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# SPATIAL EQUILIBRIUM ANALYSIS OF RICE ECONOMY OF SOUTH INDIA

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## INTRODUCTION

The inheritance of spatial equilibrium analysis is attributed to the synthesis of two well-known schools of thought, *viz.*, the classical, neo-classical and modern trade theory on one side, and location theory on the other. The traditional trade theory was criticised for its virtual neglect of the space aspects of economic activity. In order to fill up this gap, a separate theory of location developed simultaneously. The synthesis of these two theories assumes a set of regions about which resources, technologies and tastes about a commodity are given and is effectively achieved by introducing programming techniques. This new formulation permits space to be treated explicitly and presents a method in which linear programming can be employed as a tool of analysis.

Enke, Baumol and Samuelson are considered to be the pioneers who stimulated interest in finding an answer to how the economy should be organized spatially in order to maximize net national product. Enke[1] demonstrated that with "a relatively simple electric circuit," a model could be set up with the help of which estimates for a single commodity, namely, net price, quantity of exports or imports among regions, total trade and direction of trade, could be generated. Samuelson[2] relates Enke's specification to a minimum transportation-cost problem of Koopmans[3] and Hitchcock.[4] Baumol[5] converted Enke's problem as one of maximization of an objective function subject to given demand and supply functions in each of the regions which are separated by transport costs.

This study is concerned with spatial equilibrium analysis of rice economy of South India within the conceptual framework set out in Enke-Samuelson formulation. Our problem, then, becomes one of ascertaining the following for the year 1960-61 :

(1) A set of spatial equilibrium prices of rice and estimates of regional consumption.

(2) The quantity of rice exported and imported from each region under the equilibrium conditions.

(3) The volume and direction of trade between each possible pairs of regions.

* I am thankful to Dr. H. Neudecker for helpful comments. The remaining errors are mine.

1. S. Enke, "Equilibrium Among Spatially Separated Markets: Solution by Electric Analogue," *Econometrica*, Vol. 19, 1951, pp. 40-48.

2. P. A. Samuelson, "Spatial Price Equilibrium and Linear Programming," *The American Economic Review*, Vol. 42, 1952, pp. 283-303.

3. T. C. Koopmans, "Optimum Utilisations of the Transport System," *Econometrica*, Vol. 17, Supplement, July, 1949, pp. 136-146.

4. Frank L. Hitchcock, "The Distribution of a Product from Several Sources to Numerous Localities," *Journal of Mathematics and Physics*, Vol. 20, 1941, pp. 224-230.

5. W. J. Baumol: Spatial Equilibrium with Supply Points Separated from Markets with Supplies Pre-determined, Bureau of Agricultural Economics, U.S. Department of Agriculture, Washington, D.C., U.S.A., 1952.

An analysis of this nature requires specification of three types of functional relationships pertaining to rice, *viz.*, demand function, transport cost model and the supply function. These are considered as the basic data of our analysis.

There are two reasons which have made us choose South India for our analysis. Firstly, South India consisting of the States of Andhra Pradesh, Kerala, Madras and Mysore forms one of the six rice zones created in India. One of the salient features of the zonal system is that exports from and imports in to the zone are not freely allowed. In a way it resembles a closed economy which is one of the helpful requirements for a meaningful solution to spatial equilibrium analysis. These zones are homogeneous and are comprised of three to four States which are predominantly growing a particular crop like rice in rice zones. The second reason is due to the fact that rice is one of the important agricultural commodities in India and also in South India and as such any conclusion drawn thereon in respect of inter-regional movement, regional prices and regional consumption will have an important bearing on the rice economy of India.

## II

### PRELIMINARY ANALYSIS AND ASSUMPTIONS

In the simplified model, South India is demarcated into 13 homogeneous regions whose boundaries do not cut across the boundaries of each State. Each region consists of either a group of districts or a single district and is represented by a point that is identified with a certain city lying within the regional limits. Given the regional demarcation, the model includes (1) a demand function for each of the 13 regions; (2) a structure of transportation costs between all possible pairs of regions and (3) observed values of the predetermined variables—supply of rice, population and income.

*(a) Demand Function*

Regional demand functions for rice are based upon a demand function for the State in which the region is located. To elucidate this point, the demand function for rice for Andhra Pradesh is taken to be valid for all the five regions lying in this State. The demand function for each State involved a functional relationship between the quantity of rice consumed domestically and the disposable income, the price of rice, the price of its substitutes and a time trend. Specifically, a model to explain such a relationship for different States of South India was postulated for $i^{th}$ State as

$$V_i = A_i + b_{i1} I_i + b_{i2} P_i^R + b_{i3} R_i + U_i \quad .. \quad .. \quad .. \quad .. \quad (1)$$

where

$V_i$ = per capita consumption of rice in pounds,

$P_i^R$ = real retail price of rice in rupees per pound,

$R_i$ = real retail price of 'substitute commodities' of rice in rupees per pound,

$I_i$ = per capita real incomes in rupees,

$U_i$ = a random disturbance term.

The U's reflect the combined influence of other unspecified variables. The usual assumption tied up with random disturbances is that they are normally distributed with zero means and a non-singular co-variance matrix and are independent from observation to observation.

