AGENCY FOR INTERNATIONAL DEVELOPMENT
WASHINGTON, D. C. 20523

BIBLIOGRAPHIC INPUT SHEET

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1. SUBJECT CLASSIFICATION

A. PRIMARY: Economics

B. SECONDARY: General Economics

2. TITLE AND SUBTITLE

Optimization rules for producer groups in a stochastic market setting, with application to the copper and tea markets

3. AUTHOR(S)

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4. DOCUMENT DATE	5. NUMBER OF PAGES	6. ARC NUMBER
1975	17 p.	ARC

7. REFERENCE ORGANIZATION NAME AND ADDRESS

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8. SUPPLEMENTARY NOTES *(Sponsoring Organization, Publishers, Availability)*

9. ABSTRACT

The success of the Organization of Petroleum Exporting Countries (OPEC) has generated much discussion and controversy about the possibility of other international primary commodity producer cartels. This study develops a framework within which to measure, at least to a first approximation, the expected return to a primary commodity producer cartel and actually to calculate, within this framework, the expected return to various proposed cartels. A partial adjustment model was used which results in supply equations in which current supply depends on the current real price and once-lagged production. These equations were estimated by instrumental variables and by a method which yields consistent estimaters in a system with lagged endogenous variables and autocorrelated error terms. A demand for private stocks equation also is estimated. Results show that for a tea cartel consisting of India, Sri Lanka, and the main East African tea producers, the gain seems large enough and the number of countries small enough, it might succeed. But for a copper cartel consisting of all primary copper-producing countries except the United States and Canada, there does not appear to be a large enough return to justify its formation.

10. CONTROL NUMBER

PN-AAB-935

11. PRICE OF DOCUMENT

12. DESCRIPTORS

13. PROJECT NUMBER

14. CONTRACT NUMBER

CSD-2815 211(d)

15. TYPE OF DOCUMENT

AID 590-1 (4-74)

CSD-2815 211(d)
PN-AAB 935

Optimization Rules for Producer Groups in a Stochastic Market Setting, with Application to the Copper and Tea Markets (summary)

John M. Underwood

I. Introduction

A. International Producer Cartels

The Organization of Petroleum Exporting Countries (OPEC) has been extremely successful as an international cartel. It has raised substantially the price of a primary commodity to the benefit of its members. The success of OPEC has generated a great deal of discussion and controversy about the possibility of other international primary commodity producer cartels.

Many people have argued that such cartels in the future will be the rule rather than the exception. For example, C. Fred Bergsten[1] has stated that the criteria for the success of OPEC imitators are met by a wide range of agricultural and mineral products. Others, however, argue that the producers of few, if any, other commodities can successfully form a cartel.[2]

B. The Present Study

In spite of the intense argument over other OPEC's in our future, there have been very few, if any, attempts to actually measure the expected return to a cartel set up by the producers of any other primariy commodity. Therefore, the purpose of this study is to develop a framework within which to measure, at least to a first approximation, the expected return to a primary commodity producer cartel and to actually calculate, within this framework, the expected return to various proposed cartels.

The results from this study can be compared with the assertions that are presently being made about the possibility of the success of

such cartels. The experience gained here may suggest where more work needs to be done to further refine and increase our ability to tell whether and why primary commodity producer cartels might or might not succeed.

II. Commodity Markets Studied

A. Tea

Tea is a perennial tree crop that grows best in very warm, very wet environments. The tea plant takes about four years after planting to produce significant output and has a total producing life of about fifty years. Tea production is concentrated in a relatively small number of countries, mainly in South Asia and Africa. The two major producers are India and Sri Lanka. Together they account for more than half of current black tea production. Since World War II, tea production in East Africa has increased significantly. Tea consumption is also relatively concentrated. Almost half of the (black) tea produced is consumed in two countries, India and the United Kingdom. The United States, Canada and Australia are also important tea consuming countries.

The tea model estimated is an annual, linear simultaneous equations model of the world (black) tea economy. Black tea is by far more important than green tea in world trade. Green tea exports account for only about ten percent of total tea exports. (Exports of green tea from the traditional green tea consuming area are included in the supply of tea from the rest of the world in the model.)

