A SYSTEM DYNAMICS STUDY OF COMMODITY PRICE STABILIZATION BY BUFFER STOCK AND ITS EFFECT ON INDUSTRY PERFORMANCE
A Case of Indian Tea

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ABSTRACT

Using System Dynamics as the primary tool of investigation, an attempt has been made in this paper to present (i) a general model of commodity price fluctuation, (ii) a price stabilization policy based on buffer stock, and (iii) the impact of the policy on the long term growth of the commodity industry. The model has been tested for the case of Indian Tea.

Average unit cost of the commodity at the point of sale, operating profit margin desired by the sellers (computed on the basis of average quality of supply), actual inventory, and the average sales rate are considered as the chief determinants of the commodity price. Circular relationships among these variables have been considered to generate the price fluctuation over time. While testing the price stabilization policy, the model considers its operation phase. It is shown in the paper that such a price stabilisation policy tremendously boosts the overall long term growth of the industry.

1. INTRODUCTION

Commodity price fluctuation and its adverse effect on the performance of the commodity industry are well-recognised problems. However, while there are numerous explanatory models for commodity price fluctuation (for example, the classic Cobweb model and its various ramifications (Ezekiel [1], Ackerman [2], Nerlove [3] econometric model of Weymar [4] based on the setting of dynamic feedback loop mechanisms; and system dynamics model of Meadows [5], etc.), one rarely comes across models which test the effect of price fluctuation on the industry performance. Similarly, although often price stabilisation policies are attempted, their impact on the growth performance of the commodity industries are very rarely studied and assessed.

A possible cause why a partisan view of such an important problem has been taken is that traditionally only economists have taken interest in the study of commodity prices and commodity demand, who have chosen to skip the intricate details of management of commodity industries, possibly because of their specialised background and their general approach to modelling with which they stratify economic problems into either micro or macro type but rarely a combination of the two. The areas skipped usually are the production and distribution aspects, capacity investment plans, etc. On the other hand, the new brand of management scientists, while delving greatly into the production inventory problems, rarely consider pricing and marketing problems surrounding commodities and usually visualize the problem as a set of disaggregated and separate ones.

In contrast to the prevailing trends outlined above, it is proposed in this paper that commodity price fluctuation and retarded long term growth of these industries are interconnected problems and should be tackled in unison preferably taking a systems view of the total problem. Elsewhere (Bera [6]), such an approach has been followed to design tea price stabilisation policy and extension policy for long term growth of Indian tea industry. Delphi and System Dynamics studies have been used there as the main tools of investigation for designing these policies. A recent paper (Mohapatra et al. [7]) discusses the method of incorporating Delphi results in system dynamics models for the purpose of designing extension policy in Indian tea industry.

The present paper, however, highlights those features of the system dynamics model which explain fluctuations of tea prices at Indian auction and suggests a scheme of price stabilisation by creating and operating a buffer stock. It is shown that the transients of creating a buffer stock die out and give way to highly desirable long term growth performance of the industry.

2. THE INDIAN TEA INDUSTRY

Apart from providing one of the least expensive beverages to the common man, Indian tea industry gives widespread employment to rural and women population of the country, and substantially contributes to the national exchequer by way of central and state taxes, duty, cess, and more importantly, foreign exchange earning. India is the largest producer and consumer of tea in the world, and was also the largest exporter of tea till a few years back.

Fig.1 depicts the physical structure of the industry. It shows the major flows of order and shipment of tea. The Cultivation sector consists of tea gardens from where tea leaves are plucked. The tea plucking rate is usually controlled by the manufacturing and despatch sector of the garden. There are three channels of sale of tea from the garden. Tea may be shipped either directly to the wholesalers or to the auction centres, or to the export market. The plucking rate and shipment rates are primarily governed by financial considerations. Wholesalers constitute blenders, packeteers, loose tea exporters, and individual agents acting on behalf of the foreign buyers. They are generally sensitive to auction price changes and prefer to purchase tea directly from the garden if auction price is high. The retailers receive loose as well as packeted tea from the wholesalers and sell it to the general consumers of the country. The export market receives tea from the wholesalers, the gardens, and other tea-producing countries of the world, and sell it to the world consumers.

Indian tea industry, like all commodity industries, has been experiencing severe price fluctuation in the past. Roy [8] has discerned two types of price fluctuation - (a) short term fluctuation with a periodicity of about one year, and (b) long term fluctuation with a periodicity of about 7-10 years. Roy suggests that a limited cobweb type phenomenon is responsible for the long term price fluctuation where as the short term price fluctuation is largely due to real or assumed over or under production. He further suggests that the tea trade should be fully taken over by the government. It should allow a controlled flow to auction after fulfilling the demand for the foreign market so as to create an excess of demand over supply in order to stabilise the price. The

Tandon Committee on Tea Marketing [9] stressed, among other things, on the need for a study on price stabilisation through creation of buffer stocks nationally and internationally.

Curve A in Fig. 2 depicts the variation of average monthly tea price at Calcutta auction centre, and prominently shows the short term one-year cycle present in the fluctuation. The present paper concerns itself primarily with stabilisation of short term prices of tea, and reports the results of a model which shows how creation and operation of a buffer stock can not only stabilise tea prices but can also substantially boost the overall future growth of the industry.

3. THE SYSTEM DYNAMICS MODEL OF THE INDUSTRY

The tea industry model is organised into four sectors. These are (i) Domestic marketing, (ii) Production, (iii) Export, and (iv) Research and Development sectors. Each sector in turn is subdivided into various subsectors. The model consists of 28 pure level equations, 16 third-order delays, and 44 first-order smoothing level equations.

In the model, domestic and world tea consumption rates are the only two variables which are treated as exogenous. Polynomials of order 2 and 3 were fitted to their past time-series data available for the years 1965 - 77. For both the time-series data, second order polynomial curves gave higher values of correlation indices. The two exogenous variables were thus defined as second order polynomial functions of time. All other variables were generated in the model as endogenous.

The initial values of the level variables in the model were fixed at their actual values in the year 1965, and the model was run since then. The parameter values and interactions among model variables were based on variety of information sources, such as, daily newspapers, weekly magazines, bulletins, seminar and committee reports, and publications by leading professionals [8-14]. Several visits were also made to tea gardens, company headquarters, the tea research institute at Tocklai (Assam), and to the Tea Board - the only Government organisation responsible to streamline the activities of the industry. A Delphi study was also conducted to collect and obtain consensus of views of experts on various aspects of the industry. Such a study, which is reported elsewhere (Sahu et al. [15]) has helped in fixing the model boundary and in modelling the structure of certain important decision functions.

Fig. 3 shows the dominant causal relationships considered in the original model. However, no attempt is made in this paper to discuss the model. Many other publications [16-19] have been followed to choose submodel structures and parameter values.

3.1 The Validation of the Model :

Mainly based on Forrester's [20, 21] line of reasoning, a very elaborate scheme has been followed to validate the tea industry model. The scheme is broadly based on the following criteria :

A. Relevant model objectives.

B. Model structure and details adequate to generate problem symptoms similar to the actual system.

C. Plausible behavioural characteristics generated by the model under carefully chosen extreme conditions. Step, sinusoidal, ramp, and random variations are usually added to the exogenous variables for exciting the model.