The estimate of regression coefficients of equation (1) were first tested with a time series data for the period 1951-52 to 1961-62. But the regression coefficients had large standard errors, indicating the plausibility of the strong influence of multicollinearity between real prices and real income. We later tried to examine whether the degree of precision of the estimates improves if the respective demand functions are based on a combination of time series and family budget data. Family budget data were used to get the income elasticity and by using the pooling technique, the price components of the demand function were estimated from time series data for the period 1951-52 to 1961-62. The linear demand functions, thus estimated, for the four States of South India, are as follows :

$$V_A = \underset{(38.92)}{188.89} + \underset{(0.0206)}{.08621_A} - \underset{(181.00)}{386.46P^R_A} + \underset{(174.74)}{399.85R_A}$$

$$R^2 = 0.47 \quad .. \quad \text{(Andhra Pradesh)} \qquad (2)$$

$$V_M = \underset{(92.74)}{251.02} + \underset{(0.0213)}{0.10591_M} - \underset{(373.85)}{992.01P^R_M} + \underset{(316.75)}{859.11R_M}$$

$$R^2 = 0.66 \quad .. \quad \text{(Madras)} \qquad (3)$$

$$V_{MY} = \underset{(29.84)}{92.04} + \underset{(0.0323)}{0.09871_{MY}} - \underset{(127.48)}{293.08P^R_{MY}} + \underset{(130.28)}{417.56R_{MY}}$$

$$R^2 = 0.60 \quad .. \quad \text{(Mysore)} \qquad (4)$$

$$V_K = \underset{(53.80)}{121.31} + \underset{(0.0214)}{0.11421_K} - \underset{(148.76)}{235.50P^R_K} + \underset{(520.96)}{780.04R_K} + \underset{(1.57)}{5.26^t}$$

$$R^2 = 0.71 \quad .. \quad \text{(Kerala)} \qquad (5)$$

In equations (2), (3), (4) and (5), figures in brackets represent standard error of regression coefficients and alphabets A, M, MY and K stand for Andhra Pradesh, Madras, Mysore and Kerala respectively. t in equation (5) represents time trend.

### (b) *Transportation Rates*

The structure of transport rates is basic to the solution of spatial equilibrium analysis. Transport rates are defined as the cost of movement of a unit weight over a unit distance.

The transport system in India comprises of a number of distinct services, notable amongst them are the railways, road transport, water transport and the internal airlines. Out of these, internal airlines are normally used as passenger airlines. On examining the geographical location of the regions, we can rule out the possibility of transportation of rice by waterways on a large scale. The only two modes of transport that are left for consideration are the railways and the mechanised road transport. It may now be noted that the crux of the problem of spatial equilibrium analysis is to arrive at an optimum shipment pattern at minimum cost. It will, however, facilitate the analysis if the system of transport that is chosen had a lower rate and at the same time has operational advantages. Comparing rail and road transport costs, it is observed that road transport costs are higher than rail costs for bulk movement at and above 100 kilometres and the disparity between the two tends to increase with the increase in the distance of haulage. Hence, for purposes of our analysis, we consider railway transport costs only.

The rail rates for rice are reproduced below for some of the representative distances.

| Rate per quintal* (paise**) | Distance in kilometres |
|---|---|
| 59 | 100 |
| 89 | 200 |
| 116 | 300 |
| 143 | 400 |
| 190 | 600 |
| 234 | 800 |
| 271 | 1000 |
| 357 | 1500 |
| 434 | 2000 |
| 484 | 2400 |

* One quintal = 100 kilograms.
** 100 paise = One rupee.
*Source :* Indian Railways : Annual Number, 1962.

On a glance over the rate structure, we find that as the distance increases, the rates increase but at a decreasing rate. Thus, a function to reflect a non-linear relationship between the rates and the distance is postulated as

$$Y = ax^b \qquad 0 < b < 1 \qquad \ldots \ldots \ldots \ldots \qquad (6)$$

where Y = transport rate in paise per quintal,

X = distance in kilometres.

TABLE I—ESTIMATES OF TRANSPORT RATES FOR RICE BETWEEN REGIONAL POINTS : 1960-61

(*paise per pound*)

| Regional points | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 .. | — | 0.821 | 0.472 | 0.989 | 0.354 | 1.021 | 0.844 | 0.925 | 1.098 | 1.220 | 1.297 | 1.551 | 0.980 |
| 2 .. | | — | 0.912 | 0.730 | 0.975 | 1.511 | 1.225 | 1.161 | 1.433 | 1.329 | 1.216 | 1.524 | 0.907 |
| 3 .. | | | — | 1.198 | 0.662 | 1.229 | 1.071 | 1.143 | 1.297 | 1.415 | 1.483 | 1.737 | 0.971 |
| 4 .. | | | | — | 1.012 | 1.139 | 0.794 | 1.184 | 1.061 | 0.930 | 0.758 | 1.152 | 0.376 |
| 5 .. | | | | | — | 1.161 | 0.998 | 1.066 | 1.234 | 1.175 | 1.420 | 1.665 | 1.139 |
| 6 .. | | | | | | — | 0.889 | 1.297 | 1.139 | 0.417 | 0.753 | 0.576 | 0.984 |
| 7 .. | | | | | | | — | 0.730 | 0.508 | 0.680 | 0.767 | 1.107 | 0.607 |
| 8 .. | | | | | | | | — | 0.567 | 1.125 | 1.198 | 1.483 | 1.071 |
| 9 .. | | | | | | | | | — | 0.953 | 1.030 | 1.334 | 0.889 |
| 10 .. | | | | | | | | | | — | 0.523 | 0.744 | 0.758 |
| 11 .. | | | | | | | | | | | — | 0.612 | 0.599 |
| 12 .. | | | | | | | | | | | | — | 0.971 |
| 13 .. | | | | | | | | | | | | | — |