Demand equations are estimated for India, the United Kingdom, the United States, Australia, Canada and the rest of the world. Demand is assumed to be a function of the real price of tea, the real price of coffee, real national income and population. These equations are estimated either by

instrumental variables or a two-stage principal components procedure.[3] Supply equations are estimated for India, Sri Lanka, East Africa, Indonesia and the rest of the world. A partial adjustment model suggested by Fisher, Cootner and Baily was used.[4] The partial adjustment model results in supply equations in which current supply depends on the current real price and once-lagged production. These equations were estimated by instrumental variables and by a method recommended by R. C. Fair[5] which yields consistent estimators in a system with lagged endogenous variables and autocorrelated error terms. (Fisher, Cootner and Baily suggest that the error terms in the partial adjustment supply equations might be expected to be autocorrelated.) A demand for private stocks equation is also estimated. The level of stocks is assumed to be a function of the real price of tea and the once-lagged values of stocks and world demand. This may be thought of as a partial adjustment model of the demand for stocks. It is estimated by instrumental variables and by the method suggested by R. C. Fair.

B. Copper

An already estimated copper model was used (with a few changes), "An Econometric Model of the World Copper Industry," by F. Fisher, P. Cootner and M. Baily.[5a] (Henceforth, this is referred to as the FCB model.) It is an annual model with primary supply equations estimated for major producing areas, secondary supply equations for major consuming areas, demand equations for major consuming areas, three price equations and and equation for U.S. net imports.

In recent history, copper has moved in two geographically separate, only partially linked markets. One market is basically the United States while the other takes in most of the rest of the world. The U. S. price

price is determined for the most part on the London Metal Exchange and has been historically quite volatile. There have been episodes, some lasting years, where the U. S. producers' price was substantially lower than the LME price. Currently the London Metal Exchange price is substantially lower than the U. S. price.

How can this two price system be explained? It is probably made possible by the high degree of concentration in the production of primary copper in the U.S. In 1968, three vertically integrated (through refining) firms (Phelps, Dodge; Kennecott and Anaconda) held 88 percent of domestic refining capacity. Richard Cooper and Robert Lawrence offer this explanation for the existence of a relatively stable and often low U.S. price versus a volatile world price for copper. They say, "The answer lies, we think, in the presence of implicit long-term futures contracts designed to reduce uncertainty both for buyers and for sellers, so that both parties forego short-run maximization behavior for the sake of long-run security."[6]

Both demand and supply equations were assumed by FCB to be of the lagged adjustment variety discussed earlier. Therefore, most equations in the model were estimated by the method suggested by R.C. Fair.

III. Method of Calculation of Expected Gain

A. Description of the Model

The criterion chosen for optimization here is the present discounted value of total export earnings. Some justification must be given for using foreign exchange earnings as the welfare measure. As H. G. Johnson points out, "Maximizing real income is not the same thing as maximizing foreign exchange earnings, unless the resources employed in primary production have no alternative opportunity cost or alternative use. Otherwise, as standard monopoly theory demonstrates, the optimal

policy involves restricting output below the level that would maximize total revenue."[7] He goes on the say that, "Since it is impossible to ascertain whether less developed countries are over- or under-exploiting their monopoly power in commodities with elastic demand, while they must be under-exploiting it for commodities with inelastic demands in the current price range, it seems reasonable pending further research to accept maximization of foreign exchange earnings as a safe minimal standard for optimal commodity agreement policy, and inelasticity of demand at current prices as a criterion for selection of commodities for agreements in spite of the theoretical objections to these standards."[8]

This welfare measure will be seen to be very convenient in what follows. It is quadratic in the control variable to be used, an export tax. This helps us to find a unique global maximum of expected welfare.

The agreement is assumed to be of finite duration for two reasons. First, it seems to be realistic that countries are not usually willing to enter into very long term agreements. For example, the tin agreement is renegotiated every five years. Second, we would not expect the estimated world commodity market models to be useful for the very long run.