D. Partial model validation of individual sectors of the model. Each sector of the model is also tested for its plausible behaviour by holding most of the inputs coming from other sectors at constant values and by changing only the most important input variable.

E. Model analysis requiring running the model with realistic input conditions, comparing the behaviour with the past behaviour of the real system, and being able to explain the results from the influence diagram.

F. Sensitivity testing on the model for variations in (i) parameter values, (ii) shapes of table-functions, (iii) initial values of the state variables, (iv) modelling substructures, and (v) the computational parameter which is used only to simulate the model.

G. Consultations with real system managers during all the stages of model building.

For the purpose of validation, the tea industry model was run under 21 changed conditions and the results were analysed and compared with the standard run. While the model behaviour with regard to the short-term price fluctuation did not show any remarkable change in response to all the test, the behaviour related to long-term growth of the industry were affected by some of the changed conditions.

4. ANALYSING PRICE CHANGES AT INDIAN AUCTION

Price changes at Indian auction are analysed on the basis of causal mechanism underlying price changes at auction and by a thorough examination of the model generated price pattern in the standard run.

4.1 Analysis of Causal Mechanism :

Tea price at auction basically depends on demand, supply, and support price of tea. As discussed earlier, support price of tea depends primarily on average production cost and quality of supply.

Fig. 4 depicts the price - demand interactions at auction centres. Higher auction price relative to average auction price in the past recognised in the past leads to lower desired inventory at wholesaler and also raises the order for ex-garden sale, resulting in lower purchase decision by wholesalers from auction and causes auction price to go down. Thus a negative feedback loop dominates the demand - price relationship.

Fig. 5 depicts the price - supply interactions in terms of four interactions negative feedback loops. On a short-term basis, the factors most affecting supply of tea are seasonality, quantum of agricultural inputs, and plucking style; the other factors such as area under tea cultivation and effect of R&D effort on yield have only long-term impact on the supply of tea, and are skipped from the present analysis of short-term fluctuation of tea price.

Higher auction price leads to coarser plucking and higher fund for agricultural inputs as a result of favourable total fund position.

Coarser plucking reduces the overall quality of tea resulting in a reduced pressure on good prices. Coarse plucking coupled with massive use of agricultural inputs results in high tea production rate. This weakens the pressure for a sustained high price because of a reduced unit production cost and the high inventory cover.

It is, however, true that seasonality plays a significant role in controlling tea leaves available for plucking and in the supply of tea to auction centre. In fact, it predominates over other factors in the case of tea.

Fig. 6 shows the combined demand-price-supply interactions. The interacting negative feedback loops explain the fluctuating nature of tea price at the auction centres.

4.2 Analysis of the Model-generated Behaviour :

The model was simulated using DYMOSIM (Bora and Mohapatra [22]), with the solution time interval, DT, equal to 0.125 month and the initial values of level variables equal to their actual values at the start of the year 1965. However, 1965 values of certain level variables were not available. Initial values have been assumed for these cases.

The fluctuation of tea price at Indian auction over the years 1965 through 1977 has been shown in Fig.7. Fig. 8 is plotted at weekly intervals and depicts the behaviour of several variables representing the supply and demand of tea at different times of the year.

The dominant effect of seasonality is obvious from the figures. The price fluctuation beyond 1971 is quite normal, whereas that during the initial years 1965 through 1971 is not quite expected. This is probably due to initialization error which has created dynamics not attributable to the fundamental forces in the model. Thus our analysis has been confined to the model behaviour beyond 1971.

Average auction price usually peaks during July-August and slumps during February-March. During peak production time, direct sale from garden, shipment to auction and tea arrival rate at auction reach their peaks. Thus inventory at auction is reaching its peak after a delay of about two months (shipment delay, etc.). Higher availability of tea through direct sale reduces the purchase decision by wholesalers from auction. Also expecting rise in price the wholesalers reduce their desired inventory level. In fact the gap between inventory and desired inventory is the lowest during July-August. The reverse phenomenon occurs during February and March.

4.3 Real and Model-Generated Data - a Comparative Study :

Fig. 2b shows the variation of deflated value (with 1965 as the base year) of actual monthly auction prices of tea for the period January 1971 to December 1974. The price fluctuation generated by the model closely resembles the real life pattern both with respect to trend and fluctuation. Both the deflated actual price and the model generated price have their peaks during July-August and their troughs during February-March each year. Also the downward price trend over the simulation run has the similarity with the downward trend observed with the deflated real price data.

Another interesting feature of the model behaviour is the existence of a long-term cycle in prices (in addition to the one-year short-term cycle) which has been recognised by Roy [8] and discussed earlier. This paper, however, does not present the analysis for the long-term cycle.

5. FORECASTING FUTURE GROWTH BEHAVIOUR OF THE INDUSTRY

This paper does not aim at forecasting future growth behaviour of the Indian tea industry. However, since the price stabilisation policy has been tested against the future behaviour of the industry, a short discussion may be made on this aspect.

Reliability of a forecast mostly depends on (i) validity of the model and (ii) validity of the assessment of changes in the environmental forces acting on the real system. The question of validity of the tea industry model has been discussed earlier. To assess the likely future developments in the tea industry and its environment, a Delphi study was conducted and its main recommendations were also modelled. Mohapatra et al. [7] discusses in detail how the Delphi results were incorporated in the model.

Some of the dominant views of the Delphi panelists regarding the future environmental changes related to massive production plans of tea-producing countries and resultant supply to world market, lower world demand for tea due to competitiveness of other beverages, higher yield rate of Indian tea gardens due to technological innovation, and higher demand for Indian tea abroad because of better quality of tea.

Fig. 9 depicts the behaviour of some key variables of the model upto 2000 A.D. assuming that the present environmental forces will continue to operate and that the present policies will be followed in the future. Fig. 10 shows the behaviour of some of the key variables of the model assuming that the environmental forces will change as predicted by the Delphi panelists while the present policies will remain unaltered till 2000 A.D.. Table in the Appendix below gives a summary of behaviour of some of the key variables at the end of the simulation run for the cases just cited. A study of the figures and the table in the Appendix gives the impression that most of the variables exhibit wide fluctuation about their mean values. This is the main reason for the retarded growth of the industry.

In the next sections to follow, it will be shown that arresting price fluctuation will automatically lead to smooth growth be-haviour of the industry.

6. PRICE STABILIZATION POLICY

6.1 In Defence of a Buffer Stock :

The chief determinants of price are supply and demand of tea, and average unit cost of tea sold at auction. The demand of tea is dependent on price and is not directly controllable by the producers. The unit cost of tea sold fluctuates with the production rate.

But this fluctuation is marginal since it consists of a constant part representing manufacturing, transportation and selling costs, and also since its computation is based on two averaging processes, viz., the monthly tea production rate averaged over a year, and depreciation charges. Thus controlling unit cost cannot provide enough leverage to attenuate price fluctuation. This leaves supply of tea as the only important variable which could be controlled to reduce price fluctuation.