*Notes :* 1 = Hyderabad 8 = Hubli
2 = Kakinada 9 = Shimoga
3 = Kurnool 10 = Coimbatore
4 = Nellore 11 = Thanjavur
5 = Nizamabad 12 = Tirunelveli
6 = Ernakulam 13 = Madras
7 = Bangalore

Taking logarithms, equation (6) is written as

$$\text{Log } Y = \log a + b \log X \quad \ldots \quad (7)$$

Using the data given above, the fitted regression of log Y on log X will then be

$$\underset{}{\log Y} = \underset{(.0179)}{0.404} + \underset{(.0064)}{0.675} \log X \quad \ldots \quad (8)$$

$$R^2 = 0.99$$

The standard errors of the regression coefficients are given in brackets. Using equation (8) and the data on rail mileage, the transport rates between two regional points have been estimated and are presented in Table I.

(*c*) *Basic Data*

It has been noted above that the three variables, namely, supply of rice, human population and income are taken as pre-determined. The values of these variables for each region, at levels appropriate for the year 1960-61, are presented in Table II.

TABLE II—ESTIMATES OF PER CAPITA SUPPLY OF RICE AVAILABLE FOR CONSUMPTION, PER CAPITA INCOME AND POPULATION BY REGIONS: 1960-61

| Regions | Population (thousands) | Supply of rice (million pounds) | Per capita supply of rice (pounds) | Per capita income (Rs.) |
|---|---|---|---|---|
| Ernakulam .. .. .. .. | 16,904 | 2,381 | 141 | 315 |
| Hubli .. .. .. .. | 9,672 | 576 | 60 | 294 |
| Shimoga .. .. .. .. | 5,862 | 1,503 | 256 | 332 |
| Bangalore .. .. .. .. | 6,956 | 896 | 129 | 289 |
| Kakinada .. .. .. .. | 9,218 | 2,782 | 302 | 276 |
| Nellore .. .. .. .. | 7,121 | 2,578 | 362 | 368 |
| Kurnool .. .. .. .. | 6,933 | 724 | 104 | 282 |
| Hyderabad .. .. .. .. | 6,286 | 793 | 126 | 265 |
| Nizamabad .. .. .. .. | 6,424 | 959 | 149 | 239 |
| Madras .. .. .. .. | 10,119 | 2,471 | 244 | 337 |
| Coimbatore .. .. .. .. | 7,361 | 824 | 112 | 346 |
| Thanjavur .. .. .. .. | 8,858 | 3,089 | 349 | 310 |
| Tirunelveli .. .. .. .. | 7,382 | 1,463 | 198 | 348 |
| South India .. .. .. .. | 109,096 | 21,039 | 193 | 309 |

*(d) Assumptions*

The model involves a good many simplifying assumptions some of which are already enumerated in Judge and Wallace.[6] But there are some which are not formulated by them explicitly and are given here. Firstly, the movement of commodity from one region to another does not result in changes in the distribution of income. Secondly, there is no uncertainty in the system. Alternatively, all product requirements, activity cost and technical coefficients are known and fixed.

## III

### SPATIAL EQUILIBRIUM SOLUTION : 1960-61

A necessary requirement for equilibrium under perfect competition is that no individual can make a profit by transporting additional quantities of commodity from one region to another. The implication of this requirement is that if there is a shipment of commodity from one region to another, the prices in these regions differ by the amount of intervening transportation costs. Thus, a spatial equilibrium solution requires a precise structure of regional prices that are connected by specific transport costs. Such a structure is derived by choosing any one regional price as the basing point and the prices in other regions are estimated in accordance with their differentials, above and below the price in the base region. Thus if $P^R_o$ is the real retail price in the base region and $d_i$ is the estimated price differential between the base region and the ith region, then $(P^R_o + d_i)$ is the price in the ith region. Then the linear demand function of the ith region given by equation (1) is rewritten as

$$V_i = A_i + b_{i1} I_i + b_{i2} (P^R_o + d_i) + b_{i3} R_i + U_i \quad \ldots \quad \ldots \quad (9)$$

If we use equilibrium conditions that total consumption is equal to total supply of the commodity, then we get an expression for $P^R_o$ which is

$$P^R_o = \frac{S - \sum_i P_i A_i - \sum_i P_i b_{i2} d_i - \sum_i P_i b_{i1} I_i - \sum_i P_i b_{i3} R_i}{\Sigma_i P_i b_{i2}} \quad \ldots \quad \ldots \quad (10)$$

where $P_i$ represents population of the region and S represents total supply of the commodity and is equal to $\sum_i P_i V_i$.