We want to fit the estimated copper and tea models into the linear system, quadratic cost (in this case quadratic "return") stochastic control framework. We want all current state variables to be linear, stochastic functions of last period's state variables. This means that some method must be used to update the exogenous variables in each model, variables like indices of industrial production, GNP's and population figures. It was decided to treat these as first order autoregressive processes, and such processes were estimated by ordinary least squares. One additional set of

problems remains to be solved before the tea and copper models can be fit into the optimizing framework. Almost all demand and supply equations were estimated using different price variables. For example, the Japanese consumption of copper was assumed to be a function of the London Metal Exchange price of copper converted to Japanese yen and deflated by the Japanese wholesale price index. We would like to have all prices of copper in terms of real U.S. dollars. To do this, we make the assumption that the ratio of wholesale price indices in two countries times the exchange rate for their two currencies remains constant throughout the period of the commodity agreement. In the case of the Japanese example, we have:

$$PCU_t^J = (PCU_t^{LME} \times EJUS_t \times EUSUK_t) / JWPI_t$$

$$= (PCU_t^{LME} \times EUSUK / USWPI_t)(EJUS_t)(USWPI_t / JWPI_t)$$

$$= USPCU_t^{LME} [(EJUS_t)(USWPI_t / JWPI_t)]$$

It is assumed that the term in brackets in the last line remains constant. Similar assumptions about price levels and exchange rates are made in connection with the tea model.

Now, standard stochastic control techniques can be used to calculate the optimal expected return to a tea or copper cartel.[9] The expected return with no cartel can be calculated using the same techniques by setting the control variable, the export tax, identically equal to zero. The difference between the expected returns with and without a cartel is the expected gain due to the cartel.

Both the tea and the copper model have some equations in which it was assumed that the error terms were autocorrelated and coefficients of autocorrelation were estimated. By augmenting this year's state variable by including in it last year's state variable and last year's export tax, the information about the coefficients of autocorrelation can be included in the standard stochastic control model discussed above.[10] We can then compare the results obtained when the autocorrelation is ignored with the results obtained when the estimated coefficients are used.

IV. Results

A. Tea Cartel

The ten-year expected return to a tea cartel consisting of India, Sri Lanka and the major East African tea producing nations, operating from 1972 to 1981, measured in terms of the present (in 1971) discounted value of export earnings, is about one billion real (1967) U.S. dollars. This represents approximately a 29% increase over the no-cartel value of expected discounted export earnings during the same ten year period. (See Table 1.) The ten-year expected return to a tea cartel consisting of only India and Sri Lanka is about 250 million real (1967) U.S. dollars. This is approximately a 10% increase in expected export earnings from tea for these two countries over the ten years from 1972 to 1981. (See Table 3.)

Assuming that the gains due to a cartel are split such that each country has a 29.5% increase[11] in expected tea export earnins, the gains in total export earnings as a percentage of average total export earnings would range from 1.0% for Tanzania to 13.3% for Sri Lanka. (See Table 1A.) The gain seems large enough and the number of countries small enough that perhaps a tea cartel consisting of India, Sri Lanka and the main East African tea producers might succeed.

B. Copper Cartel

The expected ten-year (1969-78) return to a copper cartel consisting of all primary copper producing nations except the United States and Canada, measured in terms of the (1968) discounted value of export earnings, is about 800 million (1967) dollars. This represents approximately a 2.5% increase over the no-cartel value of discounted export earnings during the same period. (See Table 5.)

The expected increase in copper export earnings due to a cartel as a percentage of average total export earnings ranges from 2.3% for Zambia to 0.6% for Peru. (See Table 5A.) This does not appear to be a large enough return to justify the formation of a copper cartel.

C. A Comparison

It is interesting to compare the results here with some earlier speculation on the success of tea or copper cartels. Stern and Tims[12] gave a tea cartel little or no chance of success. However, they thought a copper cartel had a fair chance of realizing a sizeable short-term gain. In the present study, the conclusions would be just the opposite. There would perhaps be a chance for a tea cartel to be successful, but a copper cartel would have little or no future.