Theoretically, supply of tea could be controlled at three points. By reducing winter dormancy the seasonal fluctuation of supply can be reduced drastically. However, there is no scientific evidence to suggest that such a breakthrough is likely in the coming two decades. Second, uniform delivery can be ensured if plucking of tea leaves is controlled. This does not seem to be a sound proposition, since is is not possible to go for higher plucking during winter nor is it desirable to reduce plucking rate during the peak season since this adversely affects the future yield rate of tea bushes. Third, creation of a buffer stock between the supply from the garden and the supply to the auction centre can arrest the fluctuating supply to the auction centre. Creation of buffer stock has been widely advocated in the past to contain price instability. This is, therefore, considered to be a valid proposition to be included in this model. However, many models in the past, while testing the effect of the buffer stock and recommending for its creation, do not explicitly model its creation phase. This model, however, considers both the creation and operation phases.

6.2 Modelling Creation and Operation of a Buffer Stock :

It is assumed that ten per cent of the total shipment to domestic auction centres is diverted to create the buffer stock, while the rest goes to the inventory at auction. No shipment takes place from the buffer stock till it achieves its desired value. It is further assumed that the process of buffer stock creation starts at the start of 1981 with an initial value of zero. The desired value of buffer stock is assumed to be four weeks of average sale from auction.

When the buffer stock achieves its desired value, all the tea, after satisfaction of ex-garden sale, is supplied to the buffer stock, and the inventory at auction is replenished from this stock only.

The buffer stock position is also assumed to induce the producers to go for coarse or fine plucking as a measure to maintain the buffer stock at its desired level.

Fig. 11 is an influence diagram for the operation phase of the buffer stock at Indian auction centre.

A similar procedure has been followed to create and operate buffer stock abroad.

7. BEHAVIOURAL CHARACTERISTICS WITH THE PROPOSED PRICE STABILIZATION POLICY

The model has been tested with the proposed price stabilization policy in the two environmental conditions cited earlier.

7.1 Continuance of the Present Environmental Forces into the Future :

Fig. 12 shows the behaviour of a few key variables of the model for this case. This figure shows the reduced price fluctuation during 1987-2001 resulting from buffer stock creation. The unnatural price fluctuation during 1984-87 is due to the buffer stocks which are created but which are not yet operational.

The table in the Appendix gives some more information regarding important variables which show that price stabilisation has the positive effect on industry growth.

7.2 Future Environmental Changes as Viewed by the Delphi Panelists :

Fig. 13 and the table in the Appendix present the model results for this case. It is observed that the behaviour of auction price has not changed much while average export tea price has reduced. The long-term growth of the industry, in all its financial terms has suffered, but marginally.

8. CONCLUSION

It is shown in this paper that creation and operation of buffer stock can reduce price fluctuation of commodities like tea and can boost the overall growth of the industry. Such policies can also be very robust in the sense that it can be conducive to growth even in case of unforeseen developments in the environment.

The model, used to test the policies embraces a price generation model and an extension model, although only the price generation model was described in this paper in great detail. The price generation model is a very general one and has considered factors like cover, price expectation, suppliers' price expectation, consumers' inventory level, production cost, quality, seasonality in production and price trends etc.. In addition, the model is a dynamic one considering interaction of feedback loops and capturing the basic structure of the price phenomenon.

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APPENDIX

Behaviour of some Key variables at the end of the Simulation Run

Policies / Variables		Standard Run *	Standard Run **	Price Stabilization Policy *	Price Stabilization Policy **
Total Area Under Tea (Hectare)	a	389880	382680	403120	394550
	b	–	–	–	–
	c	Upward	Upward	Upward	Upward
	d	–	–	–	–
Average Tea Production Rate ($\times 10^8$ Kg/H)	a	0.96	0.99	0.962	1.015
	b	0.26	0.28	0.315	0.29
	c	Upward	Upward	Upward	Upward
	d	Increasing	Increasing	Increasing	Increasing
Average Sale of Tea Abroad ($\times 10^7$ Kg/H)	a	3.42	3.77	4.72	4.44
	b	–	–	–	–
	c	Upward	Upward	Upward	Upward
	d	–	–	–	–
Average Auction Price (Rs/Kg)	a	4.35	4.30	4.70	4.70
	b	1.10	1.00	0.40	0.40
	c	Downward	Downward	Downward	Downward
	d	Sustained	Sustained	Sustained	Sustained
Average Profit after Tax ($\times 10^7$ Rs/H)	a	2.51	2.445	3.63	3.44
	b	0.64	0.63	0.90	1.1
	c	Upward	Upward	Upward	Upward
	d	Sustained	Increasing	Increasing	Increasing
Retained Earning ($\times 10^9$ Rs)	a	2.66	2.689	2.88	2.87
	b	–	–	–	–
	c	Upward	Upward	Upward	Upward
	d	–	–	–	–
Return on Total Assets (Per Cent)	a	0.274	0.256	0.358	0.343
	b	0.052	0.05	0.108	0.1
	c	Constant	Constant	Constant	Downward
	d	Sustained	Sustained	Sustained	Increasing

a – Mean Value
b – Range of Fluctuation
c – Trend
d – Nature of Fluctuation
* – Present Environmental Forces continue in the Future
** – Delphi-predicted Changes in the Environment in the Future.