Inserting the regional values and estimated parameters of the demand functions in equation (10), we get

$$P^R_o = 0.23311 \quad \ldots \quad \ldots \quad \ldots \quad (11)$$

Price in the ith region is determined by using (11) and the relationship $P^R_i = (P^R_o + d_i)$. With a structure of equilibrium prices (on first approximation) the

6. G. G. Judge and T. D. Wallace: Spatial Price Equilibrium Analyses of the Livestock Economy, Technical Bulletin 78, Department of Agricultural Economics, Oklahoma State University, U.S.A., 1959.

demand functions and the population estimates of each region, the regional consumption estimates are obtained and are further compared with their corresponding estimates of supply of rice. This procedure enables us to determine which of the regions are surplus or deficit and also give us the margin of surplus or deficit of rice for each region. These estimates are presented in Table III.

TABLE III—REGIONAL EQUILIBRIUM PRICE DIFFERENTIALS, PRICES, CONSUMPTION AND SURPLUSES AND DEFICITS : 1960-61 (FIRST APPROXIMATION)

| Regions | Price differential (paise per pound) | Price (Rs. per pound) | Per capita consumption (pounds) | Total consumption (million pounds) | Total adjusted* consumption (million pounds) | Supply (million pounds) | Surplus** or deficit (million pounds) |
|---|---|---|---|---|---|---|---|
| Ernakulam .. | 0·984 | 0·24295 | 194·25 | 3,284 | 3,209 | 2,381 | —828 |
| Hubli .. .. | 1·071 | 0·24382 | 134·74 | 1,303 | 1,279 | 576 | —703 |
| Shimoga .. .. | 0·889 | 0·24200 | 139·08 | 815 | 799 | 1,503 | 704 |
| Bangalore .. .. | 0·608 | 0·23919 | 135·60 | 943 | 923 | 896 | —27 |
| Kakinada .. .. | 0·907 | 0·24218 | 191·71 | 1,767 | 1,731 | 2,782 | 1,051 |
| Nellore .. .. | 0·376 | 0·23687 | 202·04 | 1,439 | 1,406 | 2,578 | 1,172 |
| Kurnool .. .. | 0·907 | 0·24218 | 192·25 | 1,333 | 1,308 | 724 | —584 |
| Hyderabad .. | 0·971 | 0·24282 | 190·47 | 1,197 | 1,174 | 793 | —381 |
| Nizamabad .. | 1·138 | 0·24449 | 187·48 | 1,204 | 1,181 | 959 | —222 |
| Madras .. .. | 0·000 | 0·23311 | 247·55 | 2,505 | 2,451 | 2,471 | 20 |
| Coimbatore .. | 0·757 | 0·24068 | 241·03 | 1,774 | 1,750 | 824 | —926 |
| Thanjavur .. | 0·599 | 0·23910 | 238·64 | 2,114 | 2,082 | 3,089 | 1,007 |
| Tirunelveli .. | 0·971 | 0·24282 | 239·13 | 1,765 | 1,746 | 1,463 | —283 |
| Total .. .. | | | | 21,443 | 21,039 | 21,039 | |

* Estimates of total consumption have been adjusted to conform to the equilibrium conditions (*i.e.*, total consumption = total supply).

** A minus sign preceding an observation indicates that the region in question occupies a deficit position and the related number indicates the magnitude of the deficit.

From Table III, it is observed that out of a total of 13 regions, eight are found to be deficit and five are surplus in rice. We, therefore, need to devise a pattern of geographical flows of rice from surplus regions to deficit regions such that the total cost of transportation is minimum subject to the estimates of demand and supply of each region and the constraint that total production of rice in South India equals the total consumption of rice during 1960-61. We solve a linear programming transportation model to determine minimum cost flows.

Let $t_{ij}$ denote the cost of transporting rice from the $i^{th}$ region to the $j^{th}$ region. Let $x_{ij}$ represent the amount of rice transported from the $i^{th}$ surplus region to the $j^{th}$ deficit region. The problem will then be to find a set of $x_{ij}$ such that

$$\sum_{j=1}^{m}\sum_{i=1}^{n} t_{ij}x_{ij} \text{ is minimum} \quad \ldots \quad (12)$$

$$\text{subject to } \sum_{j=1}^{m} x_{ij} = S_i \quad i = 1, 2 \ldots\ldots n \quad \ldots \quad (13)$$

$$\sum_{i=1}^{n} x_{ij} = d_j \quad j = 1, 2 \ldots\ldots n \quad \ldots \quad (14)$$

$$\sum_i S_i = \sum_j d_j \quad \ldots \quad (15)$$

$$\text{and } x_{ij} \geqslant 0 \text{ for all i and j} \quad \ldots \quad (16)$$

Here $S_i$ and $d_j$ represent the margin of surplus and deficit of the $i^{th}$ and $j^{th}$ region respectively.

