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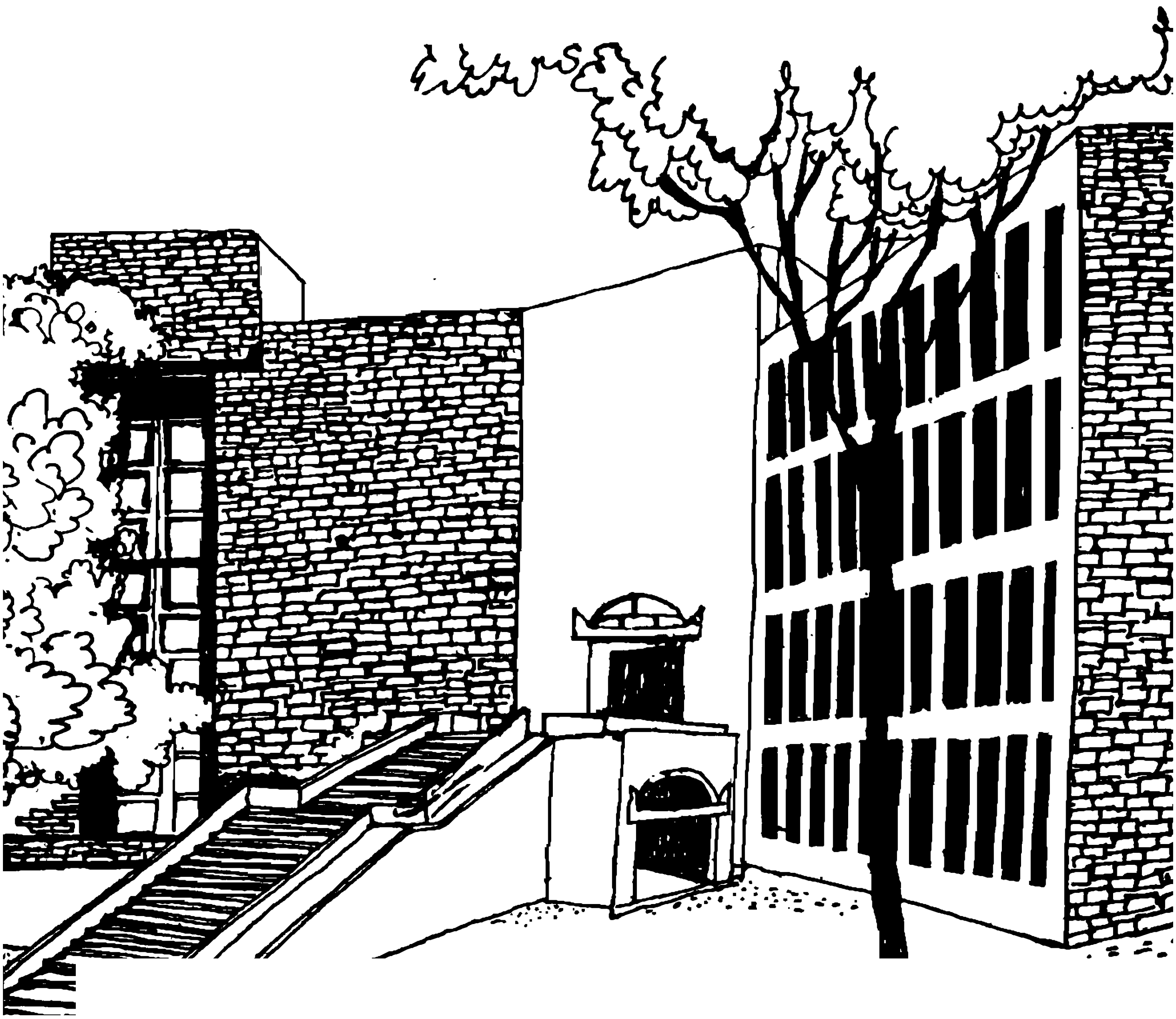

PROSPECTS OF INDIAN CASTOR OIL EXPORTS UNDER CHANGING POLICY SCENARIOS: AN ECONOMETRIC ANALYSIS

By

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INTRODUCTION

The economic significance of castor crop in recent years has increased as it brings a sizeable amount of foreign exchange to the country[1]. The major product of castor crop is castor oil which has a large international market. Although in recent years the international trade in castorbean has been increasing, castor oil predominates accounting for about 80% of the total trade, including beans and oil in both quantity and value terms (Tewari and Rao. 1991, p.66). India has a special place in the international castor oil trade as she alone supplies more than one-third of world-supply of castor oil; while both India and Brazil together makeup about 80% of the world exports.

India's special place in the international castor oil economy has not come by chance alone but significant efforts have gone into this by way of public investment in developing high yielding castor hybrids. It is worth noting that India's share in the world market has increased particularly after the introduction of castor hybrids in the country during the 1970s. Castor hybrids were phenomenally successful in Gujarat state which now accounts for about two-thirds of Indian castorbean production with only about one-third of the castor acreage in the country.

For certain, India's special place in the international castor oil market cannot be taken granted in the future because she faces stiff competition from exporting countries, primarily from Brazil and China. For example, as of now, Brazil is trying to maintain her market leadership, despite declining internal castorbean production, by allowing large imports of castorbean from China and Thailand and then re-exporting the value-added product, castor oil, in the international market. Unlike Brazil, India's policy of allowing bean imports for generating value added exports in terms of castor oil has turned out to be an unsuccessful one, primarily owing to insufficient profit margins to traders. It is also believed that the existing Indian crushing capacity may appear as a constraint in the future (Tewari and Rao, 1991, p.100).