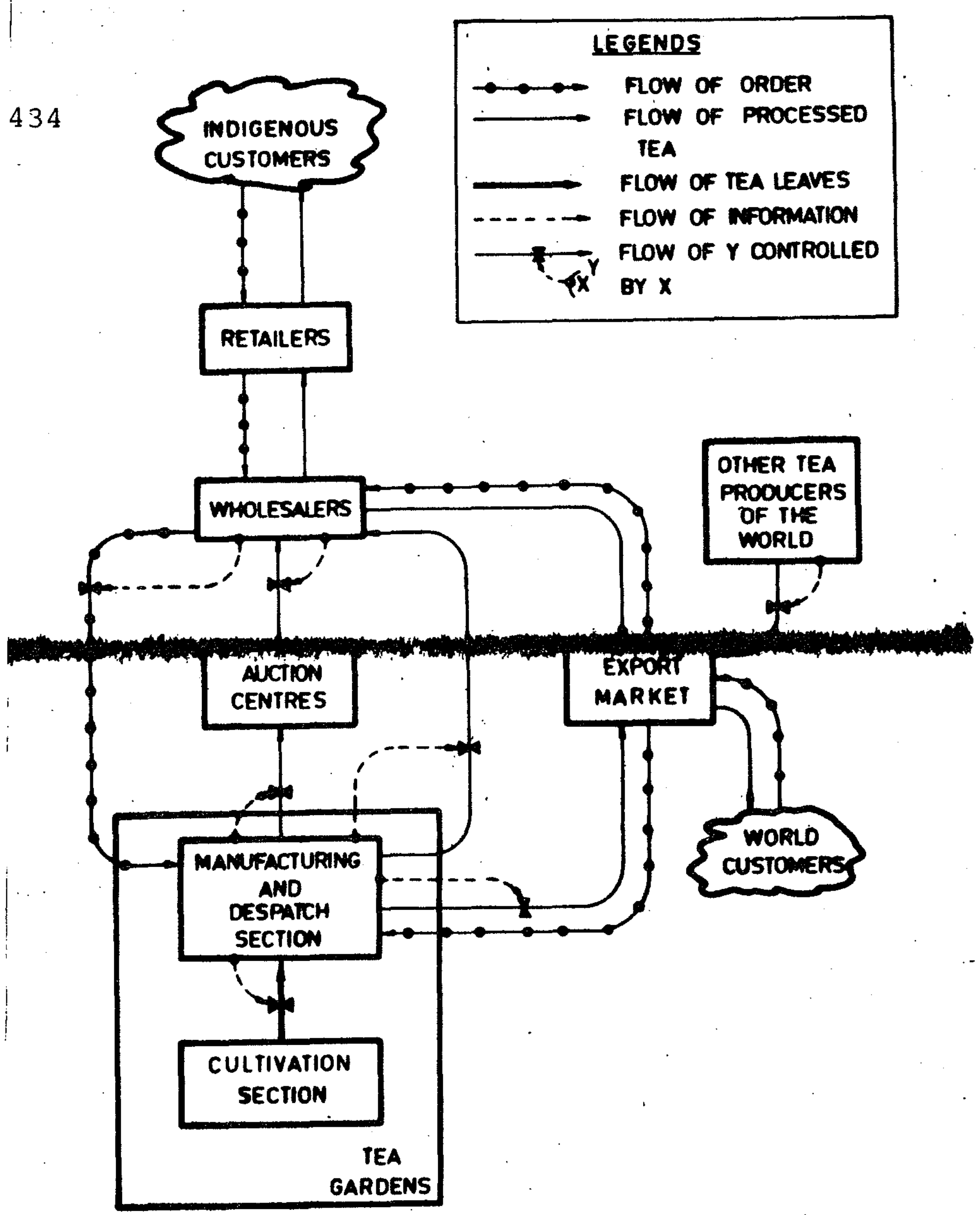
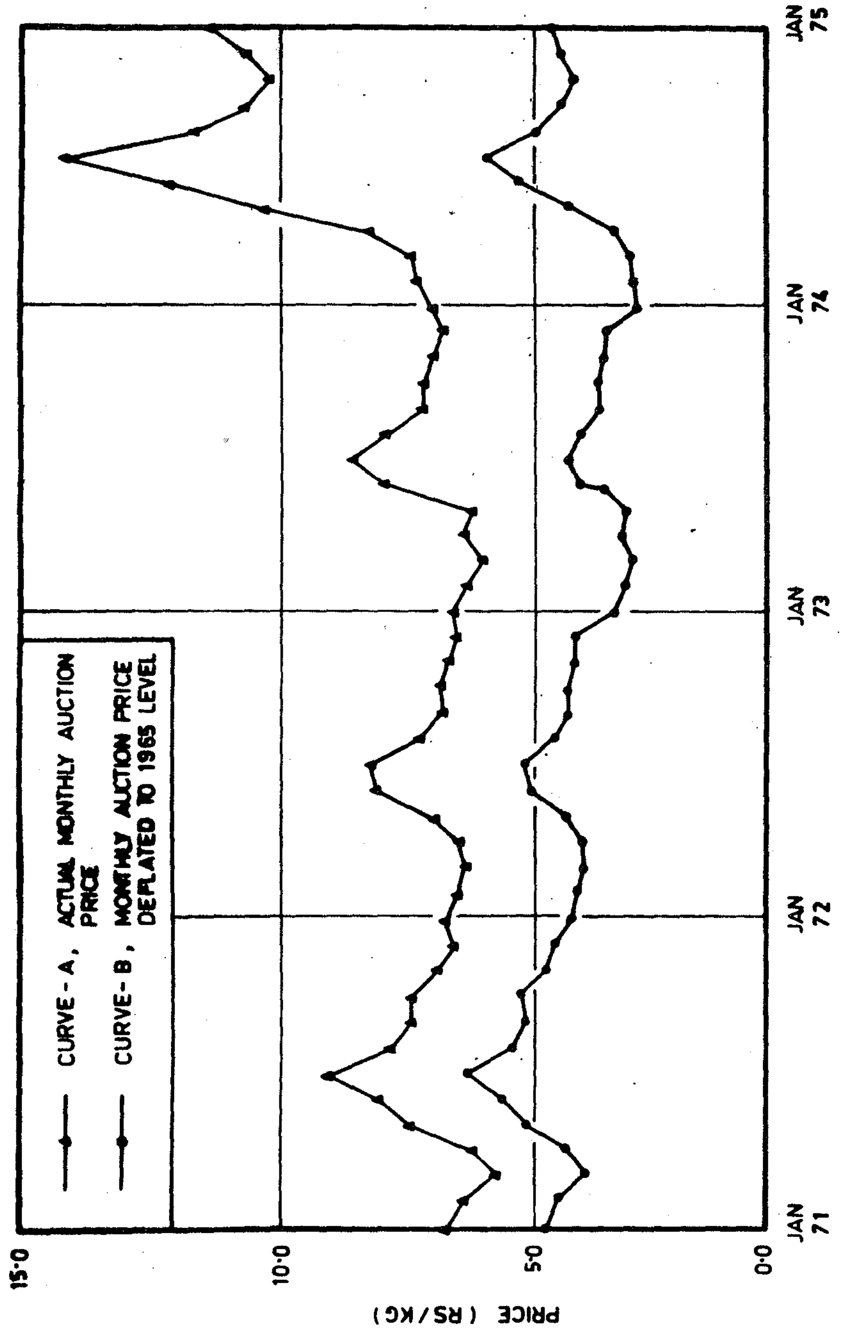
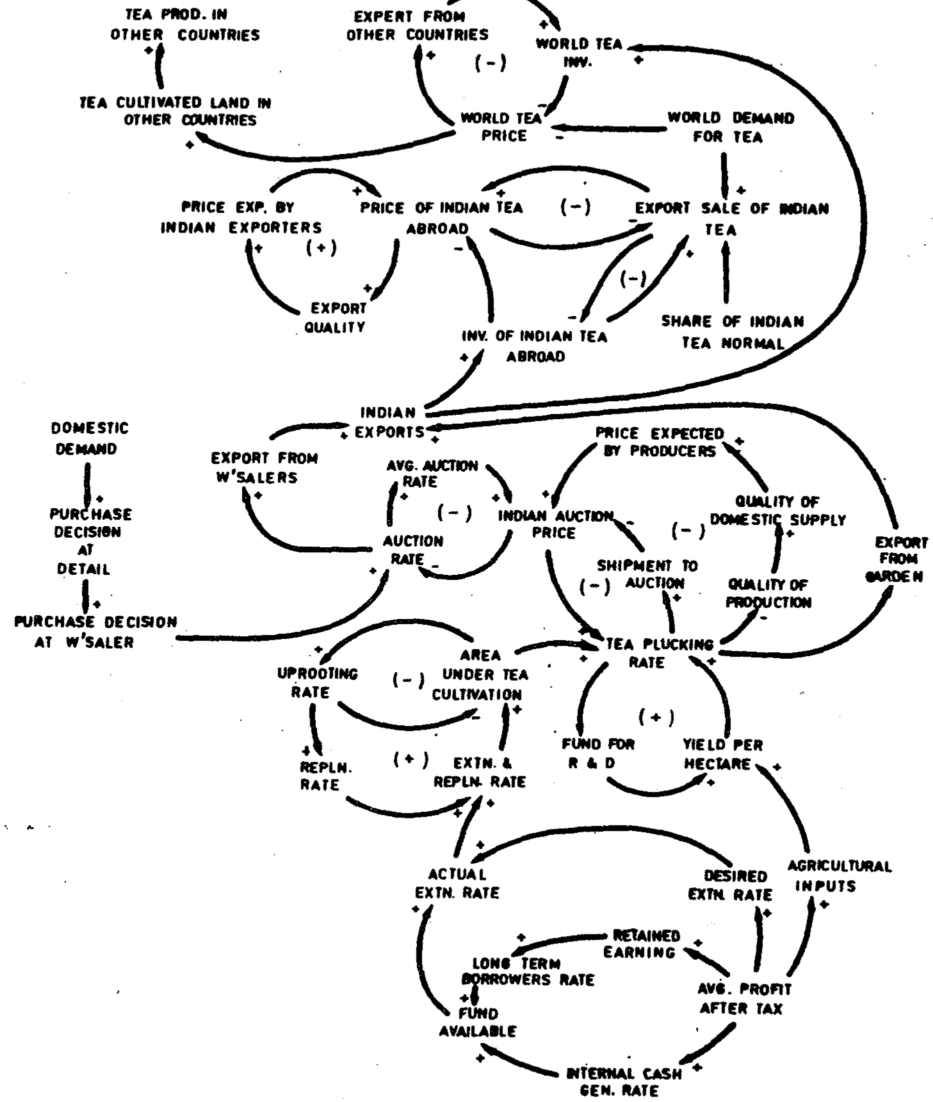