We have followed the procedure of "Northwest-Corner rule"[7] to arrive at the first basic feasible solution. It may be noted here that for a model consisting of 'm' surplus and 'n' deficit regions, there exists a solution of at most (m+n—1) positive $x_{ij}$'s where $x_{ij}$ is the quantity transported from surplus to deficit regions. The optimum shipment pattern derived by solving the transportation model is presented in Table IV.

TABLE IV—OPTIMUM SHIPMENT PATTERN FOR RICE (FIRST APPROXIMATION) : 1960-61

*(million pounds)*

| Origins/ Destinations | Shimoga | Kakinada | Nellore | Madras | Thanjavur | Total demands | $V_j$ |
|---|---|---|---|---|---|---|---|
| Ernakulam | 1·139 0·853 | 1·511 1·102 | 1·139 1·139 (828) | 0·984 0·952 | 0·753 0·732 | 828 | 0·952 |
| Hubli | 0·567 0·567 (703) | 1·161 0·816 | 1·184 0·853 | 1·071 0·666 | 1·198 0·446 | 703 | 0·666 |
| Bangalore | 0·508 0·508 (1) | 1·225 0·757 | 0·794 0·794 (6) | 0·607 0·607 (20) | 0·767 0·387 | 27 | 0·607 |
| Kurnool | 1·297 0·663 | 0·912 0·912 (584) | 1·198 0·949 | 0·971 0·762 | 1·483 0·542 | 584 | 0·762 |
| Hyderabad | 1·098 0·572 | 0·821 0·821 (381) | 0·989 0·858 | 0·980 0·671 | 1·297 0·451 | 381 | 0·671 |
| Nizamabad | 1·234 0·726 | 0·975 0·975 (86) | 1·012 1·012 (136) | 1·139 0·825 | 1·420 0·605 | 222 | 0·825 |
| Coimbatore | 0·953 0·644 | 1·329 0·893 | 0·930 0·930 (202) | 0·758 0·743 | 0·523 0·523 (724) | 926 | 0·743 |
| Tirunelveli | 1·334 0·733 | 1·524 0·982 | 1·152 1·019 | 0·971 0·832 | 0·612 0·612 (283) | 283 | 0·832 |
| Total supplies | 704 | 1,051 | 1,172 | 20 | 1,007 | 3,954 | |
| $U_i$ | 0·099 | —0·150 | —0·187 | 0·000 | 0·220 | | |

*Note* : Figures in brackets indicate quantity of rice.

7. Saul I. Gass : Linear Programming Methods and Applications, McGraw-Hill, New York, U.S.A., 1958.

Having obtained the optimum inter-regional delivery pattern, our next task is to form the dual of the direct problem. It will be recalled that the dual of a minimum problem is a maximum problem. Secondly, the coefficients of the objective function of the direct problem appear as restraining constants in the dual and the restraining constants of the direct problem are the coefficients of the objective function of the dual. The dual to our problem provides the optimum solution of the price system that will give a set of prices which corresponds to the optimum flow obtained in Table IV. We formulate the dual problem by specifying two new sets of variables $U_i$ and $V_j$ where $U_i$ represents the shadow price at $i^{th}$ supply source and $V_j$ the shadow price at $j^{th}$ demand destination. The dual problem will then be to find $U_i$ and $V_j$ such that

$$Z = \sum_j d_j V_j - \sum_i S_i U_i \text{ is maximum} \quad \ldots \quad (17)$$

subject to

$$V_j - U_i \leqslant t_{ij} \quad i = 1, 2 \ldots\ldots m$$

$$j = 1, 2 \ldots\ldots n \quad \ldots \quad (18)$$

$$U_i, V_j \geqslant 0 \quad \ldots \quad (19)$$

where $d_j$ is the demand at the $j^{th}$ destination and $S_i$ is the supply at the $i^{th}$ source and $t_{ij}$ are the transport costs.

The economic interpretation of the dual problem stated above is to find such values of $U_i$ and $V_j$ that will maximize the total gain in value of quantities transported subject to the requirement that the value differential between source and destination cannot exceed the transport costs.

Using duality theorem, we have estimated the price of differentials which appeared to be different from those used on first approximation. Introducing the new set of price differentials, the process outlined previously has been repeated and the revised estimates of regional equilibrium prices, consumption, surpluses and deficits have been obtained on second approximation. The transportation problem has again been solved in the manner as was done before. Again the price differentials estimated at this iteration were found to be different from those used earlier. We continued with the third and the fourth iterations and found that the price differentials at the fourth were not different from those estimated in the third iteration. This is an iterative procedure which continues until the price differentials arrived at any stage are not different from the one used at the penultimate iteration. The results of second, third and final iterations are given in Tables V through X.

We notice from the final solution of the optimum shipment pattern that the surplus regions on the whole send their surplus quantity to their neighbouring deficit regions, except Nellore which is sending its surplus to Ernakulam. Secondly, we may compare the direct cost from Nellore to Kurnool (1.198 paise per pound) with the corresponding indirect costs (0.949 paise per pound). This means in effect that introducing this route in the plan will increase total transport cost by 0.249 paise per pound. Alternatively, it can be inferred that the transport cost between Nellore to Kurnool will have to decrease at least by 0.249 paise per pound before any rice will be shipped in that direction.