Although China, as of now, does not compete directly with India in the international castor oil market, the threat of potential competition cannot be ruled out since she had emerged as a major exporter of castorbean in recent years and her exports of castor oil are also rising rapidly. The competition has been also intensified from the buyers side as well, in particular due to political-cum-economic system changes that have taken place in the Eastern Europe and independent states of former Soviet Union--a major importer of Indian castor oil in the past. The obvious question then is: What are the prospects of Indian Castor oil exports under changing times in the future? The answer is speculative and uncertain but is required for developing India's strategy with respect to castor oil exports.

Knowledge about the prospects of Indian castor oil exports depending upon the potential situations that may arise as a result of new nexus of events taking place worldwide, is essential for policy makers and planners, in particular to those in Ministries of Agriculture and Commerce. No such study has been yet conducted, although a broad understanding and various facts of castor economy have been dealt by Tewari and Rao (1990). The major objective of this article is to analyze prospects of Indian castor oil exports/economy under alternative scenarios which would be useful for designing long-term strategy towards castor oil export-marketing; this is done by developing an econometric simulation model. The international castor oil market model is discussed in the next section; followed by model simulation and validation results, and results of policy experiment scenarios in the subsequent sections. Summary and conclusions are described at the end.

INTERNATIONAL CASTOR OIL MARKET (ICOM) MODEL

International trade is the major activity in the world castor economy--about one-third to two-thirds of world castor production is internationally traded. More than 80% of castorbean production takes place in Brazil, India, and China; and, these countries crush very large amounts of beans domestically. For example, India, Brazil, and China together crush about 70% of the world castorbean production. Among the exporting regions, Brazil and India are two major exporters accounting for about 80% or more of the world exports. China is a minor but promising exporter. Major importers on the importing side are the United States of America (USA), the European Economic Community (EEC), and countries of erstwhile USSR, accounting for about 80-90% of world imports. Other minor importing regions are Japan and Canada. In terms of stock-holding of castor oil, three-fourths of world castor oil stocks are housed in two major exporters-Brazil and India-and three major importers--USA, EEC, and countries of erstwhile USSR. In brief, the major actors in the international castor oil market can be summarized as in Table 1.

[Insert Table 1 here]

Since a model is an abstraction--not a replication of reality, it requires idealization or simplification of real world to the extent that model can represent a part of total reality in a reasonable manner. This necessitates making assumptions for modelling purpose; these modelling assumptions/considerations made for ICOM are as follows:

(1) Based on the past work, it is believed that the ICOM can be described through the perfectly competitive market hypothesis. The analysis of various indicators and structure of international castor oil market suggests that it is a perfectly competitive one (Tewari and Rao, 1991). The perfectly competitive market framework is considered to be good for the most primary commodities.

(2) For modelling purpose, the total world is divided into three regions: Brazil, China, and India. The model has four sectors including Indian, Brazilian, Chinese and International sectors.

(3) The ex-Rotterdam price is taken as international price which is determined by the interaction of aggregate world demand for and aggregate world supply of castor oil.

The price formation in the ICOM can be explained by Figure 1. The international price P is determined by joint interaction of export supply (X^S) and export (X^D) demand schedules. The export supply schedule is influenced by factors affecting the domestic demand and supply in the castor oil exporting countries. Likewise, export demand schedule is influenced by factors affecting the domestic demand for and supply of castor oil in the castor oil importing countries. Using the above conceptual model, the international castor oil market is then divided into four sectors: (1) India, (2) Brazil, (3) China, and (4) International. The country sectors--India, Brazil and China--show the demand-supply situations in the domestic economies; while the international sector shows the trade and price linkages among them. Sectorwise details of numbers of equations and identities are summarized in Table 2. The sector-wise description of the model follows:

[Insert Figure 1 and Table 2 here]

The Indian sector contains 5 behavioral equations and 5 identities. The five behavioral equations are: (1) Gujarat castor hectarage (GUHC), (2) Gujarat castor yield (GUYD), (3) castorbeans production in the Rest of India (RIBP), (4) castorbeans crushed in India (INBC), and (5) domestic demand for castor oil (INOD).

Based on the review of past studies, field knowledge about castorbean production in Gujarat and the economic theory, the following independent or explanatory variables along with their expected relationships with Gujarat castor hectarage (GUHC) were specified on a priori basis: (a) expected price of castorbean/oil received by producers (expected sign +ve); (b) expected price of competitive crop such as millet or other spices crop grown in the area (expected sign +ve); (c) price of water or irrigation charges (expected sign -ve); (d) support prices if there are any (expected sign +ve); (e) lagged castor yield to capture producers' assurances about the expected profits (expected sign +ve); (f) introduction of high yielding varieties/hybrids (expected sign -ve); (g) pre-sowing rainfall (expected sign +ve); and (h) other variables (expected sign ±). Similarly, Gujarat castorbean yield is specified to be a function of the following explanatory variables: (a) fertilizer consumption in castor with expected +ve sign; (b) irrigated acreage under castor crop with expected +ve sign, (c) production/sale of certified hybrid seed of castorbeans with expected +ve sign; (d) introduction of high yielding varieties/hybrids with expected +ve sign; (e) rainfall during growing season with expected +ve/-ve sign; (f) trend to capture technological change with expected ± sign.

Beans Production in the Rest of India (RIBP) is expected to capture the castor production behavior of the remaining provinces; namely, Orissa, Karnataka, Andhra Pradesh, and other states, excluding Gujarat. The castor hectarage in the rest of India is specified as function of time trend and other weather variables (temperature and rainfall). Castorbeans crushed in India (INBC) depends upon basically castor oil price, production of beans, and indigenous crushing capacity. All explanatory variables are here positively related with the crush of castorbeans. The domestic disappearance of castor oil (INOD) is specified to be function of domestic price of castor oil (with -ve expected sign), price of substitute of castor oil (with +ve expected sign), tastes and preferences (with ±ve expected sign), exchange rate between US dollar and rupee, and other variables.

