. One reason is that the four tin agreements have all operated in the shadow of the U. S. "strategic stockpile" of tin. This stock, formed in the late 1940s and early 1950s, was to be of a size sufficient to maintain U. S. consumption of tin at normal levels during a four-year war in which all foreign sources of the metal were cut off! This objective implied a stock which exceeded total annual western world consumption of tin in every year, 1952-73.[2] The U. S. began using the tin stockpile as a market stabilizer in the mid and late 1950s and has done so periodically ever since.[3]

The nearly absurd size of the stockpile was recognized by the early 1960s. Since then, the long range U. S. goal, which resulted in total net sales of 120,000 tons, 1956-74, has been to reduce its tin stock gradually by selling mainly during periods of very high prices. The simulations indicate that the GSA had much greater effect than the ITC buffer stock.[4]

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[1] See William S. Fox, op. cit., p. 391.

[2] See Table 4.

[3] See Table 4.

[4] See Table 1 and Graph I.

TABLE 4: Annual Western World Tin Consumption
and Stock Sales (+) or Purchases (-)
International Tin Council Consumption
U.S. General Services Administration
th. metric tons

| | ITC | Consumption | GSA | Total GSA Stock (end of year) |
|---|---|---|---|---|
| 1956 | 0 | 153.7 | -19.5 | 347.0 |
| 57 | -15.5 | 150.4 | -4.0 | 351.0 |
| 58 | -8.2 | 143.1 | 0 | 351.0 |
| 59 | 13.5 | 149.9 | -1.8 | 352.8 |
| 60 | 0 | 159.7 | -5.2 | 357.8 |
| 61 | 10.2 | 158.8 | 2.8 | 355.1 |
| 62 | -3.3 | 163.3 | 2.2 | 352.9 |
| 63 | 3.3 | 166.9 | 10.0 | 342.8 |
| 64 | 0 | 172.3 | 29.1 | 313.7 |
| 65 | 0 | 171.5 | 24.4 | 289.3 |
| 66 | 0 | 172.7 | 16.4 | 272.9 |
| 67 | -4.8 | 172.2 | 7.4 | 265.5 |
| 68 | -6.6 | 175.5 | 3.6 | 261.9 |
| 69 | 6.8 | 183.5 | 1.7 | 260.2 |
| 70 | 3.5 | 183.4 | 3.5 | 256.7 |
| 71 | -5.4 | 185.7 | 1.8 | 254.9 |
| 72 | -5.8 | 186.4 | .2 | 254.7 |
| 73 | 11.5 | 202.4 | 19.6 | 235.1 |
| 74 | negligible | n.a. | 27.7 | 207.4 |

SOURCES: Metallgesellschaft A.G., Metal Statistics; International Tin Council; GSA; Bureau of Mines, "Mineral Industry Surveys: Tin."

Not only were price fluctuations reduced substantially by GSA activity, but year-to-year instability in producer income around its simulated trend were less than with the ITA alone.

The U. S. actions have received little praise from tin producers, however. Eighty percent of U. S. tin sales came from stocks formed before 1956. Hence, the GSA brought not only greater stability but also significantly lower total producer incomes in the period simulated.[1] Furthermore, the uncertainties created by possible changes in U. S. disposal policy were bound

[1] 5.9 percent lower in $1967, at a 2 percent real discount rate.

to produce some resentment in tin producers. When the U. S. did in fact sell heavily in 1973-74, an ex-secretary of the International Tin Council wrote:[1]

> This (tin) industry--with its long and unique record of international cooperation aimed at securing at least a degree of order in a market notoriously disorderly--deserved something better than to have thrown upon it the consequences of the massive disposal of a strategic stockpile which had been built up unnecessarily and perhaps even irresponsibly 20 and even 30 years earlier.