TABLE V—REGIONAL EQUILIBRIUM PRICE DIFFERENTIALS, PRICES, CONSUMPTION AND SURPLUSES AND DEFICITS : 1960-61 (SECOND APPROXIMATION)

| Regions | Price differential (paise per pound) | Price (Rs. per pound) | Per capita consumption (pounds) | Total consumption (million pounds) | Total adjusted consumption (million pounds) | Supply (million pounds) | Surplus or deficit (million pounds) |
|---|---|---|---|---|---|---|---|
| Ernakulam .. | 0·952 | 0·24800 | 193·06 | 3,263 | 3,220 | 2,381 | —839 |
| Hubli .. | 0·666 | 0·24514 | 134·35 | 1,299 | 1,285 | 576 | —709 |
| Shimoga .. | 0·099 | 0·23947 | 139·82 | 819 | 808 | 1,503 | 695 |
| Bangalore .. | 0·607 | 0·24455 | 134·03 | 932 | 921 | 896 | —25 |
| Kakinada .. | —0·150 | 0·23698 | 193·72 | 1,786 | 1,766 | 2,782 | 1,016 |
| Nellore .. | —0·187 | 0·23661 | 202·14 | 1,439 | 1,420 | 2,578 | 1,158 |
| Kurnool .. | 0·762 | 0·24610 | 190·73 | 1,322 | 1,308 | 724 | —584 |
| Hyderabad .. | 0·671 | 0·24519 | 189·55 | 1,191 | 1,178 | 793 | —385 |
| Nizamabad .. | 0·825 | 0·24673 | 186·62 | 1,198 | 1,185 | 959 | —226 |
| Madras .. | 0·000 | 0·23848 | 242·22 | 2,451 | 2,419 | 2,471 | 52 |
| Coimbatore .. | 0·743 | 0·24591 | 235·84 | 1,736 | 1,722 | 824 | —898 |
| Thanjavur .. | 0·220 | 0·24068 | 237·07 | 2,100 | 2,082 | 3,089 | 1,007 |
| Tirunelveli .. | 0·832 | 0·24680 | 235·18 | 1,736 | 1,725 | 1,463 | – 262 |
| Total .. | | | | 21,272 | 21,039 | 21,039 | |

Footnotes : Same as in Table III.

TABLE VI—OPTIMUM SHIPMENT PATTERN FOR RICE (SECOND APPROXIMATION) : 1960-61

*(million pounds)*

| Origins/ Destinations | Shimoga | Kakinada | Nellore | Madras | Thanjavur | Total demands | $V_j$ |
|---|---|---|---|---|---|---|---|
| Ernakulam | 1·139 0·522 | 1·511 1·102 | 1·139 1·139 (839) | 0·984 0·967 | 0·753 0·732 | 839 | 0·967 |
| Hubli | 0·567 0·567 (695) | 1·161 1·147 | 1·184 1·184 (14) | 1·071 1·012 | 1·198 0·777 | 709 | 1·012 |
| Bangalore | 0·508 0·162 | 1·225 0·742 | 0·794 0·779 | 0·607 0·607 (25) | 0·767 0·372 | 25 | 0·607 |
| Kurnool | 1·297 0·332 | 0·912 0·912 (584) | 1·198 0·949 | 0·971 0·777 | 1·483 0·542 | 584 | 0·777 |
| Hyderabad | 1·098 0·241 | 0·821 0·821 (385) | 0·989 0·858 | 0·980 0·686 | 1·297 0·451 | 385 | 0·686 |
| Nizamabad | 1·234 0·395 | 0·975 0·975 (47) | 1·012 1·012 (179) | 1·139 0·840 | 1·420 0·605 | 226 | 0·840 |
| Coimbatore | 0·953 0·313 | 1·329 0·893 | 0·930 0·930 (126) | 0·758 0·758 (27) | 0·523 0·523 (745) | 898 | 0·758 |
| Tirunelveli | 1·334 0·402 | 1·524 0·982 | 1·152 1·019 | 0·971 0·847 | 0·612 0·612 (262) | 262 | 0·847 |
| Total supplies | 695 | 1,016 | 1,158 | 52 | 1,007 | 3,928 | |
| $U_i$ | 0·445 | —0·135 | —0·172 | 0·000 | 0·235 | | |

*Note :* Figures in brackets indicate quantity of rice.