In addition to above five behavioral equations, the following five identities are also included in this sector: (1) an identity which specifies Gujarat castorbean production (GUBP) as product of hectarage and yield, (2) other identity to obtain Indian beans production (INBP) by summing the Gujarat and the rest of India beans production i.e., GUBP + INBP, (3) Indian castor oil exports which are generated from the world exports by multiplying it with India's share which is specified in the international sector,

(4) an identity for castor oil production which equals to castorbeans production times the extraction efficiency, and (5) ending oil stocks which are endogenized through the supply-disposition identity.

The Brazilian sector contains four behavioral equations and four identities. The four behavioral equations are: (i) hectarage (BZHC), (ii) yield (BZYD), (iii) crush (BZBC) and, (iv) domestic disappearance (BZOD). The Brazilian hectarage and yield equations are specified to be function of similar variables as specified for Gujarat hectarage and yield equations; hence, the description is not repeated. The crush equation is specified to be function of domestic castor oil price, castorbean supply to crushers, and crushing capacity. The a priori expected signs for these variables are all positive. The domestic demand equation is specified as function of domestic castor oil price to consumers in Brazil, industrial production index of Brazil, taste and preferences which are captured through the time trend. Among identities, the beans production identity is nothing but product of hectarage and yield. Similarly the oil production identity is equal to beans production times the extraction efficiency. Like Indian sector, Brazilian castor oil exports are also generated from world exports by multiplying it with Brazil's share in the world exports. Lastly, the ending stocks are generated through the usual supply-disposition identity.

The Chinese sector contains three equations and three identities. The three behavioral equations are: (i) castorbean production (CHBP), (ii) bean crushed (CHBC), and domestic disappearance (CHOD). Unlike Indian and Brazilian sectors, the castorbean production is not endogenized through product of acreage and yield; rather, one single equation for production is specified. Other equations CHBC and CHOD are specified similar to their counterparts in Indian/Brazilian sectors. The identities generate: (i) beans exports (CHBX) which equal to beans production minus beans crushed; (ii) castor oil production (CHOP) which is nothing but castorbean production times the extraction efficiency; and, (iii) castor oil exports (CHOX) which equal to oil production minus oil consumption.

The international sector contains six behavioral equations and one identity. The behavioral equations comprise: (i) world exports of castor oil (WDOX), (ii) world or international price of castor oil (WDPR), (iii) Indian price of castor oil (INPR), (iv) Indian bean price (INBPR), (v) Indian share in the world castor oil exports (INSH), and (vi) Brazilian share in the world castor oil exports (BZSH). The identity generates castor oil exports (ROWX) by the rest of the world. The world export demand for castor oil is specified to be a function of following variables: (1) international castor oil price, (2) industrial production indexes of importing countries, (3) opening stocks of castor oil in the importing countries, (4) beans/oil production in the importing countries, (5) prices of other substitute of castor oil in importing countries, (6) taste and preferences or changes in consumption technology, (7) exchange rate, and (8) other policy related variables, etc.

Since both export-supply and export-demand jointly determine the international price (WDPR), it was specified as a function of supply-consumption ratio (which was defined as oil production divided by oil consumption) in the exporting (XSCR) and importing (MSCR) regions, respectively. In addition, other policy related variables were also included. There are two share functions respectively for Brazil and India. The share of each country (INSH and BZSH) is specified as function of world price, domestic bean production, the castor production in the rest of the world, and the exchange rate. Indian castor oil price is derived through price possibility frontier by specifying Indian price as a function of world price and exchange rate. Similarly Indian bean price is derived from Indian castor oil price. Since domestic prices for Brazil and China were not available, the international price was directly introduced in the domestic functions in these sectors with the assumption that domestic prices follow the international price.

The driving force in the model is the international price which is determined by the interaction of the aggregate supply and aggregate demand forces. The world export demand/supply and world price are jointly determined. Having determined the world exports, the Indian and Brazilian exports are determined through their respective share functions. Chinese exports are determined as residual from the domestic market. Rest of the variables such as domestic disappearance, production, stocks are determined domestically in each sector, i.e., in India, Brazil, and China. A schematic representation of functioning of the model is shown in Figure 2.

[Insert Figure 2 here]

MODEL ESTIMATION AND VALIDATION

Data for the study were obtained from secondary sources, primarily from *Oil World* and *Food and Agriculture Organization (FAO)*. Different methods of estimation were tried including ordinary least square (OLS), two-stage least square (2SLS) for simultaneous relationships, and Zellner's technique. The estimated coefficients and t-values come almost same under all methods. Zellner's method was preferred for it captures the interactions across equations which are of similar nature across sectors. Hence, for estimation purpose, the whole model was divided into small subsystems such as production, crush, domestic demand, and export. Each subsystem was then estimated using Zellner's technique. The model was estimated and simulated using Time Series Processor (TSP).

The estimated model was validated prior to using it for policy experimentation. The validation basically meant to improve the model for making real-world predictions. There are, in principle, three schools of thought regarding validation of economic models. The first school of thought says that the validation of economic models is done through assumption; this is called a **prioristic** approach. The second school calls for empirical verification of each and every part of the model--this is the **ultra-empiricist** approach. The third school follows the go-between approach, i.e., it says that certain parts of model have to empirically validated while some other parts are validated by assumption or conceptually. Naylor et al (1971) has suggested a three-stage procedure of validation for economic models. Stage one calls for conceptual validation of model, followed by validation by results in stage two, and finally model is tested for certain logical experiments in stage three. Again one should remember that validation of a model is not an objective as such but is rather a means to make the model accurate enough so as to use it for further economic analyses. Basically, validation or verification of any economic model means to prove the model to be true. This requires comparing the model generated predictions with the actual data. This is hence an iterative process of comparing model predictions with real world, making adjustments to the model and comparing again, and so on until the model is judged to be sufficiently accurate.