FIG. - 1



CURVE - A, ACTUAL MONTHLY AUCTION PRICE
CURVE - B, MONTHLY AUCTION PRICE DEFLATED TO 1965 LEVEL
PRICE (RS / KG)
15·0
10·0
5·0
0·0
JAN 71
JAN 72
JAN 73
JAN 74
JAN 75

FIG.- 2



TEA PROD. IN OTHER COUNTRIES
EXPERT FROM OTHER COUNTRIES
WORLD TEA INV.
TEA CULTIVATED LAND IN OTHER COUNTRIES
WORLD TEA PRICE
WORLD DEMAND FOR TEA
PRICE EXP. BY INDIAN EXPORTERS
PRICE OF INDIAN TEA ABROAD
EXPORT SALE OF INDIAN TEA
EXPORT QUALITY
INV. OF INDIAN TEA ABROAD
SHARE OF INDIAN TEA NORMAL
INDIAN EXPORTS
DOMESTIC DEMAND
EXPORT FROM W'SALERS
PRICE EXPECTED BY PRODUCERS
AVG. AUCTION RATE
INDIAN AUCTION PRICE
QUALITY OF DOMESTIC SUPPLY
EXPORT FROM GARDEN
PURCHASE DECISION AT DETAIL
AUCTION RATE
SHIPMENT TO AUCTION
QUALITY OF PRODUCTION
PURCHASE DECISION AT W'SALER
AREA UNDER TEA CULTIVATION
TEA PLUCKING RATE
UPROOTING RATE
FUND FOR R & D
YIELD PER HECTARE
REPLN. RATE
EXTN. & REPLN. RATE
ACTUAL EXTN. RATE
DESIRED EXTN. RATE
AGRICULTURAL INPUTS
RETAINED EARNING
LONG TERM BORROWERS RATE
AVG. PROFIT AFTER TAX
FUND AVAILABLE
INTERNAL CASH GEN. RATE