TABLE VII—REGIONAL EQUILIBRIUM PRICE DIFFERENTIALS, PRICES, CONSUMPTION AND SURPLUSES AND DEFICITS : 1960-61 (THIRD APPROXIMATION)

| Regions | Price differential (paise per pound) | Price (Rs. per pound) | Per capita consumption (pounds) | Total consumption (million pounds) | Total adjusted consumption (million pounds) | Supply (million pounds) | Surplus or deficit (million pounds) |
|---|---|---|---|---|---|---|---|
| Ernakulam .. .. | 0.967 | 0.25134 | 192.27 | 3,250 | 3,244 | 2,381 | —863 |
| Hubli .. .. | 1.012 | 0.25179 | 132.41 | 1,281 | 1,279 | 576 | —703 |
| Shimoga .. .. | 0.445 | 0.24612 | 137.87 | 808 | 807 | 1,503 | 696 |
| Bangalore .. .. | 0.607 | 0.24774 | 133.09 | 926 | 924 | 896 | —28 |
| Kakinada .. .. | —0.135 | 0.24032 | 192.43 | 1,774 | 1,771 | 2,782 | 1,011 |
| Nellore .. .. | —0.172 | 0.23995 | 200.85 | 1,430 | 1,428 | 2,578 | 1,150 |
| Kurnool .. .. | 0.777 | 0.24944 | 189.44 | 1,313 | 1,311 | 724 | —587 |
| Hyderabad .. .. | 0.686 | 0.24853 | 188.26 | 1,183 | 1,181 | 793 | —388 |
| Nizamabad .. .. | 0.840 | 0.25007 | 185.33 | 1,191 | 1,189 | 959 | —230 |
| Madras .. .. | 0.000 | 0.24167 | 239.06 | 2,419 | 2,415 | 2,471 | 56 |
| Coimbatore .. .. | 0.758 | 0.24925 | 232.53 | 1,712 | 1,710 | 824 | —886 |
| Thanjavur .. .. | 0.235 | 0.24402 | 233.76 | 2,071 | 2,069 | 3,089 | 1,020 |
| Tirunelveli .. .. | 0.847 | 0.25014 | 231.87 | 1,712 | 1,711 | 1,463 | —248 |
| Total .. .. | | | | 21,070 | 21,039 | 21,039 | |

Footnotes : Same as in Table III.

TABLE VIII—OPTIMUM SHIPMENT PATTERN FOR RICE (THIRD APPROXIMATION) : 1960-61

*(million pounds)*

| Destinations / Origins | Shimoga | Kakinada | Nellore | Madras | Thanjavur | Total demands | $V_j$ |
|---|---|---|---|---|---|---|---|
| Ernakulam | 1.139 0.522 | 1.511 1.102 | 1.139 1.139 (863) | 0.984 0.967 | 0.753 0.732 | 863 | 0.967 |
| Hubli | 0.567 0.567 (696) | 1.161 1.147 | 1.184 1.184 (7) | 1.071 1.012 | 1.198 0.777 | 703 | 1.012 |
| Bangalore | 0.508 0.162 | 1.225 0.742 | 0.794 0.779 | 0.607 0.607 (28) | 0.767 0.372 | 28 | 0.607 |
| Kurnool | 1.297 0.332 | 0.912 0.912 (587) | 1.198 0.949 | 0.971 0.777 | 1.483 0.542 | 587 | 0.777 |
| Hyderabad | 1.098 0.241 | 0.821 0.821 (388) | 0.989 0.858 | 0.980 0.686 | 1.297 0.451 | 388 | 0.686 |
| Nizamabad | 1.234 0.395 | 0.975 0.975 (36) | 1.012 1.012 (194) | 1.139 0.840 | 1.420 0.605 | 230 | 0.840 |
| Coimbatore | 0.953 0.313 | 1.329 0.893 | 0.930 0.930 (86) | 0.758 0.758 (28) | 0.523 0.523 (772) | 886 | 0.758 |
| Tirunelveli | 1.334 0.402 | 1.524 0.982 | 1.152 1.019 | 0.971 0.847 | 0.612 0.612 (248) | 248 | 0.847 |
| Total supplies | 696 | 1,011 | 1,150 | 56 | 1,020 | 3,933 | |
| $U_i$ | 0.445 | —0.135 | —0.172 | 0.000 | 0.235 | | |

*Note :* Figures in brackets indicate quantity of rice.

TABLE IX—REGIONAL EQUILIBRIUM PRICE DIFFERENTIALS, PRICES, CONSUMPTION AND SURPLUSES AND DEFICITS : 1960-61 (FINAL SOLUTION)

| Regions | Price differential (paise per pound) | Price (Rs. per pound) | Per capita consumption (pounds) | Total consumption (million pounds) | Total supply (million pounds) | Surplus or deficit (million pounds) |
|---|---|---|---|---|---|---|
| Ernakulam | 0.967 | 0.25174 | 192.18 | 3,248 | 2,381 | —867 |
| Hubli | 1.012 | 0.25219 | 132.29 | 1,279 | 576 | —703 |
| Shimoga | 0.445 | 0.24652 | 137.75 | 807 | 1,503 | 696 |
| Bangalore | 0.607 | 0.24814 | 132.98 | 924 | 896 | —28 |
| Kakinada | —0.135 | 0.24072 | 192.27 | 1,771 | 2,782 | 1,011 |
| Nellore | —0.172 | 0.24035 | 200.70 | 1,429 | 2,578 | 1,149 |
| Kurnool | 0.777 | 0.24984 | 189.29 | 1,312 | 724 | —588 |
| Hyderabad | 0.686 | 0.24893 | 188.11 | 1,182 | 793 | —389 |
| Nizamabad | 0.840 | 0.25047 | 185.17 | 1,189 | 959 | —230 |
| Madras | 0.000 | 0.24207 | 238.66 | 2,415 | 2,471 | 56 |
| Coimbatore | 0.758 | 0.24965 | 232.13 | 1,708 | 824 | —884 |
| Thanjavur | 0.235 | 0.24442 | 233.36 | 2,067 | 3,089 | 1,022 |
| Tirunelveli | 0.847 | 0.25054 | 231.47 | 1,708 | 1,463 | —245 |
| Total | | | | 21,039 | 21,039 | |

Footnotes : Same as in Table III.