The current model of international castor oil market was deemed to be conceptually valid as it is based upon the sound principles of economic theory and insights about the ground reality; the validation by results are tested here. For this, the estimated model was simulated for the historical data period and its forecasting performance was tested using various forecasting performance criteria. The Theil's inequality coefficient (U_2), turning point error percentage (TPEP), and root mean square error (RMSE), and mean absolute percentage error (MAPE). The forecasting performance of the simulated model is summarized in Table 3. Results seem more or less good except a few equations which could not be improved. The forecasting power of the model seemed relatively good when examined in terms of plots of historical actual vis-a-vis forecast values. From the historically validated model, the baseline prediction from 1989 to 2000 A.D. were obtained by simulating the model with the projected values of explanatory variables in the future. Projections were based on historical growth rates. This conditional baseline was used as control/benchmark for comparing results of exogenous shocks given to the model. Several policy scenarios hypothesized for the analysis are summarized in Table 4.

[Insert Table 4 here]

RESULTS AND DISCUSSION

The estimated resnlts of Indian, Brazilian, Chinese, and International sectors are presented at the end of this paper in Appendix A. The estimated equations, along with identities, for Indian sector are given in Table A-1. The explanatory power of different equations ranges from 52 to 98% and most regression coefficients on explanatory variables appear with right signs. In the Gujarat hectarage equation, the lagged beans price and lagged yield, which were included to capture the expected price and yield in the farmer's mind, appear significant and with right signs. In the Gujarat yield equation, the fertilizer consumption (GUFC) and introduction of castor hybrids (GUHY) are significant at 5% level of significance; and the de-martonne index (MMJL) for July is significant at 10% level of significance. The overall explanation power of the equation is about 87%. The rest of India beans production (RIBP) was estimated as function of rest of India castor hectarage (RIHC) and time trend (TIME). Both variables appear significant and explanation power of equation in terms of R^{-2} is about 55%. Similarly in the Indian beans crush (INBC) equation, both variables, world price and time trend, appeared significant with right sign--explaining some 98% of the variation. The domestic disappearance is primarily explained by the industrial production index (ININ).

Estimated equations, along with identities, for Brazilian sector are given in Table A-2. Except domestic disappearance (BZOD), all other equations have moderate explanatory power, R^{-2} hovering around 80% or so. Estimated equations, along with identities, for Chinese sector are given in Table A-3. Almost all estimated equations have high R^{-2} and most explanatory variables appear with right signs and are significant.

Results of estimated equations and identities for the international sector are presented in Table A-4. Results in general appear robust. In the world export demand function, the world price is rightly signed and is significant. Other variables which appeared to be important to be included in the equation are: industrial production index of EEC (ECIN), oil stocks of importing countries (IMOBS), and a dummy variable for capturing energy crisis in 1973-74 (SHOK). The other behavioural equations in this sector are the two share functions for Brazil and India, which show a reasonable degree of explanatory power (R^2 = 70%). In the world price equation, the demand-supply ratios in the exporting and importing countries (XSCR and MSCR) appear with right signs and are significant. The Indian castor oil price is specified as function of world price and exchange rate (Rs/US$).* Results of some key policy experiments are being discussed here in order to conserve space.

Scenario 1: Improvement in the Indian Extraction Efficiency

This scenario simulated the impact of improved extraction efficiency of castor oil industry in India. To do so, four shocks in terms of increased extraction efficiency--that is 5, 10, 15, and 20% from the baseline were given to the model exogenously and simulated results were then compared to benchmark values. Two important changes that are predicted under this scenario are: (1) sizeable amount of increase in the Indian castor oil production with mild increase in India's castor exports; and (2) consequent to the above change India would experience slight reduction in Gujarat hectarage due to slightly depressed domestic prices. A 20% improvement in the extraction efficiency would likely to increase castor oil production by 20 to 30 thousand tonnes--an increase of 18 to 19% in oil production. The impact of increased oil production was to depress domestic prices by 1-2% from the baseline. This ultimately reduces Gujarat castor hectarage by 1-2% from the baseline. The impact upon Indian castor oil exports is marginal as demand for our exports depends upon the foreign country's conditions rather than our internal production as such.

Scenario 2: Impact of Rupee Devaluation

This scenario examines the impact of rupee devaluation upon India's castor oil trade. Simulation results indicated a mild increase in the Indian castor oil production (which obviously presumed increased production of castorbean) depending upon the degree of devaluation, the increase in castor oil production ranged between 1 to 8% only. Unlike the normal expectation that the devaluation would induce large exports of castor oil, does not come true. For example, with a 25% devaluation of rupee from baseline the castor oil exports increased by only 8% from the baseline for the entire sample period.

The probable explanation of this not so enthusiastic response of castor oil exports to rupee devaluation can be seen in terms of export demand elasticity. Since the export demand elasticity for castor oil is very inelastic[2], the response to rupee devaluation cannot be very high. This is specially true in the case of primary commodities which are generally exported by the less developed countries. The other major impact of devaluation is the increase in the internal bean and oil prices. The expected increase in these prices is within the range of 5% to 30% from the base level.

Scenario 3: Change in the Importing Region

This scenario tried to simulate the changes that may result from changes in the importing countries. The following three situations were simulated:

(A) Improvement in the industrial production index of the European Economic Community.