FIG.- 3

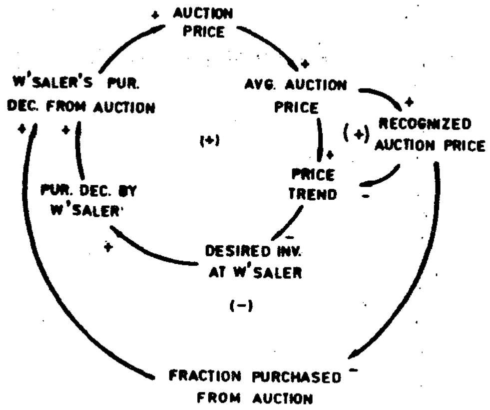


FIG. - 4

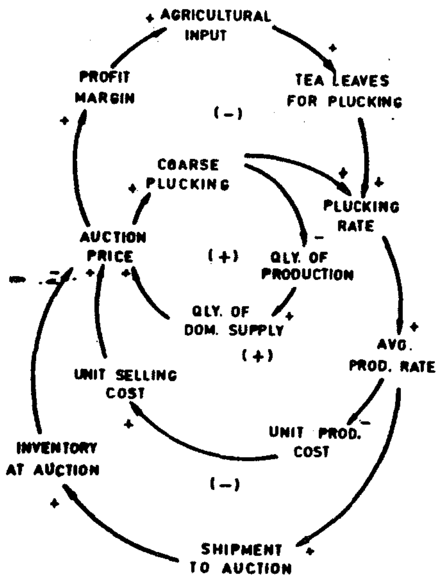


FIG. - 5

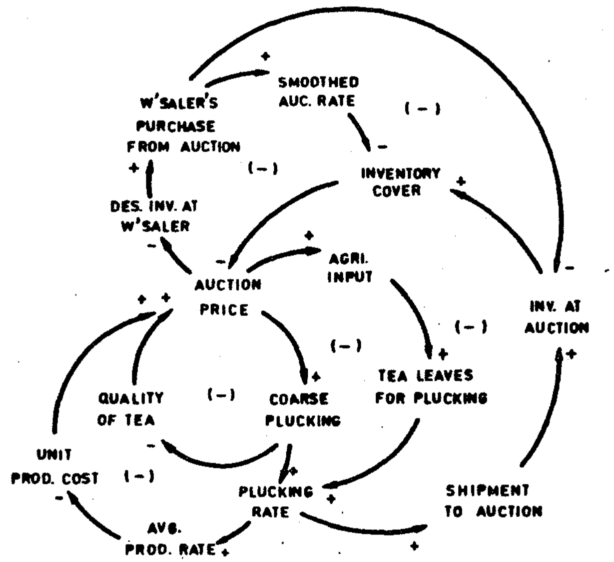


FIG. - 6

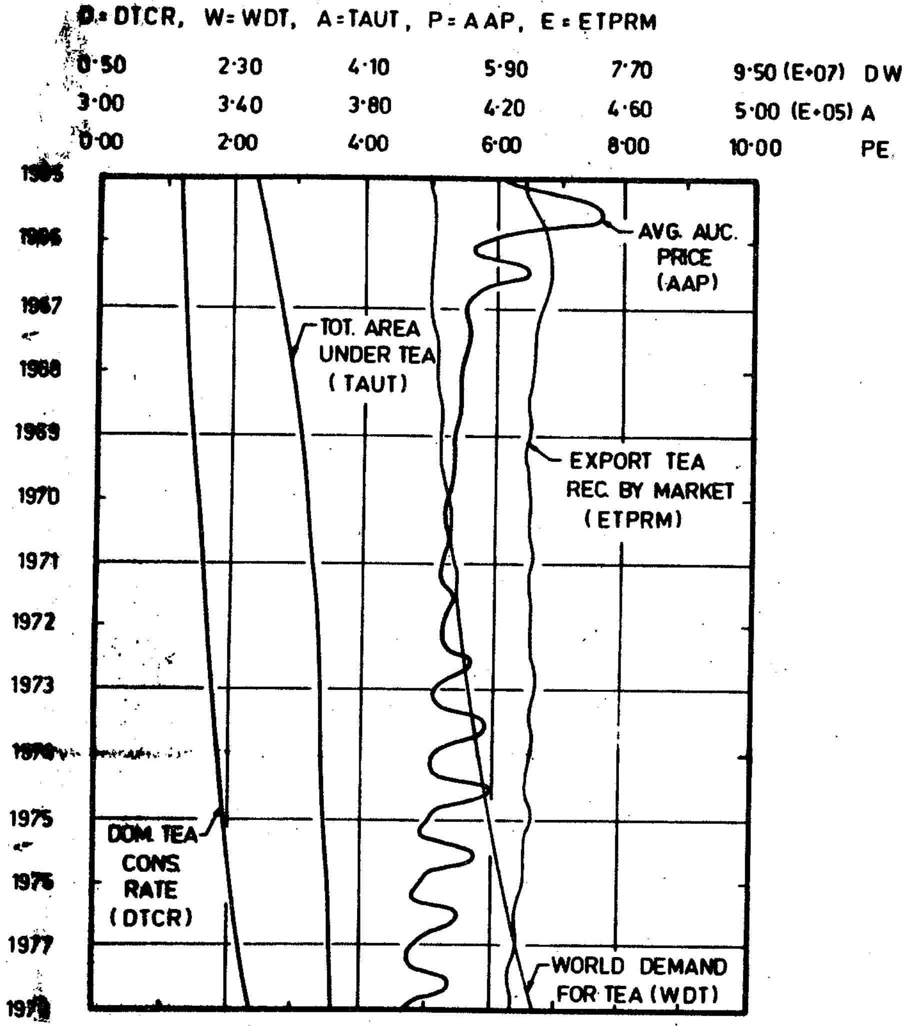

D = DTCR, W = WDT, A = TAUT, P = AAP, E = ETPRM
0·50 2·30 4·10 5·90 7·70 9·50 (E+07) DW
3·00 3·40 3·80 4·20 4·60 5·00 (E+05) A
0·00 2·00 4·00 6·00 8·00 10·00 PE
1967
1968
1969
1970
1971
1972
1973
1975
1977
AVG. AUC. PRICE (AAP)
TOT. AREA UNDER TEA (TAUT)
EXPORT TEA REC. BY MARKET (ETPRM)
DOM. TEA CONS. RATE (DTCR)
WORLD DEMAND FOR TEA (WDT)

FIG. - 7

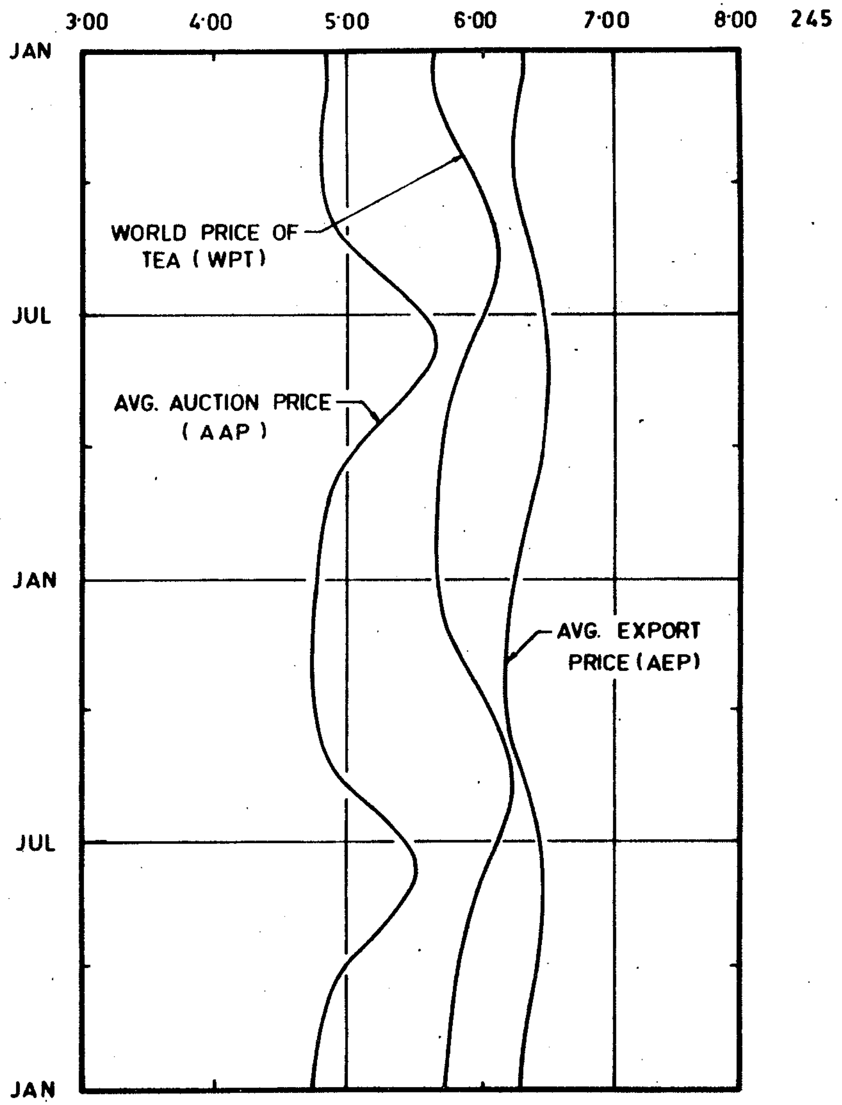

2 = AAP, 4 = AEP, 5 = WPT
3·00 4·00 5·00 6·00 7·00 8·00 245
JAN
JUL
JAN
JUL
JAN
WORLD PRICE OF TEA (WPT)
AVG. AUCTION PRICE (AAP)
AVG. EXPORT PRICE (AEP)