TABLE X—OPTIMUM SHIPMENT PATTERN FOR RICE (FINAL SOLUTION): 1960-61

(*million pounds*)

| Destinations / Origins | Shimoga | Kakinada | Nellore | Madras | Thanjavur | Total demands | $V_j$ |
|---|---|---|---|---|---|---|---|
| Ernakulam | 1.139 0.522 | 1.511 1.102 | 1.139 1.139 (867) | 0.984 0.967 | 0.753 0.732 | 867 | 0.967 |
| Hubli | 0.567 0.567 (696) | 1.161 1.147 | 1.184 1.184 (7) | 1.071 1.012 | 1.198 0.777 | 703 | 1.012 |
| Bangalore | 0.508 0.162 | 1.225 0.742 | 0.794 0.779 | 0.607 0.607 (28) | 0.767 0.372 | 28 | 0.607 |
| Kurnool | 1.297 0.332 | 0.912 0.912 (588) | 1.198 0.949 | 0.971 0.777 | 1.483 0.542 | 588 | 0.777 |
| Hyderabad | 1.098 0.241 | 0.821 0.821 (389) | 0.989 0.858 | 0.980 0.686 | 1.297 0.451 | 389 | 0.686 |
| Nizamabad | 1.234 0.395 | 0.975 0.975 (34) | 1.012 1.012 (196) | 1.139 0.840 | 1.420 0.605 | 230 | 0.840 |
| Coimbatore | 0.953 0.313 | 1.329 0.893 | 0.930 0.930 (79) | 0.758 0.758 (28) | 0.523 0.523 (777) | 884 | 0.758 |
| Tirunelveli | 1.334 0.402 | 1.524 0.982 | 1.152 1.019 | 0.971 0.847 | 0.612 0.612 (245) | 245 | 0.847 |
| Total supplies | 696 | 1,011 | 1,149 | 56 | 1,022 | 3,934 | |
| $U_i$ | 0.445 | —0.135 | —0.172 | 0.000 | 0.235 | | |

*Note :* Figures in brackets indicate quantity of rice.

## IV

### IMPLICATIONS OF THE RESULTS

As a basis for policy action, spatial equilibrium analysis provides us with a price structure against which to judge the actual price structure and to indicate possible areas for choice or action if there is a divergence between ideal price and actual price. This also gives a clue to the policy-maker about the basis of price policy. From the point of view of economic policy, the difference between 'what could be' price and 'what is' price suggests probing into the actual operations of transportation of rice and also the assumptions of the model.

In Table XI, it is interesting to compare the spatial equilibrium prices with prices only observed in the regions 1960-61. If there is a high correlation between the two, one can conclude that transport costs are important as criteria of inter-region organization and are well represented despite the simplifying assumptions. The squared correlation coefficient is however less than 0.50, thus indicating that only a small fraction of spatial price variation is explained by shipments that minimize transport costs.

TABLE XI—COMPARISON OF SPATIAL EQUILIBRIUM PRICE AND MARKET RETAIL PRICE BY REGIONS: 1960-61

| Regions | Retail price (Rs. per pound) | Spatial equilibrium (Rs. per pound) | Saving as percentage of market retail price |
|---|---|---|---|
| Ernakulam | 0.31908 | 0.25174 | 21.1 |
| Hubli | 0.28748 | 0.25219 | 12.3 |
| Shimoga | 0.26926 | 0.24652 | 8.4 |
| Bangalore | 0.24897 | 0.24814 | 0.3 |
| Kakiñada | 0.26926 | 0.24072 | 10.6 |
| Nellore | 0.28858 | 0.24035 | 16.7 |
| Kurnool | 0.32029 | 0.24984 | 22.0 |
| Hyderabad | 0.26962 | 0.24893 | 7.7 |
| Nizamabad | 0.27351 | 0.25047 | 8.4 |
| Madras | 0.28870 | 0.24207 | 16.2 |
| Coimbatore | 0.29344 | 0.24965 | 14.9 |
| Thanjavur | 0.28262 | 0.24442 | 13.5 |
| Tirunelveli | 0.29745 | 0.25054 | 15.8 |

If we examine the two sets of prices, we observe that spatial equilibrium price is lower than that of the actual price in all the regions. The range of difference between the two varies from 0.3 per cent in Bangalore region to that of 22 per cent in Kurnool. It may be seen then that even if no regional production was interfered with and no intra-regional consumption determined by consideration of efficiency while, only the amount sent by a region to another was directed optimally, a saving in price from 0.3 per cent to 22 per cent could have been effected during 1960-61.