(B) Change in the stock position of castor oil importing countries.

(C) Combined effect of change in the EEC industrial production index and change in stock of importing countries.

<u>**Experiment A:**</u> This was supposed to capture the impact of improved industrial production in the EEC as it happens to be one of the most important importing region in the world market. In order to simulate impacts of improved industrial production, the EEC industrial index was raised from baseline to the tune of 2.7, 5, and 8% from the baseline. The impact of such a change is tremendous on Indian and Brazilian castor oil exports. It is predicted that a 5% increase in the industrial production index could lead to doubling of Indian exports; similar improvements are also predicted for Brazil.

<u>**Experiment B:**</u> Unlike experiment A, this experiment simulated the impacts of stock build-up or their replenishment upon the world castor oil economy. Three possible situations of stock changes were hypothesized. That is, stocks increase, decrease, and decrease respectively by 5, 5, 10% from the baseline. The major impact of this change is seen on India's castor oil exports. It is predicted that a 5% increase in the importing countries stocks would cause India's exports to decline by about 20% from the baseline. Similar impacts

would also be felt upon Brazilian exports.

__Experiment C:__ It was included to measure the combined effect of changes in the EEC industrial production index and in the stocks of importing countries. Two specific situations were considered: (1) A 5% increase in the EEC industrial index plus a 5% decrease in the importing countries stocks; and (2) a 5% increase in the industrial production index of EEC plus on 10% decline in stocks in importing countries. Impacts of these changes upon Indian and Brazilian export levels were large.

Scenario 4: Impacts of Improved Agri-production Technology in Gujarat

The improved agri-production technology which includes better seeds, fertilizer, and irrigation has been a major source of growth in castorbean production in Gujarat since 1973. Therefore, three possible situations were hypothesized in order to assess the impacts of new technology upon castor economy: (1) a 10 and 10% increase in irrigation and fertilizer consumption in the state, (2) a 20 and 20% increase in irrigation and fertilizers respectively in the state, and (3) a 30 and 30% increase in irrigated area and fertilizer consumption in the Gujarat state. The most important impact of this change was to see increased production of castorbean in Gujarat. It is predicted that by mere 30% increase in the irrigated area and fertilizer consumption the castorbean production may increase by more than 50% from the baseline. As a result of this the Indian beans production may go up by 30-40% from the baseline. Increased production in Gujarat results from both acreage and yield improvements. Impacts ultimately would be felt upon the castor oil production and exports. As a result of increased Indian exports, the Indian share in the world market would increase to the tune of 10-30% depending upon the change in technology. Most of the increase in our exports in the international market will replace chinese exports as they are allowed to be determined residually in the model. The other impacts of this increased Indian production will be realized in terms of depressed international prices to the tune of 3 to 10% from the baseline; similarly, domestic Indian castor oil prices would also be depressed to the tune of 1 to 6% from the baseline.

Scenario 5: Impacts of Increased Castor Hectarage in China

China is considered to be a potential competitor of India in the international castor trade. This scenario was conceived to see the possible impacts of increased castor hectarage in China upon India's exports and her trade competitiveness. To simulate impacts of increased castor hectarage, the shocks of 10, 20, 30, and 50 increase in Chinese castor hectarage from the baseline were given and impacts were estimated in a comparative static manner. Results show that a 10% increase in castor hectarage would increase castorbean production in China by 40% from the base level. And, a 50% increase in area will quadruple production from the baseline. Similar impacts are felt upon Chinese beans crush too. As a result of increased Chinese beans production and crush, the tremendous increase is predicted on Chinese oil exports. And as a result exports from the rest of the world region are expected to decline significantly. Because of the constant structure assumption of the model, no major changes are predicted in the Indian and Brazilian exports. However, in real world this is less likely to happen and castor oil exports from India and Brazil would also be affected.

SUMMARY AND CONCLUSIONS

Based on the premise of perfectly competitive framework, an international model of castor oil market was developed and validated. The empirical model was then used for policy experimentation using simulation technique. Some key scenarios examined are discussed here in brief. Results of various scenarios give some insights to policy makers. For example, a 20% improvement in the extraction efficiency would likely to increase Indian castor oil production by 20-30 thousand tonnes per annum. Similarly, a 25% devaluation of rupee increased Indian castor oil exports by only 8% from the benchmark but had tremendous impact on domestic bean and oil prices which rose upto 30% from the baseline. Improved industrial activity in the EEC is expected to have positive impacts on Indian exports. For example, 5% increase in the industrial production index could lead to doubling of Indian exports. In another scenario examined, a 10% increase in castor hectarage in China would increase castorbean production in that country by 40% from the baseline. Results of this study thus provide some linking about the impacts of possible scenarios which might be useful for policymakers.