1/ See Bergsten, C. F., "The New Era in World Commodity Markets," Challenge, September- October, 1974, 34-42.

2/ See Mikesell, R. F., "More Third-World Cartels Ahead?" Challenge, November-December, 1974, and Varon, B., and Takeuchi, K., "Developing Countries and Non-Fuel Minerals," Foreign Affairs, April, 1974.

3/ See Johnston, J. Econometric Methods, p. 393 for a discussion of this method of estimation.

4/ See Fisher, F., Cootner, P., and Baily, M., "An Econometric Model of the World Copper Industry," Bell Journal of Economics and Management Sciences, Autumn, 1972, pp. 568-609.

5/ See Fair, R. C., "Estimation of Simultaneous Equation Models with Lagged Endogenous Variables and Autocorrelated Errors, " Econometrica, May, 1970, pp. 507-517.

5a/ See footnote 4.

6/ See Cooper, R., and Lawrence, R., "The 1972-75 Commodity Boom," mimeographed, presented at the Brookings Panel on Economic Activity,Washington, D.C., December 4-5, 1975.

7/ See Johnson, H. G., Economic Policy Toward Less Developed Countries, p. 155.

8/ ibid, p. 156.

9/ See, for example, Aoki, M., Optimization of Stochastic Systems, Chapter II, or Chow, G., Analysis and Control of Dynamic Economic Systems, Chapter 8.

10/ Exactly how this is done is discussed in detail of Chapter V of the complete paper.

11/ This is the expected gain to a tea cartel using a discount factor of 1/1.1 and taking into account estimated coefficients of autocorrelation.

12/ See Stern, H. and Tims, W.,"The Relative Bargaining Strengths of the Developing Countries," mimeographed, presented at the American Economic Association meetings, San Francisco, December 1974.

Table 1

Expected Return to an India-Sri Lanka-East Africa Tea Cartel
(In millions of 1967 dollars)

A. Discount facotr: 1.0/1.1

	10-yr. Cartel-No Autocorrelation	10-yr. Cartel-Autocorrelat
Optimal Return	4,340	4,264
No-cartel Return	3,380	3,293
Gain due to Cartel	960 (28.4%)	971 (29.5%)

B. Discount factor 1.0/1.05

Optimal Return	5,449	5,361
No-cartel Return	4,264	4,164
Gain due to Cartel	1,185 (27.8%)	1,197 (28.7%)

Table 1A

Tea Exports as a Percent of Total Export Earnings[1]
1972-74
(except where noted)

	Tea Earnings a Percent of total	(Expected Tea Earnings as a Percent of Total[4])
India	10.1	(3.0)
Sri Lanka	45.1	(13.3)
Kenya	13.7	(4.0)
Malawi	17.8	(5.3)

TABLE 2

Tea Model

India - Sri Lanka - East Africa Cartel
Expected Cartel vs. No Cartel Values of Selected State
Variables - 1976
(In thousands of metric tons except where noted)

	Expected-cartel[1]	Expected-no cartel[1]	Actual 1971 values
price ('63 new pence/kg.)	49.54	29.85	29.05
Total Consumption[2]	965.9	1,003.5	941.0
U.K. Cons.	195.8	201.1	208.0
U.S. Cons.	68.0	75.1	79.5
Canadian Cons.	17.6	19.5	21.3
Australian Cons.	23.5	25.0	28.3
Indian Cons.	237.2	256.8	220.6
Rest-of-World Cons.	423.9	426.0	383.3
Total Production[2]	966.7	1,004.2	940.0
Cartel Production[2]	663.7	846.1	753.3
Indian Prod.	345.8	466.6	435.5
Sri Lanka Prod.	167.2	213.8	217.8
East Africian Prod.	150.7	165.7	100.0
Rest-of-World Prod.	303.0	158.1	186.8
Export tax ('63 new pence/kg.)	39.21		

1/ These are values from the calculation using the discount rate of 1/1.1 and taking into account estimated coefficients of autocorrelation.