FIG. - 8

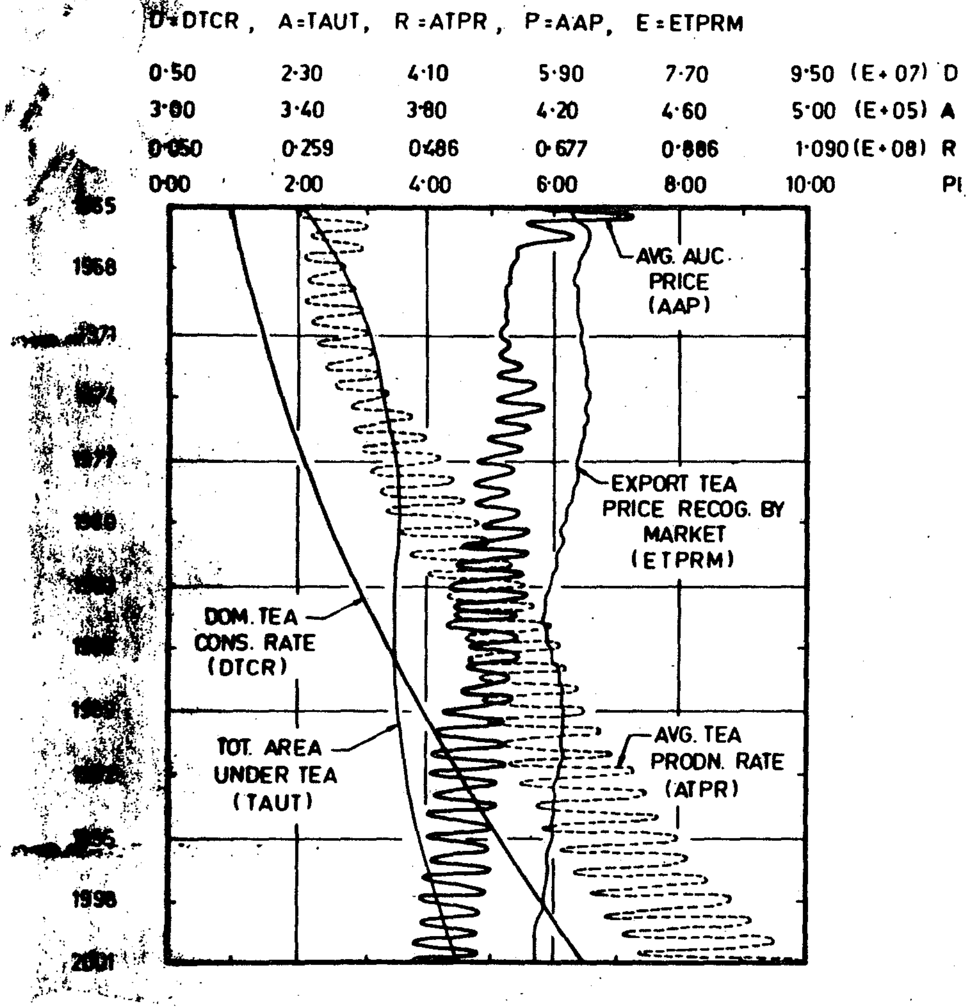

D=DTCR, A=TAUT, R=ATPR, P=AAP, E=ETPRM
0·50 2·30 4·10 5·90 7·70 9·50 (E+07) D
3·00 3·40 3·80 4·20 4·60 5·00 (E+05) A
0·050 0·259 0·486 0·677 0·886 1·090 (E+08) R
0·00 2·00 4·00 6·00 8·00 10·00 P
1968
AVG. AUC. PRICE (AAP)
EXPORT TEA PRICE RECOG. BY MARKET (ETPRM)
DOM. TEA CONS. RATE (DTCR)
TOT. AREA UNDER TEA (TAUT)
AVG. TEA PRODN. RATE (ATPR)
1998

FIG. - 9

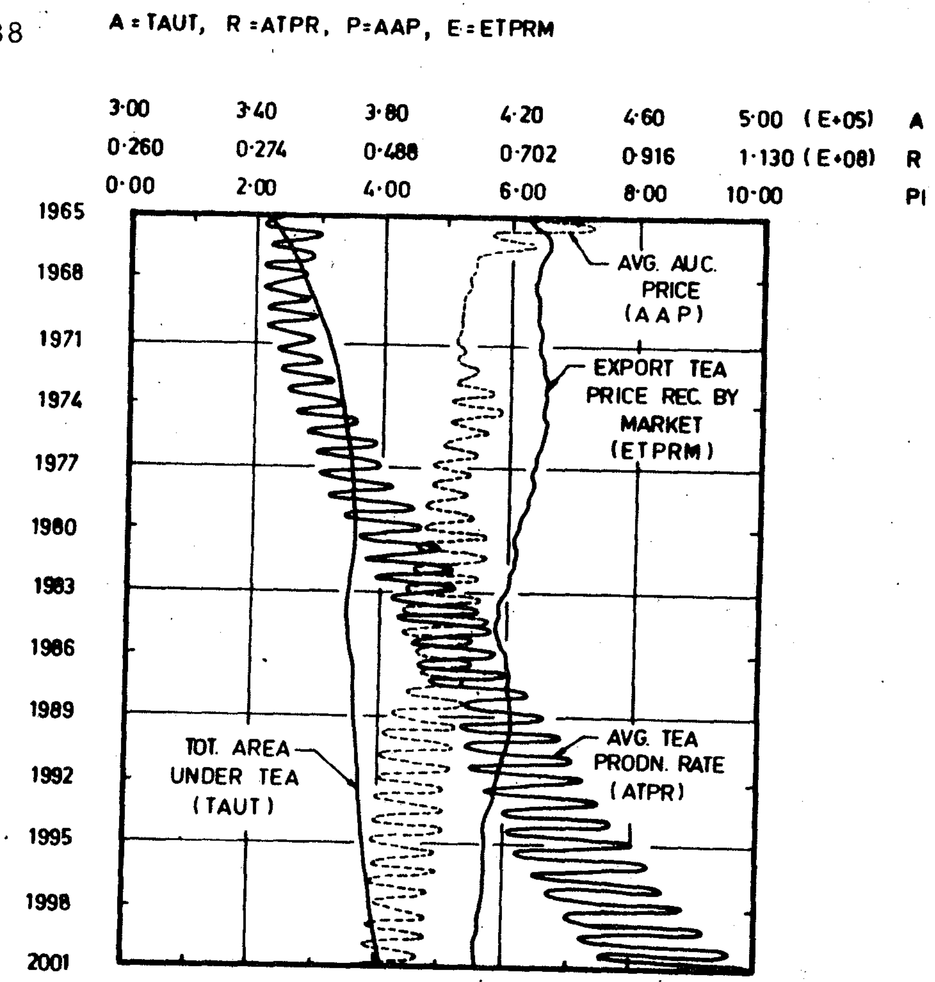

A=TAUT, R=ATPR, P=AAP, E=ETPRM
3·00 3·40 3·80 4·20 4·60 5·00 (E+05) A
0·260 0·274 0·488 0·702 0·916 1·130 (E+08) R
0·00 2·00 4·00 6·00 8·00 10·00 PI
1965
1968
1971
1974
1977
1980
1983
1986
1989
1992
1995
1998
2001
AVG. AUC. PRICE (AAP)
EXPORT TEA PRICE REC. BY MARKET (ETPRM)
TOT. AREA UNDER TEA (TAUT)
AVG. TEA PRODN. RATE (ATPR)

FIG. - 10

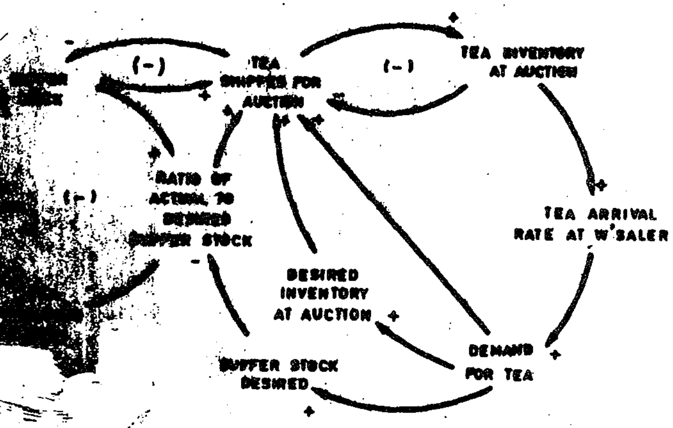

(-)
(-)
(-)
TEA INVENTORY AT AUCTION
TEA ARRIVAL RATE AT W'SALER
DEMAND FOR TEA
DESIRED INVENTORY AT AUCTION
BUFFER STOCK DESIRED
RATIO OF ACTUAL TO DESIRED BUFFER STOCK