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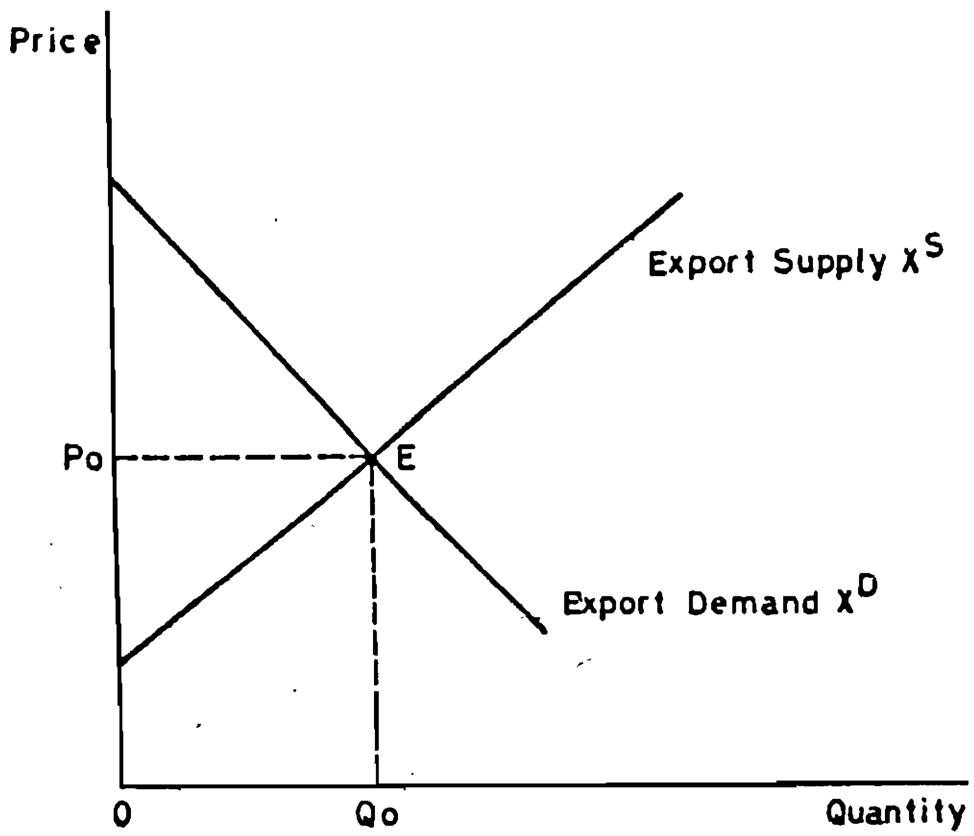

Figure 1: Price Formation in the International Castor Oil Market

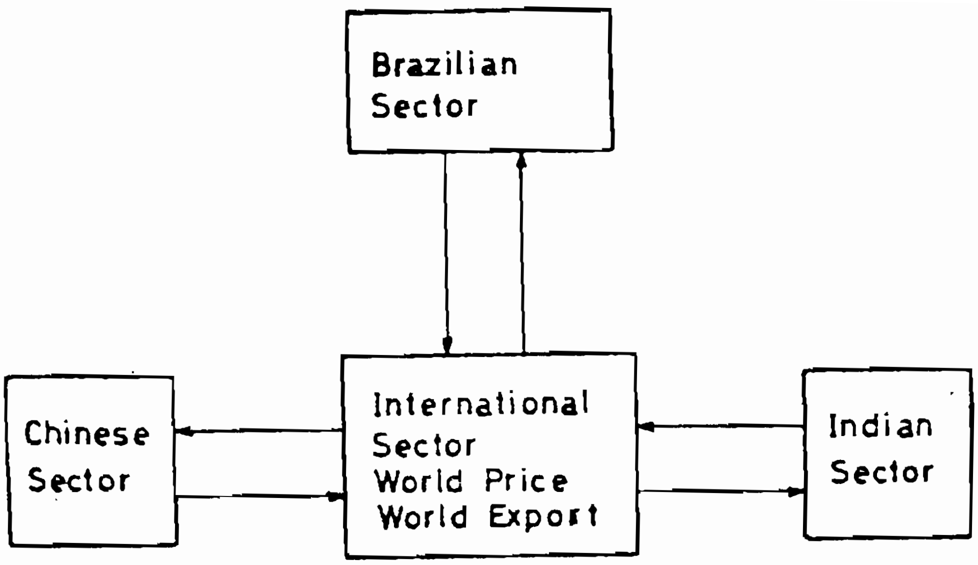

Figure 2: Functioning of the Model

Table 1: Major Actors in the International Castor Oil Market

Particulars	Actors	
	Major	Minor
Exporters	Brazil India	China
Importers	USA EEC Ex-USSR Countries	Japan
Stockholders	Brazil India Ex-USSR Countries	EEC USA
Crushers	Brazil India China	Others

Table 2: Details of Equations and Identities, ICOM Model

Sector	Equations	Identities	Total
India	5	5	10
Brazil	4	4	8
China	3	3	6
International	6	1	7
Total	18	13	31

Source: Estimated Model

Table 3: Forecasting Performance of the ICOM Model

Endogenous Variable	RMSE (%)	U_2	TPE (%)	MAPE (%)
Indian Sector				
GUHD	45.03	1.00	0.5	36.72
GUYD	158.62	0.92	0.42	15.49
GUBP	53.60	0.90	0.35	37.76
RIBP	17.23	0.77	0.31	13.20
INBP	52.93	0.84	0.27	12.67
INBC	44.63	0.90	0.23	10.74
INOP	17.19	0.92	0.23	10.74
INOD	10.31	1.04	0.42	34.67
INOX	14.21	1.06	0.42	152.38
INOS	18.15	1.37	0.65	224.90
Brazilian Sector				
BHC	66.46	0.99	0.35	14.33
BZYD	138.13	1.00	0.50	15.03
BZBP	81.53	0.94	0.35	22.11
BZBC	30.24	0.93	0.31	21.21
BZOP	0.11	1.03	0.42	2.78
BZOD	0.20	1.03	0.42	3.71
BZOX	88.24	1.03	0.58	363.94
BZOS	0.11	0.57	0.15	2.00
Chinese Sector				
CHBP	13.14	0.69	0.35	233.65
CHBX	0.15	1.08	0.38	2.95
CHBC	5.19	1.13	0.35	12.46
CHOP	0.12	0.88	0.31	2.90
CHOD	4.50	1.26	0.31	592.21
CHOX	0.17	1.13	0.65	2.63
International Sector				
WDOX	0.24	1.02	0.58	3.22
ROWX	11.87	1.87	0.38	109.43
WDPR	0.88	1.11	0.54	17.37
INSH	0.08	0.94	0.31	125.44
BZSH	31.87	1.17	0.58	26.21
INPR	597.50	0.90	0.38	17.65
INBPR	0.23	1.05	0.38	2.28