2/ Details may not add to totals because of rounding.

TABLE 3

Expected Return to an India-Sri Lanka Tea Cartel
(In millions of 1967 dollars)

Discount factor: 1.0/1.1

	10-yr. Cartel-No Autocorrelation	10-yr Cartel-Autocorrelation
Optimal return	2,758	2,625
No-cartel return	2,493	2,377
Gain due to cartel	265 (10.6%)	248 (10.4%)

TABLE 4

Tea Model

India - Sri Lanka Cartel
Expected Cartel Vs. No-Cartel Values of
Selected State Variables - 1976
(In thousands of metric tons except where noted)

	Expected-cartel[1]	Expected-no cartel[1]	Actual 1971 Value
price ('63 new pence/kg)	41.10	29.85	29.05
Total Consumption[12]	987.3	1,003.5	941.0
U.K. Cons.	198.8	201.1	208.0
U.S. Cons.	72.0	75.1	79.5
Canadian Cons.	18.7	19.5	21.3
Australian Cons.	24.4	25.0	28.3
Indian Cons.	248.3	256.8	220.6
Rest-of-World Con	425.1	426.0	383.3
Total Production[2]	988.0	1,004.2	940.0
Cartel Production[2]	595.2	680.4	653.3
Indian Prod.	405.2	466.6	435.5
Sri Lanka Prod.	190.0	213.8	217.8
East African Prod.	170.7	165.7	100.0
Rest-of-World Prod	222.1		186.6
Export tax ('63 new pence/kg)	18.18		

1/ These are values from the calculation using the discount rate of 1/1.1 and taking into account estimated coefficients of autocorrelation.

2/ Details may not add to totals becuase of rounding.

TABLE 5

Expected Return to a Copper Cartel
(in millions of 1967 dollars)

1. Discount Factor: 1.0/1.1

	10-yr. Cartel-No Autocorrelation	10-yr. Cartel-Auto correlation
Optimal Return:	33,072	33,148
No- cartel return:	32,274	32,348
Gain due to Cartel:	798 (2.5%)	800 (2.5%)

2. Discount factor 1.0/1.05

Optimal return:	43,921	44,009
No-cartel return:	42,845	42,930
Gain due to cartel:	1,076 (2.5%)	1,079 (2.5%)

Table 5A

Copper Exports as a Percent of Total Export Earnings[1]
1972-74
(except where noted)

	Copper Earnings as a Percent of Total	(Expected Earnings as a Percent of Total)[2]
Chile	72.5	(1.8)
Zambia	92.7	(2.3)
	60.2	(1.5)

TABLE 6

Cooper Model

Expected Versus Actual Values of Selected
State Variables - 1973
(in thousands of metric tons except where noted)

	Expected-cartel[1]	Expected-no cartel[1]	Actual
ME Price ('67 dollars per metric ton)	1,631	1,408	1,234
MJ Price ('67 dollars/metric ton)	1,078	1,026	964
otal Consumption	8,942	9,241	9,510
U.S. Cons.	3,193	3,310	3,181
European Cons.	2,730	2,862	3,559
Japanese Cons.	2,035	2,065	1,639
Rest-of-world Cons.	984	1,004	1,135
otal Mine Production	5,479	5,692	6,049
Cartel Mine Prod.	2,983	3,359	3,667
Chilean Mine Prod.	607	820	735
Zambian Mine Prod.	765	780	707
Rest-of-world mine Prod.	1,611	1,759	2,225
U.S. Mine Prod.	1,726	1,592	1,567
Canadian Mine Prod.	770	741	815
otal Production from Scrap	3,623	3,627	3,575
U.S. Prod from old scrap	502	478	403
U.S. Prod from new scrap	969	1,012	1,004
Rest-of-world scrap prod.	2,152	2,137	2,168
xpected Export tax ('67 dollars per metric ton)	216		

1/ These are values from the calculation using the discount factor of (1.0/1.1) and taking into account estimated coefficients of autocorrelation.