FIG. - 11

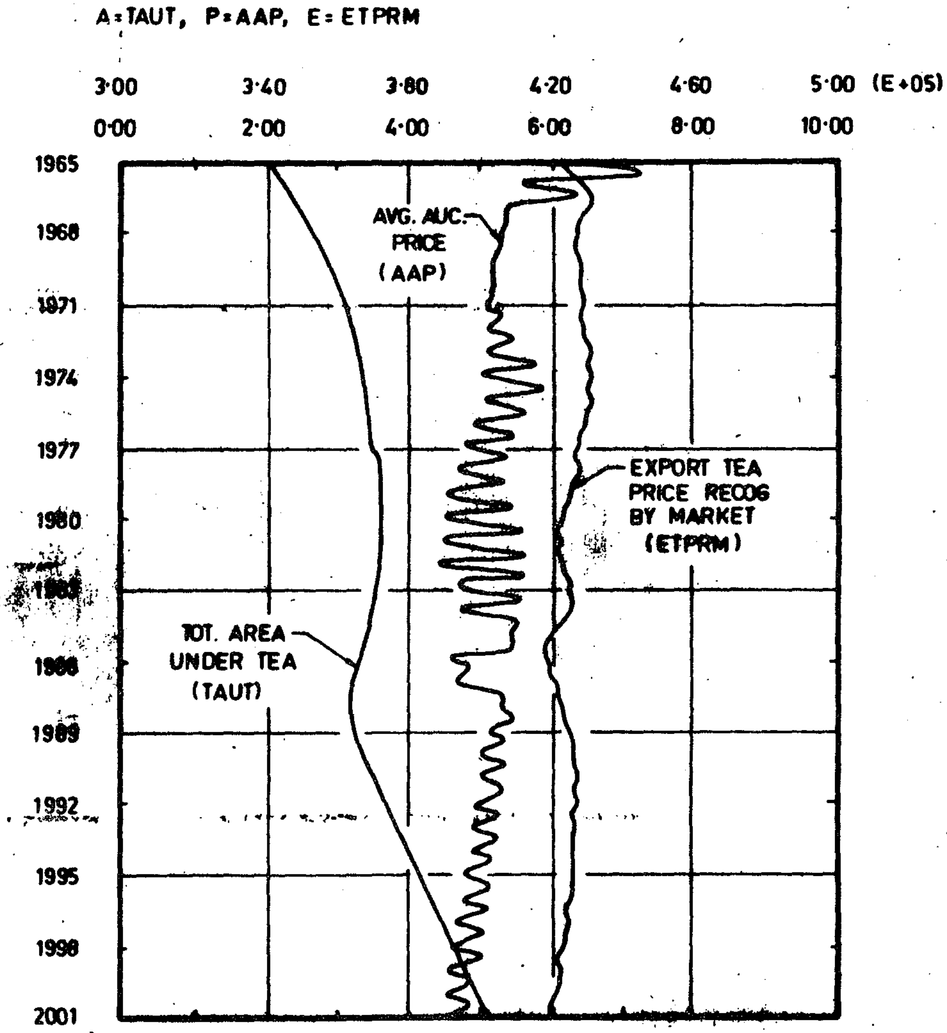

A: TAUT, P=AAP, E= ETPRM
3·00 3·40 3·80 4·20 4·60 5·00 (E+05)
0·00 2·00 4·00 6·00 8·00 10·00
1965
1968
1971
1974
1977
1980
1986
1989
1992
1995
1998
2001
AVG. AUC. PRICE (AAP)
EXPORT TEA PRICE RECOG BY MARKET (ETPRM)
TOT. AREA UNDER TEA (TAUT)

FIG. - 12

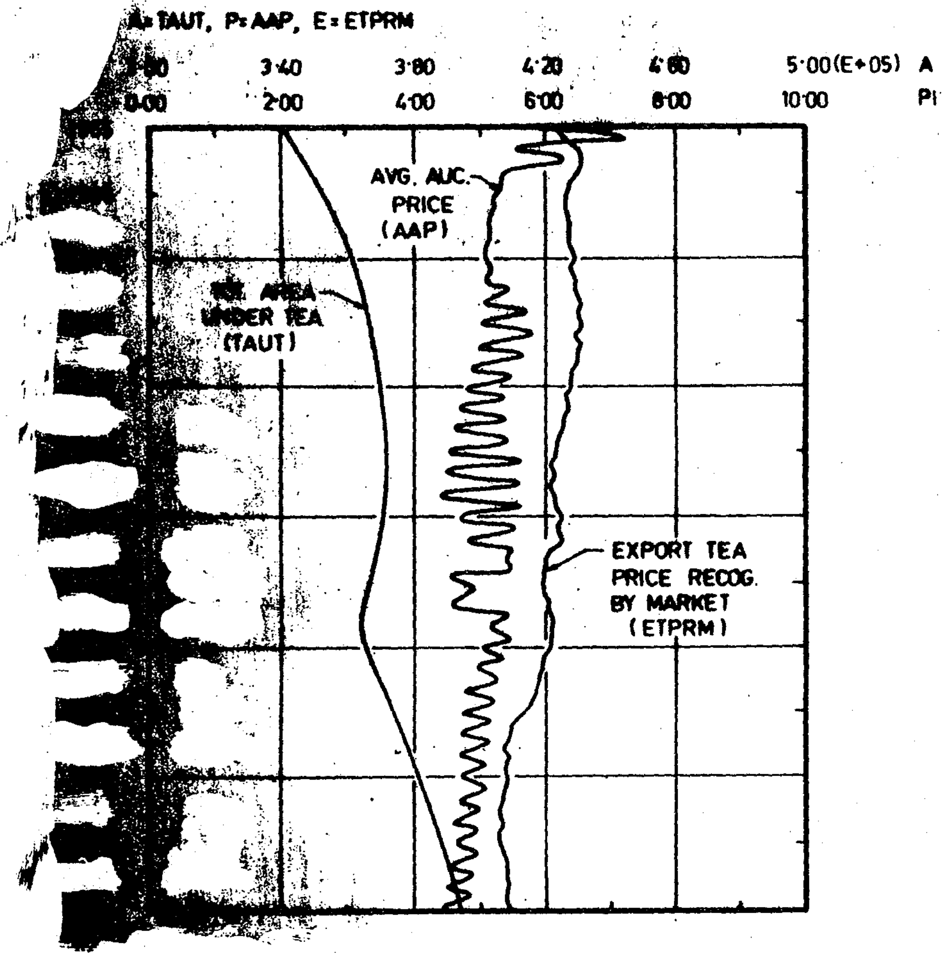

A=TAUT, P=AAP, E=ETPRM
3·40
3·80
4·20
4·60
5·00(E+05) A
0·00
2·00
4·00
6·00
8·00
10·00
P
AVG. AUC. PRICE (AAP)
UNDER TEA (TAUT)
EXPORT TEA PRICE RECOG. BY MARKET (ETPRM)

FIG-13