Source: Estimated

Table 4: Policy Experiment Scenarios

Sl No	Scenario	Per cent increase/decrease from Baseline								
		2.7	5.0	8.0	10	15	20	25	30	50
1	Indian extraction efficiency		↑		↑	↑	↑			
2	Indian exchange rate		↓		↓	↓	↓	↓		
3 a)	EEC industrial index	↑	↑	↑						
b)	Oil stock in importing countries		↓		↓					
c)	Combination of (a) and (b)		↑[1]↓[2]		↓[2]					
4	Yield improvement in Gujarat through irrigation and fertilizers				↑		↑		↑	
5	Increase in Chinese castor hectarage				↑		↑		↑	↑

↑ % increase from baseline;

↓ % decrease from baseline;

↑[1] % change in EEC industrial index;

↓[2] % change in stocks of importing countries.

APPENDIX A: THE ESTIMATED ICOM MODEL

Table A-1: Identities and Estimated Equations, Indian Sector

Sl. No.	Estimated Equation	R^2	F	D.W.
1.	Gujarat Castor Hectarage			
	ln GUHC = -2.16 + 0.4507 ln INBPR (-1) + (1.66) (3.02)*			
	0.5342 ln GUYD (-1) - 0.3645 GUHY (2.80)* (1.49)	0.53	10.6*	0.7069
2.	Gujarat Castor Yield ln GUYD = 6.07 + 0.9899 ln GUIR + 0.1811 (6.76) (1.45) (2.37)*			
	ln GUFC + 0.0764 ln MMJL + 0.5428 GUHY (1.94)@ (2.69)*	0.87	45.7*	1.5069
3.	Gujarat Beans Production GUBP = GUHC x GUYD			
4.	Rest of India Beans Production RIBP = -47.54 + 0.3443 RIHC + 1.1361 TIME (2.29) (7.03)* (2.77)*	0.55	17.0*	1.5886
5.	Indian Beans Production INBP = GUBP + RIBP			
6.	Indian Beans Crush INBC = 5.80 + 0.0281 WDPR + 0.8058 TIME (1.38) (4.03)* (32.66)*	0.99	1039.0*	1.9111
7.	Indian Oil Production INOP = INBC x INEF			
8.	Indian Oil Demand INOD = -0.48 - 0.0002 INPR + 0.3917 ININ (0.07) (0.16) (2.66)*	0.57	18.9*	1.4785
9.	Indian Oil Export INOX = INSH x WDOX			
10.	Indian Ending Oil Stocks INOS = INOS (-1) + INOP - INOD - INOX - INBF	--	--	--

* Significant at 5% level of significance

@ Significant at 10% level of significance

Source: Estimated

Table A-2: Identities and Estimated Equations, Brazilian Sector

Sl. No.	Estimated Equation	R^2	F	D.W.
1.	Castor Hectarage			
	BZHC = 56.28 + 0.1599 WDPR (-1) +			
	(0.87) (4.6)*			
	0.2614 BZYD (-1)	0.39	9.4*	1.2209
	(4.29)*			
2.	Castor Yield			
	BZYD = 758.88 + 0.2925 BZYD (-1)			
	(5.28) (2.23)*			
	-12.4875 TIME	0.54	16.5*	1.7825
	(3.5)*			
3.	Beans Production			
	BZBP = BZHC x BZYD			
4.	Beans Crush			
	BZBC = 112.92 + 0.0122 WDPR + 0.5688 BZBP	0.47	12.7*	1.4122
	(2.46)* (0.37) (5.36)*			
5.	Oil Production			
	BZOP = BZBC x BZEF			
6.	Oil Demand			
	ln BZOD = -0.32 + 0.0858 ln WDPR +			
	(0.94) (0.97)			
	0.7387 ln BZIN - 0.0867 ln TIME	0.87	61.9*	0.9882
	(4.23)* (1.45)			
7.	Oil Export			
	BZOX = WDOX x BZSH			
8.	Ending Oil Stocks	--	--	--
	BZOS = BZOS (-1) + BZOP - BZOD - BZOX - BZBF			

* Significant at 5% level of significance

Source: Estimated

Table A-3: Identities and Estimated Equations, Chinese Sector

Sl. No.	Estimated Equation	R^2	F	D.W.
1.	Beans Production Ln CHBP = 2.13 + 0.0123 CHHC + 0.0103 TIME (19.98) (17.41)* (2.7)*	0.95	266.2*	1.3185
2.	Beans Crush ln CHBC = -0.99 + 0.3031 ln WDPR + (2.91) (5.13)* 0.7052 ln CHBP (11.9)*	0.91	131.1*	1.1218
3.	Beans Export CHBX = CHBP - CHBC			
4.	Oil Production CHOP = CHBC x CHEF			
5.	Oil Demand ln CHOD = 1.97 - 0.0738 ln WDPR + (5.78) (1.00) 0.4203 ln CHIN (9.86)*	0.90	121.5*	1.1255
6.	Oil Export CHOX = CHOP - CHOD - CHBF	--	--	--