By this point it should be clear that the Tin Agreements have been rather special arrangements. Given the small ITC buffer stock and potential "veto" of U. S. stockpile sales, the effective power of the International Tin Council has been quite restricted, and its decisions have not usually been very critical. Indeed, it seems fair to say that the longevity of the Tin Agreement owes a good deal to its very ineffectiveness. The normal producer-consumer conflicts which have led to the breakdown of other agreements (or have prevented their negotiation) have not surfaced to nearly the extent they would have in the absence of the U. S. tin stockpile. Producers realized that a push for high floor prices, after the manner of a producer cartel, would probably have brought the GSA into the market. Consumers, on the other hand, knew that they could rely on GSA sales to mitigate the largest penetrations of the ceiling. Hence, they did not press as much as they otherwise would have for larger, more effective buffer stocks.

These two items of conflict, the height of the floor price and the size of the buffer stock (and its financing) were thus greatly mitigated by the GSA stockpile. Indeed, they tended to take the form of "consultations" and diplomacy between tin producers and the U. S. government rather than debates within the Tin Council itself. The outcome has been a loose, informal

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[1] William A. Fox, op. cit.

"commodity agreement" in which the GSA defended fairly high, but unknown ceiling prices and the ITA, fairly low, known floor prices. The effective price band was quite wide (± 20 to 25 percent around long-run trends), but market instability was reduced significantly.

Still, the existence of the GSA stockpile was the key to the arrangement. To illustrate the problems which an effective tin agreement without the GSA would have faced we turn to our second set of simulations. They re-run history on the assumption that the U. S. strategic stockpile contin to be held in its entirety for strategic purposes. In other words, the GS is eliminated as a factor in the market.

In place of the ITA we substitute an ambitious, "balanced" producer-consumer agreement.[1] Most economists, could probably agree that a "balanced" agreement would seek to stabilize prices within a range around longer-run (moving) equilibrium levels. This goal precludes extensive recourse to export controls, which can reduce supply in times of glut, but do little to increase supply in times of scarcity.[2] Hence the main tool of our balanced agreement is a buffer stock.[3]

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[1]This may not be entirely possible within the framework of the Wharton EFA model. Supply elasticities of tin may have been lowered by the size of the U. S. stockpile, while private stocking behavior may well change with an effective ITA buffer stock.

[2]Technically, export quotas permit stock accumulation in producer countries. But if quotas are severe, or are expected to be prolonged, there is little incentive for private firms to increase their stocks rather than lower their output. Of course, producer governments may choose to operate a domestic buffer stock during export control periods. But this alternative merely shifts the financial burden of stocks from the international agreement to producer governments in an unpredictable fashion, and has little to recommend it over an explicit buffer stock arrangement.

[3]The simulations retain export quotas as they were actually imposed however. Most importantly, the severe quotas of 1958-60 were allowed to defend the floor against Russian sales.

Many buffer stock rules could be analyzed in considerable detail. For present purposes, a very simple approach will suffice. The simulations determine ex post the set of buffer stock actions which would have been required to maintain real annual market prices within bands of ± 5, 10, and 15 percent around actual trends. Since this procedure basically abstracts from uncertainty, the results can be considered minimum requirments for the specified stabilization goals. The price bands simulated include the range of reasonable targets. Stabilization greater than ± 5 percent would probably be too costly, while a band much wider than ± 15 percent hardly seems worth the effort.

Table 5 and Graph II summarize the simulations. The 5 percent rule turns out to be the most interesting for present purposes.[1] Initial required stocks are minimal (6,500 tons).[2] The buffer stock makes a small real profit, discounted producer revenue for the period as a whole is higher than it was in fact and the same as it would have been with no stock activity at all. Price fluctuations and producer income instability are both reduced markedly. In retrospect, this would have been an agreement near the ideal.

But there are two reasons to doubt whether in the real world of uncertainty and impatience anything approaching the magnitude of even this minimal agreement would have been negotiated and implemented. First, there

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[1] We do not mean to suggest, however, that the ± 5 percent rule is best for the future or that it would have been the best ex ante rule as of 1956.