* Significant at 5% level of significance

Source: Estimated

Table A-4: Identities and Estimated Equations, International Sector

Sl. No.	Estimated Equation	R^2	F	D.W.
1.	World Oil Export ln WDOX = 3.06 - 0.4107 ln WDPR + 1.1281 (3.71) (5.07)* (5.66)* ln ECIN - 0.0946 ln IMOBS + 0.1409 SHOK (1.69) (2.56)*	0.46	6.4*	1.7948
2.	World Oil Price ln WDPR = 6.61 - 0.6189 ln XSCR - 0.6904 (40.24) (5.92)* (9.94)* ln MSCR + 0.3802 SHOK (4.31)*	0.86	55.0*	0.9834
3.	Indian Share INSHP = 13.55 + 0.0031 WDPR + 0.0835 (2.97) (0.95) (9.09)* INBP - 0.0146 WLINBP (2.67)*	0.72	23.2*	1.3026
4.	Brazilian Share ln BZSHP = 6.4 - 0.0262 ln WDPR + 0.3451 (7.68) (0.47) (5.32)* ln BZBP - 0.6425 ln WLBZB (5.22)*	0.71	21.7*	0.6558
5.	Rest of World Oil Export ROWX = WDOX - INOX - BZOX - CHOX			
6.	Indian Oil Price ln INPR = 2.48 + 0.5305 ln WDPR + (5.34) (5.40)* 1.2265 ln INEX (7.19)*	0.89	103.4*	1.2201
7.	Indian Beans Price INBPR = 15.00 + 0.4382 INPR (0.30) (59.94)*	0.99	2971.3*	2.6943

* Significant at 5% level of significance

Source: Estimated

Table A-5: List of Variables with Acronyms

Endogenous Variables	
GUHC	Hectarage of Gujarat (00 ha)
GUYD	Yield of castorbeans in Gujarat (Kg/ha)
GUBP	Beans production in Gujarat (000 tonnes)
RIBP	Beans production in Rest of India (000 tonnes)
INBP	Beans production in India (000 tonnes)
INBC	Indian beans crush (000 tonnes)
INOP	Indian castor oil production (000 tonnes)
INOD	Indian oil demand (000 tonnes)
INOX	Indian castor oil exports (000 tonnes)
INOS	Indian oil ending stocks (000 tonnes)
BZHC	Brazilian hectarage (000 ha)
BZYD	Yield of castor beans in Brazil (Kg/ha)
BZBP	Brazilian beans production (000 tonnes)
BZBC	Brazilian beans crush (000 tonnes)
BZOP	Brazilian oil production (000 tonnes)
BZOD	Brazilian oil demand (000 tonnes)
BZOX	Brazilian oil exports (000 tonnes)
BZOS	Brazilian oil ending stocks (000 tonnes)
CHBP	Chinese beans production (000 tonnes)
CHBC	Chinese beans crush (000 tonnes)
CHBX	Chinese beans exports (000 tonnes)
CHOP	Chinese oil production (000 tonnes)
CHOD	Chinese oil demand (000 tonnes)
CHOX	Chinese oil exports (000 tonnes)

WDOX	World oil exports (000 tonnes)
WDPR	World castor oil price (US$/tonne)
INSHP	Indian share in the world castor oil exports (percentage)
BZSHP	Brazilian share in the world castor oil exports (percentage)
ROWX	Rest of world oil exports (000 tonnes)
INPR	Indian price of castor oil (Rs/tonne)
INBPR	Indian price of castor beans (Rs/tonne)
XSCR	Ratio of oil production to oil consumption in exporting countries (India and Brazil) ((INOP + BZDP)/ (INOD + BZOD))

Exogenous Variables

GUIR	Irrigated hectarage in Gujarat (00 ha)
GUFC	Fertilizer consumption in Gujarat (000 tonnes)
MMJL	Demartonne index for July
GUHY	Dummy for introduction of castor hybrids in Gujarat (1961-7- = 0; 1971-88 = 1)
RIHC	Castor hectarage in Rest of India (000 ha)
RIYD	Castor beans yield in Rest of India (Kg/ha)
TIME	1961 = 1 .... 1988 = 28
INEF	Indian oil extraction efficiency
ININ	Indian industrial production index (1980 = 100)
INSH	Indian share in world castor oil exports (INSHP/100)
WLINBP	World less Indian beans production (000 tonnes)
INBF	Indian balancing factor (000 tonnes)
BZEF	Brazilian oil extraction efficiency
BZIN	Brazilian industrial production index (1980 = 100)
BLBZBP	World less Brazilian beans production (000 tonnes)

BZSH	Brazilian share in oil exports (BZSHP/100)
BZBF	Brazilian balancing factor (000 tonnes)
CHHC	Chinese hectarage (000 ha)
CHEF	Chinese oil extraction efficiency (percentage)
CHIN	Chinese industrial production index (1980 = 100)
CHBF	Chinese oil balancing factor (000 tonnes)
ECIN	EEC's Industrial production index (1980 = 100)
IMOBS	Importing countries' (USA, earstwhile USSR, EEC) beginning stocks of castor oil (000 tonnes)
EXOBS	Exporting countries' (Brazil, India) beginning stocks of castor oil (000 tonnes)
SHOK	1961-73 = 0; 1973-74 = 1; 1974-88 = 0
INEX	Indian exchange rate (Rs/US$)
XSCR	Ratio of oil production to oil consumption in exporting countries (India and Brazil) (INOP + BZOP/INOD + BZOD)
MSCR	Ratio of oil production to oil consumption in importing countries (EEC and USA) ((ECOP + USOP)/(ECOD + USOD))

NOTES

1. For example, in 1989 A.D., about US$ 88 million worth of castor oil was exported from India. Further, there exists a potential to raise this upto US$ 400 million per year by 2000 A.D., (Tewari and Rao, 1991).

The export demand elasticity for castor oil is estimated to be -0.33 (Tewari and Rao, 1991, p.87).