[2] The initial stock rises with the width of the band because less tin is bought in the early years in support of prices. If 1974 had been included in the simulation, the ± 5 percent rule would have required larger initial stocks to defend the ceiling in the terminal year. Lack of data prevented the simulation of 1974.

TABLE 5: Simulations of the Impact 1956-73 of Hypothetical Buffer Stock to Maintain Real LME Price within ±5, 10, 15% around Trend[a]

| Variable/Simulation | 5 % | 10 % | 15 % |
|---|---|---|---|
| Average Annual Percentage Change in Real Prices (absolute value)[b] | 4.8 % | 5.8 % | 6.6 % |
| Discounted Real Producer Revenue (million 1967 $)[c] | 7729.2 | 7558.3 | 7407.5 |
| Discounted Real Buffer Profit[d] (million 1967 $) | 24.3 | 48.3 | 73.6 |
| Maximum Stock Reached (m.t.) | 104,000 | 113,400 | 111,700 |
| Initial Stock (m.t.) | 6,500 | 41,830 | 71,700 |
| Terminal Stock (m.t.) | 0 | 0 | 0 |
| Standard Error of the natural log of Producer Revenues Around Simulated Trends[e] | .159 | .154 | .155 |

---

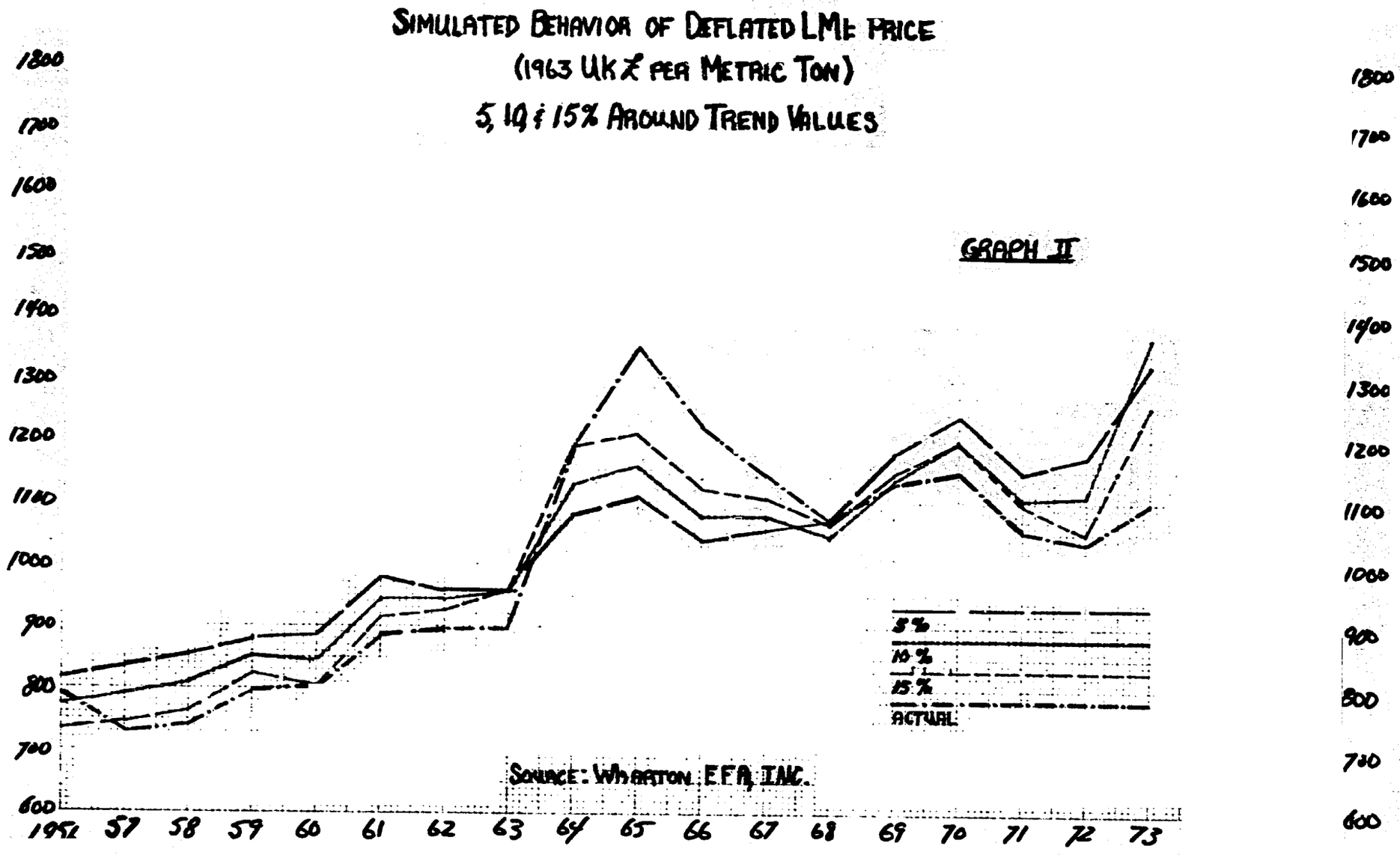
[a]Trend is for years 1961-1973, estimated by least squares in semi-log form.

[b]Annual average LME tin price deflated by U.N. index of dollar price of exports of developed countries, adjusted for changes in the £ / $ exchange rate.

[c]Total revenues were discounted back to 1956, using a 2 percent real discount rate.

[d]2 percent real discount rate, a 1 percent ad valorem transactions costs and a .25 percent ad valorem storage cost, all per annum, were assumed. Profits=(Sales-operating costs-value of initial stock + value of terminal stock)--all in $1967 and discounted back to 1956.

[e]Trends estimated for each simulation by ordinary least squares in semi-log form.


SIMULATED BEHAVIOR OF DEFLATED LME PRICE
(1963 UK £ PER METRIC TON)
5, 10 & 15% AROUND TREND VALUES
GRAPH II
5%
10%
15%
ACTUAL
SOURCE: WHARTON EFA, INC.
1800
1700
1600
1500
1400
1300
1200
1100
1000
900
800
700
600
1956
57
58
59
60
61
62
63
64
65
66
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68
69
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71
72
73

is the size of the required stock. It exceeded 100,000 tons, even in the ±15 percent rule, for four consecutive years, 1960-63. This was almost seven months western world consumption, far larger than has ever been contemplated in tin, four times the authorized stock of the first agreement, and 2-1/2 times the level proposed in the draft of the fifth agreement.[1] In relation to consumption, such a stockpile is also much larger than any of the current proposals for the other minerals.[2]

Secondly, the problem of stock size is aggravated by the fact the first sale from stocks in each of the three rules occurs only in the ninth year of operation, 1964. Up to that time, all buffer stock transactions were in support of the floor price. Surely before 1964 consumer nations would have begun to suspect that the agreement was one-sided in favor of producers and would either have withdrawn or forced substantial cuts in target prices required for longer-term stabilization.

Thus it appears that an effective and "balanced" tin agreement in the absence of the GSA would have required a far greater financial commitment and considerably longer time horizon than could reasonably have been expected from governments.

## Conclusions

We conclude that supporters of commodity agreements can take small encouragement from the experience with tin. The longevity of the ITA may stem in good part from its relative powerlessness, while the major factor stabilizing the market since 1960, U. S. strategic stockpile, owes its existence to miscalculation. An effective tin agreement in the absence of the GSA would have required a commitment of resources and patience not likely to have been forthcoming.

[1] Desai, op. cit., writing in the early 1960s, recommended a 35,000 ton buffer stock, but he permitted extensive recourse to export controls.

[2] For example, UNCTAD recommended between one and two months buffer stocks for copper, lead and zinc. See UNCTAD, op. cit., Supp. 1, p. 22.

## Appendix

### Wharton EFA World Tin Market Model[1]

The tin model utilized for this study is basically a supply-demand model with a market clearing equation for prices. Most of the 25 behavioral equations are estimated by two-stage least squares, using annual data for 1950-1972. Data points for 1973 are included in the estimation of the price equations so as to have such equations reflect the large price rises in 1973.

Supply equations for mined tin-in-concentrates are separately estimated for the following major producing sectors: Malaysia, Indonesia, Bolivia, and Africa, which, all together, account for 86 percent of Western World production in 1973. The residual supply category ("Rest-of-Western World") is also modeled to arrive at an aggregate total for Western World tin mine production. The specification of these supply equations includes a distributed lag structure on the response of mine producers to the real price of tin (an export price index for developed countries is used as a deflator for nominal tin price to reflect the purchasing power of tin exports in terms of the amount of industrial commodities which can be purchased), and the impact of export controls imposed by the International Tin Council on primary producing countries. Equations are estimated relating the U.S. recovery of secondary tin from new scrap and from old scrap to the real price of scrap tin and present and lagged U.S. tin consumption.

On the demand side, consumption of tin in the various regional demand sectors is disaggregated by enduse. The four basic demand sectors in the model for the Western World consumption of tin are the United States, Western Europe (including the U.K.), Japan, and the rest of Western World. U.S, consumption demand is broken down into three enduse categories: tinplate, solder, and

[1]This model was initially constructed in 1974 under contract to the General Services Administration.

others. The disaggregation for western Europe as well as for Japan is in terms of tinplate and non-tinplate uses. For the residual category, no disaggregation is applied.

In all the demand equations, attempts were made to model the effects of changes not only in the real price of tin but also in the real prices of substitutes such as aluminum and of complements such as steel, lead, copper, and zinc. The estimated demand functions that we have used for the model, judged best to reflect the structure of the market, contain the price of tin either in real terms or relative to aluminum price. The real price of hot-rolled steel strips, which are the major component of tinplate, also appears significantly in some of the equations for the U. S. sectors.

Together with the above price variables, relevant activity variables are used in the demand equations of the model. In the case of consumption demand for tin used in the production of tinplate, the activity variables used are the industrial production of or gross product originating from food, beverages and tobacco. For the non-tinplate enduse categories, the activity variables appearing in the model include motor vehicle production, new construction put in place, and output of fabricated metals and electrical machinery. These reflect the various manufacturing sectors where solder, brass and bronze are used. Furthermore, the effects of the technical substitution of the electrolytic for the hot-dipped process of tinplate production are incorporated into the demand equations as well as the substitution effects of the use of aluminum cans in place of tin cans.

The crucial equation in the model is the behavioral equation for the LME price of tin deflated by a pound sterling index for the unit value of exports of developed countries. This provides the market clearing equation which reconciles the supply and demand relationships through the reactions of the

real price of tin to changes in tin stocks. Other market prices in nominal terms (New York and Penang) are linearly related in the model to the LME nominal price. The high correlation observed between the LME price and either the New York or Penang price indicates that while there may be short-run discrepancies in the fluctuations of these three market prices, these differences are smoothed out when yearly price averages are calculated. The LME real price equation used in the model is actually an average of two estimated equations: (1) a function of the lagged real tin price and the ratio of Western World stocks of tin to current tin sales; and (2) a function of the lagged real tin price and the inverse of the above ratio. This combination of functions was incorporated in the analysis to allow sharp price responses to both exceptionally high and exceptionally low stock levels relative to tin sales. Tin sales are defined as production of tin in concentrates less changes in producers stocks and International Tin Council (ITC) stocks.

Sample period (1956-1972) simulations of the estimated model generate error statistics and time paths for crucial behavioral variables which are within reasonable limits. The crucial variables in the model are the real London Metal Exchange price of standard cash tin, total Western World consumption of primary and secondary tin, and total Western World stocks of tin. The long=run dynamic simulation of the model from 1956 to 1972 exhibits mean absolute percentage errors of 6 percent for the LME real tin price, 2 percent for world production and world consumption of tin, and 13 percent for world tin stocks.

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